ASM Science JOURNAL

In Pursuit of Excellence in Science

Vol. 1, No. 2, Dec 2007 • ISSN : 1823-6782

ASM Science
JOURNAL

Editorial

We are in an era where information and communications technology (ICT) pervades every sphere of our lives and it has an impact on every sphere of knowledge and technology and their advancement and acquisition. Hence it is not surprising that ICT related issues dominate the pages of the second issue of the *ASM Science Journal*. The articles show that computational techniques, procedures, modelling, simulations, and statistical analyses are effectively employed to solve a myriad of scientific problems related to communication of sound, vehicle seat assembly line, analysis of speech signal generation and colour coding.

In addition, this issue carries a review on the future direction of agriculture in sustaining productivity without degrading the environment.

Related to agriculture are the food security issue and the current food crisis. This leads us to the question: How do we put ICT to better use, interweaving it into relevant scientific research, policy prescriptions and implementation plans, thus providing solutions, in large or small part, to the current food crisis? This crisis stems not only from a lack of supply but also, *inter alia*, from inefficient distribution, inequitable ownership of land, and, recently, elements of speculative trading. How can ICT contribute to solving these problems in a scenario where agriculture is becoming less resource-intensive and more knowledge-intensive against a backdrop of the need to induce agriculture and agriculture-related activities to generate more income, create more jobs and, of course, produce more food? The world community at large will be well served by an ICT community that extends its focus to these questions.

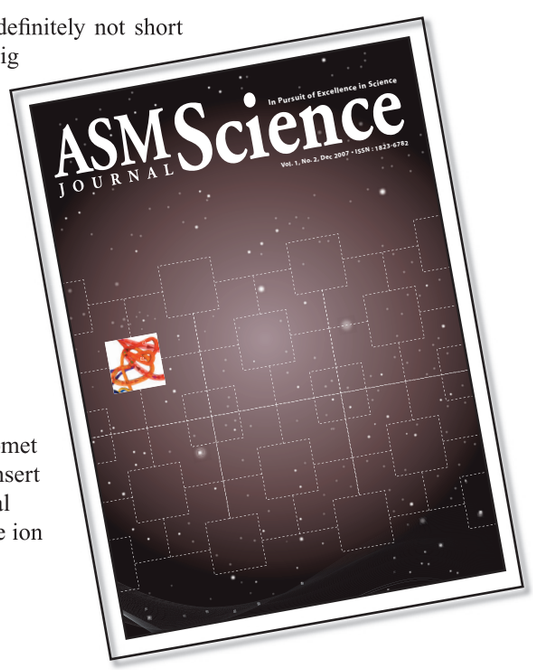
Also found in the pages of this issue is a report on the education programme associated with the national Angkasawan (astronaut) project. The education programme, led by the Academy of Sciences Malaysia, was carefully conceived and well co-ordinated, spanning a few years and involving many teachers, academics and space scientists who prepared the lesson plans for schools. Unfortunately its execution was far from ideal.

Had the full aspirations and objectives of the programme been met, much of the negative perception on the scientific aspects of the Angkasawan project could have been averted. The plan called for the media, public and students to be systematically and consistently educated and informed of the substantive scientific elements of the activities the Angkasawan carried out at the International Space Station. A million school children were targetted, all of them directly engaged in the classroom at the cognitive level under the supervision of teachers, which would have ensured that the Angkasawan project had an optimal impact on the country, both in the short- and long-term. The final number of school children who eventually managed to get directly involved with the project through the education programme remains to be tallied.

We are also proud to profile the winners of the 2006 Mahathir Science Award. Not least for the fact that they are home grown researchers, solving a problem of immense gravity under challenging circumstances. Perhaps their success story could lead to the establishment of a national disease crisis centre of sorts, something the Academy has always advocated and Tun Mahathir himself has referred to on several occasions.

A journal is only as good as those who contribute to it. And ASM is definitely not short of supporters, particularly from the local research oganisations. The big question is how do we sustain our efforts to produce a journal worthy of eventually being included in the ranks of other world class journals? To achieve this we need nothing less than a scientific community heaven-bent on continuously striving to produce the best research results on Earth.

Mazlan Othman
Vienna, Austria
June 2008



Cover:
Background includes an image of Comet 17P/Holmes (Holmes 3: p. 84); the insert reveals the zooming effect of the local colour scale when viewed close to the ion trajectories (Article: p. 109).

The Academy of Sciences Malaysia (ASM)

The Academy of Sciences Malaysia (ASM) was established, under the *Academy of Sciences Act 1994* which came into force on 1 February 1995, with the ultimate aim to pursue excellence in science. Thus the mission enshrined is to pursue, encourage and enhance excellence in the field of science, engineering and technology for the development of the nation and the benefit of mankind.

The functions of the Academy are as follows:

- To promote and foster the development of science, engineering and technology
- To provide a forum for the interchange of ideas among scientists, engineers and technologists
- To promote national awareness, understanding and appreciation of the role of science, engineering and technology in human progress
- To promote creativity among scientists, engineers and technologists
- To promote national self-reliance in the field of science, engineering and technology
- To act as a forum for maintaining awareness on the part of the Government of the significance of the role of science, engineering and technology in the development process of the nation and for bringing national development needs to the attention of the scientists, engineers and technologists
- To analyse particular national problems and identify where science, engineering and technology can contribute to their solution and accordingly to make recommendations to the Government
- To keep in touch with developments in science, engineering and technology and identify those developments which are relevant to national needs to bring such developments to the attention of the Government
- To prepare reports, papers or other documents relating to the national science, engineering and technology policy and make the necessary recommendations to the Government
- To initiate and sponsor multi-disciplinary studies related to and necessary for the better understanding of the social and economic implications of science, engineering and technology
- To encourage research and development and education and training of the appropriate scientific, engineering and technical man power
- To establish and maintain relations between the Academy and overseas bodies having the same or almost similar objectives in science, engineering and technology as the Academy
- To advise on matters related to science, engineering and technology as may be requested by the Government from time to time; and
- To carry out such other actions that are consistent with the *1994 Academy of Sciences Act* as may be required in order to facilitate the advancement of science, engineering and technology in Malaysia, and the well being and status of the Academy.

The Academy is governed by a Council. Various Working Committees and Task Forces are charged with developing strategies, plans and programmes in line with the Academy's objectives and functions.

The functions of the Council are:

- To formulate policy relating to the functions of the Academy
- To administer the affairs of the Academy
- To appoint such officers or servants of the Academy as are necessary for the due administration of the Academy
- To supervise and control its officers and servants
- To administer the Fund; and
- To convene general meetings of the Academy to decide on matters which under this Act are required to be decided by the Academy.

The Academy has Fellows and Honorary Fellows. The Fellows comprise Foundation Fellows and Elected Fellows. The Academy Fellows are selected from the ranks of eminent Malaysian scientists, engineers and technocrats in the fields of medical sciences, engineering sciences, biological sciences, mathematical and physical sciences, chemical sciences, information technology and science and technology development and industry.

The Future

Creativity and innovation are recognised the world over as the key measure of the competitiveness of a nation. Within the context of K-Economy and the framework of National Innovation System (NIS), ASM will continue to spearhead efforts that will take innovation and creativity to new heights in the fields of sciences, engineering and technology and work towards making Malaysia an intellectual force to be reckoned with.

Published by the Academy of Sciences Malaysia

ASM Sci. J., **1(2)**, 87–100

Development of an Automated Testing Tool for Java® Program

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Covering as much as 25% to 35% of the development cost, software testing is an integral part of the software development lifecycle. Despite its importance, the current software testing practice is still based on highly manual processes from the generation of test cases (i.e. from specifications) up to the actual execution of the test. These manually generated tests are sometimes executed using *ad hoc* approaches, typically requiring the construction of a test driver for the particular application under test. In addition, test engineers are also under pressure to test increasing lines of code in order to meet market demands for more software functionalities. While there are significant proliferations of helpful testing tools or research prototypes in the market, much of them do not adequately provide the right level of abstraction and automation as required by test engineers. In order to facilitate and address some of the aforementioned issues, an automated testing tool was developed, called SFIT, based on Java® technology. This paper describes the development, implementation and evaluation of SFIT. Two case studies involving the robustness assessment of an adder module and a Linda-based distributed shared memory implementation are described in order to demonstrate the applicability of SFIT as a helpful automated testing tool.

Key words: Java® program; software; testing; development; life-cycle; application; market; prototypes; automated testing tool; evaluation; Linda-based

In the last decade, computer software has become an essential need that we may not be able to do without. From banking systems to mobile phone control, the use of computer software has tremendously uplifted the quality of our lives. In order to ensure software reliability, there is a need for thorough testing. Often, many input parameters and system conditions need to be verified based on the specifications. Lack of testing often leads to disastrous consequences including loss of data, wealth and even lives.

Despite its importance, much of the current software testing practice is still based on highly manual processes from the generation of test cases (i.e. from the specifications documents) up to the actual execution of the test. These manually generated tests are sometimes executed using *ad hoc* approaches, typically requiring the construction of a test driver for the particular application under test (Ghezzi *et al*., 2003; Beizer 1990; Myers 1976). The construction of a test driver is a tedious, error prone, and cumbersome process, as it puts extra burden on test engineers especially if the test cases are significantly large.

Furthermore, test engineers are also under pressure to test increasing lines of code in order to meet market demands and deadlines for more software functionalities. To attain the required level of quality, test engineers need to maintain high test coverage, typically requiring a large number of test cases (Beck & Gamma 1998; Gupta *et al*. 2000; Pressman 2000). In order to facilitate and address some of the aforementioned issues, we have developed an automated testing tool, called SFIT, based on Java® technology. This paper describes the development, implementation and evaluation of SFIT.

RELATED WORK

The gradual shift toward software testing automation is not new. A number of tools do exist either commercially or as research prototypes. As far as Java® is concerned, some of these tools are summarized below:

- Jaca (Moraes and Martin 2003) developed at the State University of Campinas, is a useful testing tool that permits testing of Java® classes by corrupting the method interfaces and attributes. Jaca does not require the application's source code, but it needs some information about the application such as class name and method interfaces.

- JUnit (Matt 2003) is a testing tool used to write and run automated and repeatable tests. In JUnit, test engineers write a Java® unit test case, essentially a

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collection of tests designed to verify the behaviour of a single unit within a user program. The Java® unit test case can then be automatically executed by the JUnit environment.

- FIONA (Silva *et al*. 2004) is a Java® software testing tool for distributed applications. FIONA provides a Java® Virtual Machine Tool Interface that enables the inspection and execution of faults of distributed applications running in the Java® Virtual Machine.

- Simple (Acantilado & Acantilado 2002) is a functional testing tool that can be used to assess reliability, robustness and performance of a system as a whole. The aim of Simple is to facilitate testing of Java® classes used in safety critical applications.

- SoftTest (Childers *et al*. 2003) is a testing tool that is based on a pre-defined test plan. Based on the test plan, SoftTest automatically inserts and removes in executing the code to carry out testing strategies.

Although useful to alleviate some of the mundane activities inherent in the testing processes, much of the aforementioned tools does not adequately provide the right level of abstraction and automation as required by test engineers. Within this context, the testing tool should not assume that the user has significant knowledge of Java® in order to be able to use the tool (as required by Jaca® and JUnit®). In fact, a good tool should be of a sufficiently high level to facilitate the testing process in the sense that test engineers need not conduct any coding whatsoever in order to perform the actual testing.

Additionally, test automation provided by the tools must be sufficiently intuitive for the test engineers to master, providing that some level of intuition is important to help junior engineers to grasp the context of the testing work particularly in terms of how each testing activity fits in the whole picture.

In general, test automation can come in a number of forms. In a nut shell, test automation should relieve the test engineer from the routine tasks of creating Java® test drivers for execution. In addition, test automation should also facilitate the generation and execution of actual test cases. In this manner, test engineers can put significant focus on the job at hand (i.e. coming up with good test cases) and be released from manually writing test drivers.

Apart from test automation and in line with the current trend of using commercial off the shelf (COTs) components to speed up the software development process, there is also a need for an automated testing tool to be able to perform functional and unit testing even in the absence of a source code. As far as implementation is concerned, the tool can utilize the reflection capability provided by the Java® programming language in order to permit introspection (i.e. allowing a particular program to access and change the details of other programs at runtime).

Finally, providing an intuitive user interface also can help improve the tool. In fact, graphical user interface (GUI) can help improve usability of the test tool. Often, GUI interface is better than the command line interface as far as ease of use is concerned.

Summing up, based on the analysis of the Java® testing tool described earlier, the desirable characteristics that form the requirements for an automated testing tool can be highlighted further in Table 1.

Based on the aforementioned requirements, as well as building and complementing from earlier work, it was the development, implementation, and evaluation of SFIT which is the main focus of this paper.

Table 1. Summary of automated Java® testing tools.

✓ Implemented feature × Not implemented feature	Automated Java® testing tool				
	JACA	JUNIT	FIONA	SIMPLE	SOFTTEST
Characteristics:					
High level abstraction	×	×	×	×	×
Testing in the absence of source code	✓	×	×	✓	×
Test automation	×	✓	✓	×	✓
Graphical user interface support	×	×	✓	✓	✓

Overview of SFIT

SFIT is an automated unit testing tool developed as part of our ongoing research (Ahmad 2005; Alang Hassan 2005; Zamli *et al.* 2005; Alang Hassan *et al*. 2005; Zamli *et al*. 2006). The main novel features of SFIT are:

- It permits automation of the testing process allowing 2500 iterative test cases to be executed automatically with a single click of a button.
- It allows testing of Java® classes even in the absence of source codes (i.e. for public, protected and private methods); and
- It permits high level abstraction for the testing process as the users are relieved from writing Java® test drivers. Instead, the user can concentrate only on specifying the test cases as the test drivers are automatically generated and executed by SFIT.

Concerning implementation, SFIT development relied heavily on the Java® Reflection Application Programmer's Interface (API) to manipulate the runtime access to the classes and objects loaded in the Java® Virtual Machine (JVM). The fact that reflection allows introspection, that is, permits a particular program to access and change the details of other programs (e.g. primitive types, arrays, classes and interfaces) as well as dynamically alter the execution of a program without modifying the program itself, was helpful in the design of SFIT.

Conventional systems manipulate data that represents entities to the system. A reflective system contains data that represents the system itself, that is, in terms of its structural and behavioural aspects (i.e. *meta-information*). In reflective programming, there is a notion of base-level and meta-level structure. Base-level makes computations on an external domain in which the target system resides whilst meta-level makes computation on the target system itself. Thus, reflective programming is different than normal programming because it deals with meta-data, that is, the data that describes other data.

Utilizing the reflective programming approach, the main components that make up SFIT can be seen in Figure 1.

Briefly, the main components of SFIT can be described as follows:

(i) *Class inspector*. The main purpose of the class inspector is to inspect the Java® class in order to obtain detailed information of its interfaces. Here, the class inspector exploits the Java® Reflection API in order to interrogate the class for method interfaces including public, private, and protected ones. This information will be used to set up the fault setting (as discussed below).

(ii) *Fault setting*. Fault setting is a configuration file. With the fault setting, the user can define faults to be used through its methods interfaces (i.e. up to 2500 interface parameter values as test cases in a

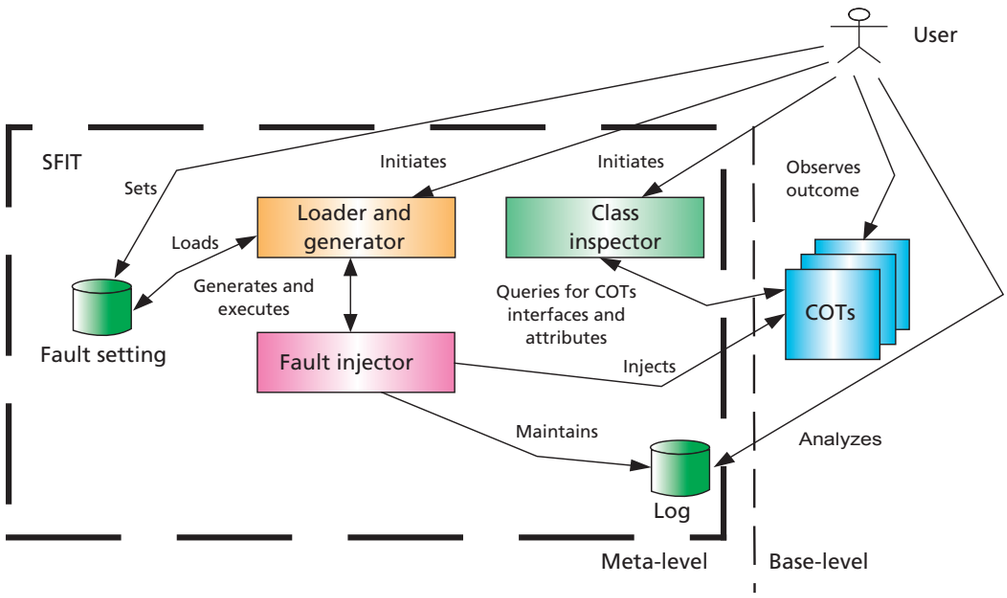


Figure 1. SFIT components.

pre-defined format). Figure 2 below highlights the sample fault file required by SFIT. Here, keywords are shown in bold. Details on the use of these keywords can be found in Ahmad (2005).

(iii) *Loader and generator*. The purpose of the loader and generator component is to parse the test cases and the fault setting configuration as well as automatically generate reflective Java® code that will be used to drive the test cases, although the generated codes are completely hidden the user. The generated codes will be used by the fault injector component (discussed next).

(iv) *Fault injector*. The purpose of the fault injector is to load the generated codes into the Java® Virtual Machine (JVM) in order to 'inject' the faults as specified by the test cases in the fault setting. The process of generating (i.e. performed by the loader and generator) and executing faults are performed iteratively based on the number of test cases specified in the fault setting.

(v) *Log*. The purpose of the fault injector is to load the generated log into a special database for permitting offline analysis of the output and behaviour of the software under test.

@FaultFile

Common header definition

***Class name** : Adder*
***Method name** : Add_basictypes_integer*
***Specifier** : Private*
***Paramtypes** : 2*
***Return type** : int*
Parameter : partypes[0]=Integer.TYPE
Parameter : partypes[1]=Integer.TYPE

Body—Test case 0

***arglist:arglist[0]**=new Integer(Integer.MAX_VALUE)*
***arglist:arglist[1]**=new Integer(Integer.MAX_VALUE)*

Body—Test case 1

***arglist:arglist[0]**=new Integer(Integer.MIN_VALUE)*
***arglist:arglist[1]**=new Integer(Integer.MIN_VALUE)*

Figure 2. Sample of a Fault File.

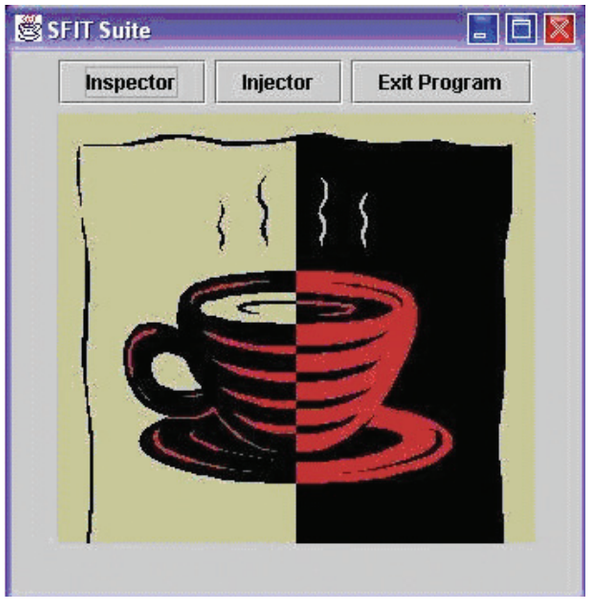


Figure 3. SFIT main user interface.

Using SFIT

The testing activities in SFIT begin with the user inspecting COTs using the Class Inspector in order to query the details on the method interfaces, that is, in terms of access rights and passing parameters. The Class Inspector is accessible through the main SFIT interface (see Figure 3).

Here, only the compiled code (i.e. the Java® class file) is required. Basing on the method interfaces from the class inspector (see Figure 4), the user then selects a particular method interface of interest (i.e. including private and protected ones). The selection is often done based on the user's assessment of the risk that such a method poses to the overall dependability of the system. The user then specifies up to 2500 test cases in the fault setting configuration in order to test that method interface through the loader and generator component of SFIT. The testing process is actually performed by the Fault Injector component which permits the automated execution of all the specified test cases with a single button click (see Figure 5).

During the testing process, the user may also observe the corresponding results (see Figure 6), which are also saved into a log file. All the aforementioned activities may be repeated with a new set of test cases as required.

Assessment of SFIT

Two case studies were identified to evaluate the features offered by SFIT involving the simple adder module as well as the COTs Java® based Linda distributed shared

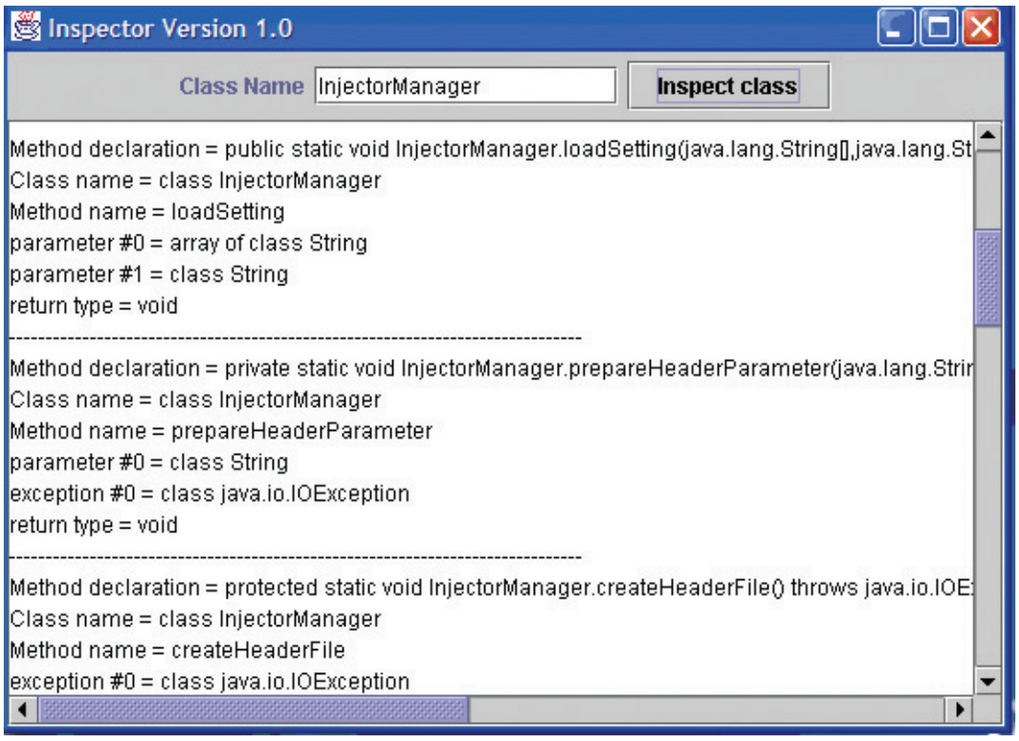


Figure 4. Output of the Class Inspector.

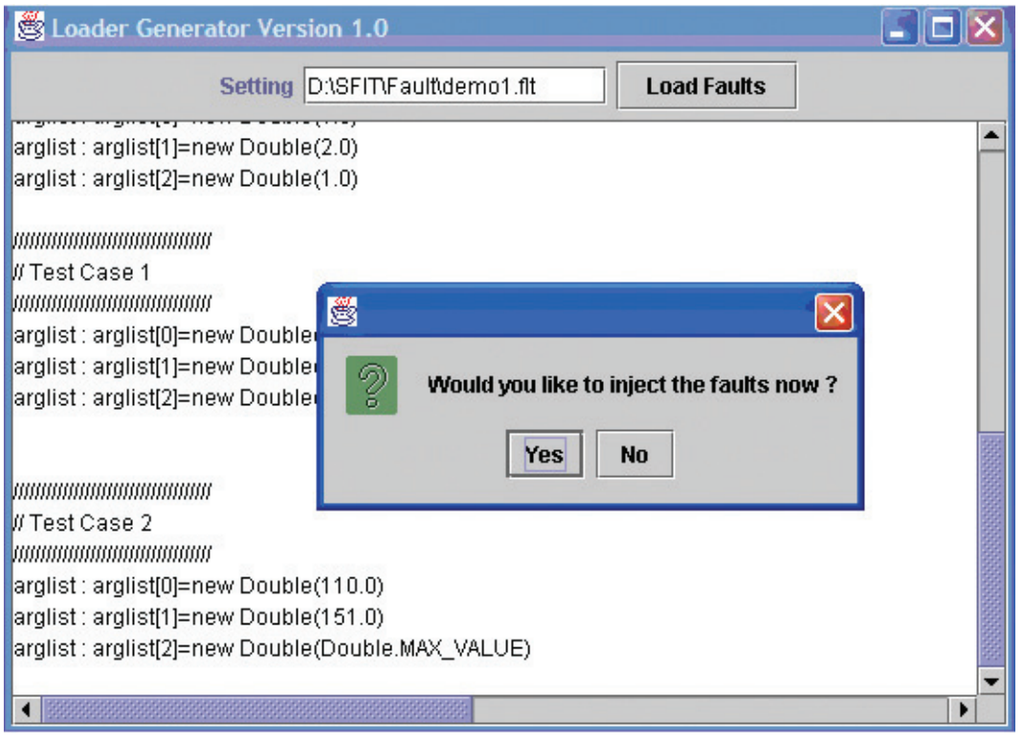


Figure 5. Loader Generator and Injector.

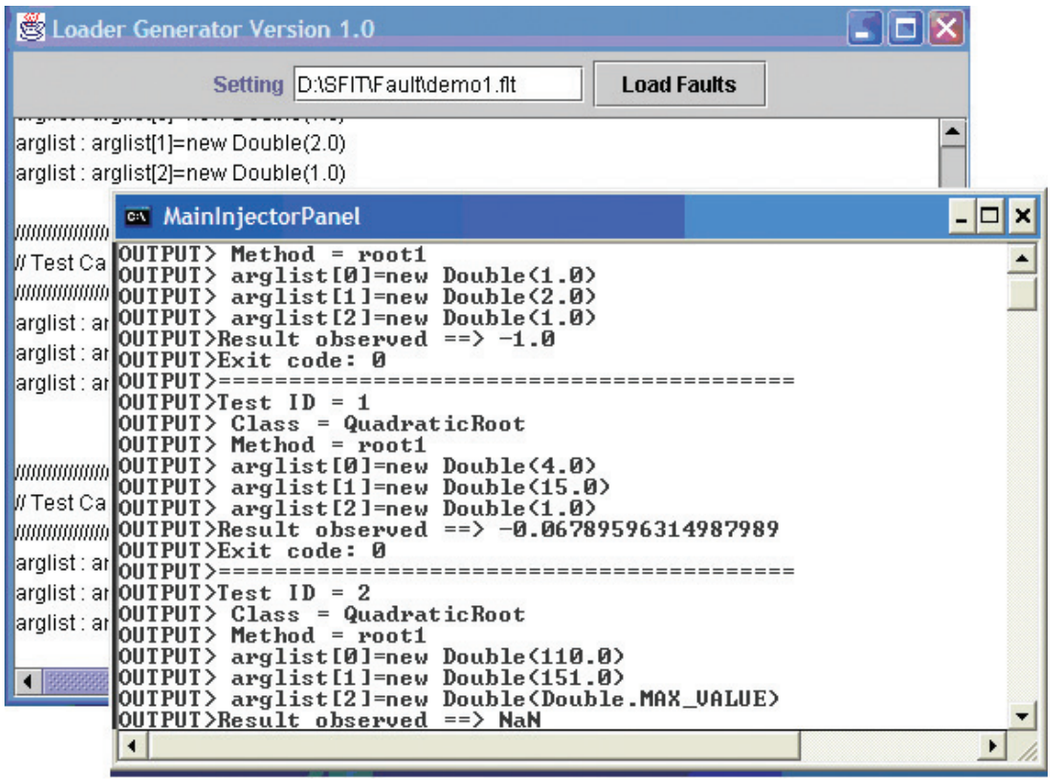


Figure 6. Automated test case execution output.

memory implementation (Ciancarini & Rossi 1997). The main aim of these studies were to demonstrate that SFIT had sufficiently rich features to perform automated and robustness testing of Java® classes for private, protected and public methods even in the absence of source codes. The experiments followed the methodology summarized in Figure 7.

In order to develop meaningful test cases, it is necessary to get hold of the reference documents. The reference documents could be the source code, the software specification or the design documentation. Upon completion of the test, conformance analysis would be made against the actual and the expected output based on the reference documents. As far as the work described here is concerned, the first case study (i.e. involving an adder module) used source codes as the reference document, whilst the second case study (i.e. involving COTs components) used the software specification and design documentation as the reference document.

Evaluating an adder module. A number of experiments were undertaken to evaluate SFIT over a wide range of data types including arrays, user-defined classes as well as Java® standard classes with extreme inputs.

The method interfaces of the adder module are shown in Figure 8 as the output of the SFIT Class Inspector. The main purpose of the adder module is to perform addition of two integer numbers as well as two complex floating point numbers. The complete source code implementation for the adder module is straightforward and will not be shown here.

As can be seen above, there are three methods declared in the adder module. The method interface *add_basictypes_integer*, is declared as private, returns an integer, and takes two integers as input parameters. Unlike the method interface *add_basictypes_integer*, the method interface *add_java_Integer*, is declared as protected, returns void, and takes two integer classes as input parameters. Finally, the method interface *add_user_defined_Complex_Double*, is declared as public, returns void, and takes two user-defined classes called Complex. Not shown here is the fact that the user-defined Complex class takes a constructor of the real part and imaginary part of type String (later converted to floating points) in order to initialize the Complex object.

For each of the method interfaces, 65 test cases (the number of test cases could be a maximum of 2500, that is, the maximum possible constant array as defined in

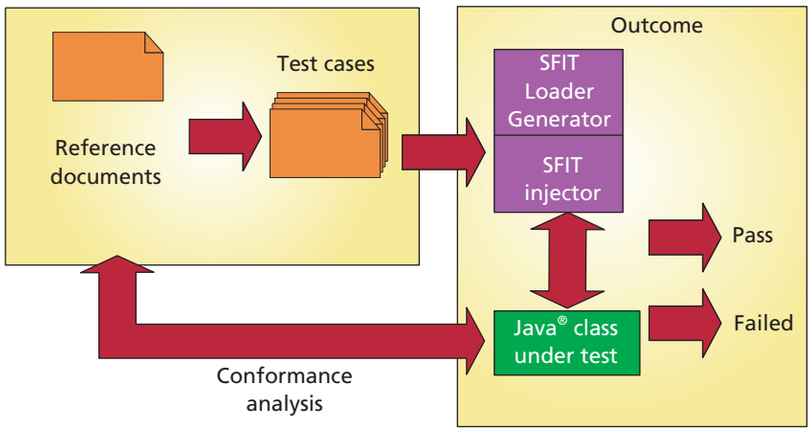


Figure 7. Methodology.

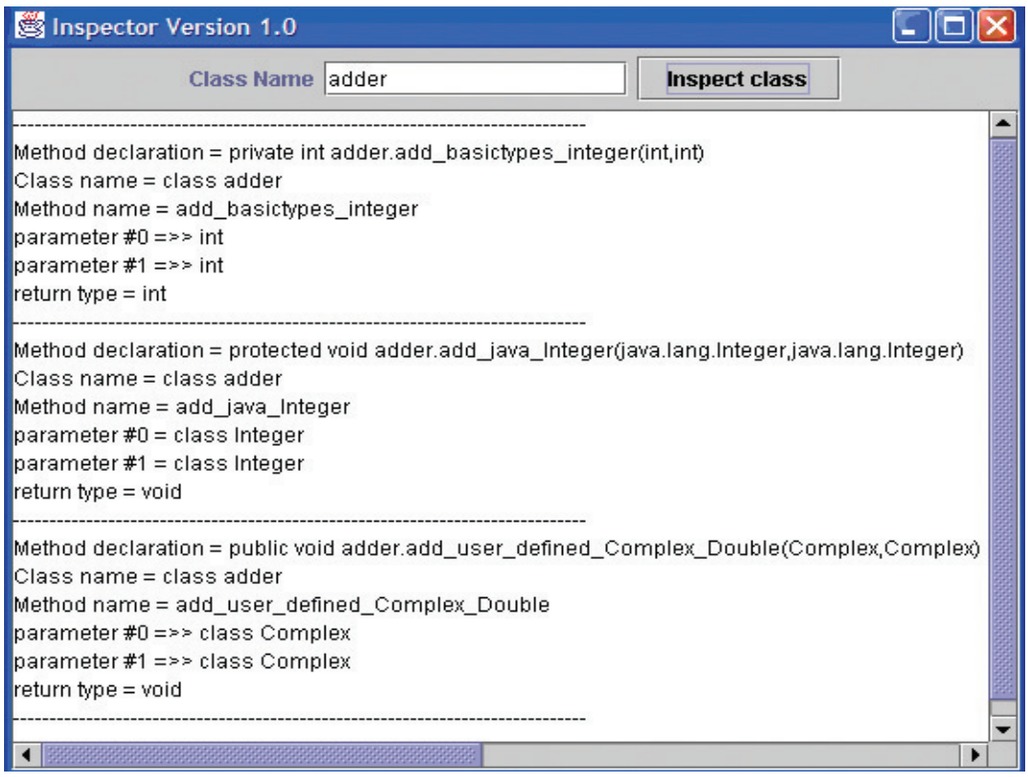
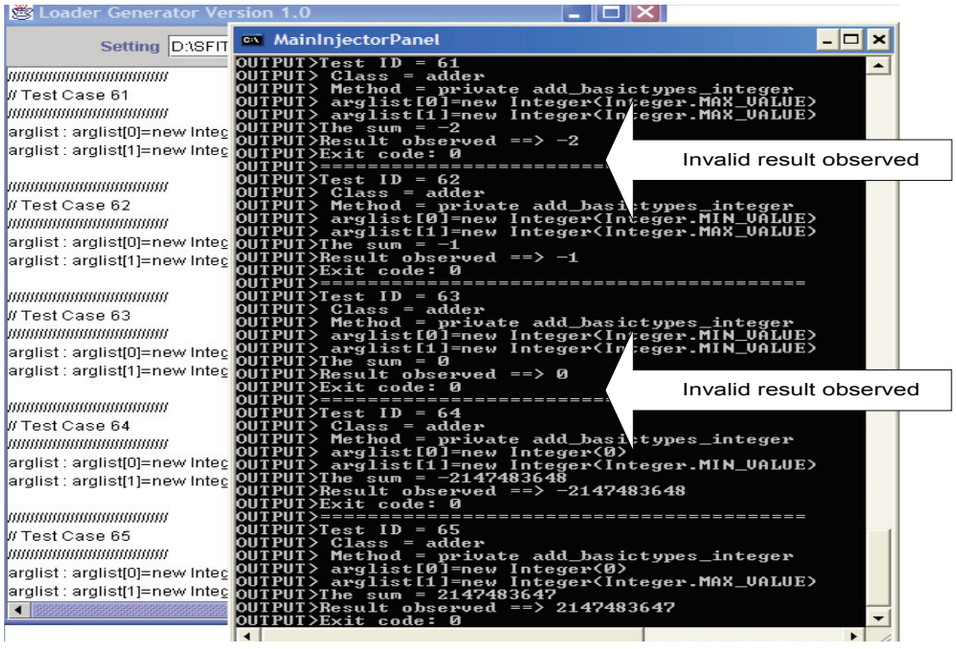


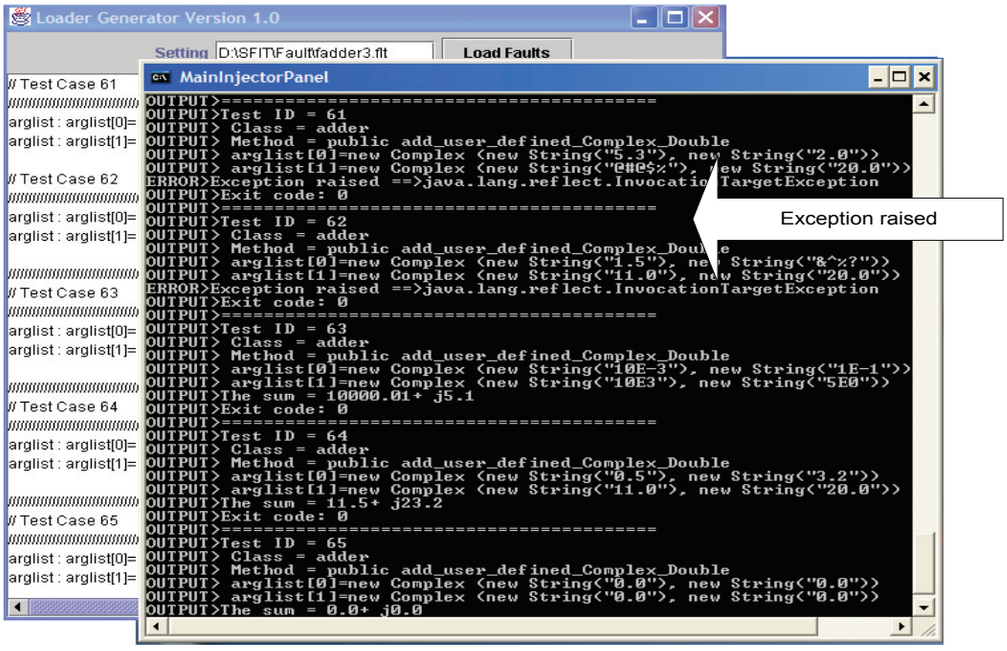
Figure 8. Inspecting the adder module.

SFIT) were defined. Concerning the method interface *add_basictypes_integer*, testing was still possible although the method was declared as private (and returned an integer). A snapshot of the testing output can be seen in Figure 9.

In testing the method interface *add_basictypes_integer*, an alarming result was observed when two maximum boundary values based on the Java® pre-defined constant *Integer.MAX_VALUE* were added together. It were expected that the operation would throw a floating point overflow exception. Rather, the operation gave a wrong value of –2 (see Figure 9). Similarly, adding two minimum boundary values based on Java® pre-defined constant *Integer.MIN_VALUE* also produced an erroneous answer. These results



Snapshot of the results for *add_basictypes_integer*



Snapshot of the results for *add_user_defined_Complex_Double*

Figure 9. Snapshot of the selected results.

showed that the adder module used in this experiment could not tolerate even the simplest robust inputs.

As far as the method interface *add_java_Integer* was concerned, it was possible to execute all the 65 test cases even though the method was declared as protected. Similar to the method interface *add_basictypes_integer*, the method interface would fail to give correct results when the boundary values were used.

Finally, concerning the method interface *add_user_defined_Complex_Double*, 65 test cases were also defined. Unlike the two method interfaces defined earlier, *add_user_defined_Complex_Double* was declared as public. While public methods were universally accessible to all, it was also necessary to demonstrate the fact that SFIT could also test public methods in order to qualify as a general software testing tool.

In order to initialize the Complex object as the passing parameters of *add_user_defined_Complex_Double*, two input String classes were used for the real and imaginary parts of the complex numbers of interest as part of the constructor. The reason for using string inputs was to demonstrate that SFIT could also trigger the Java® exception handling mechanism in the case of invalid String class inputs (e.g. '@#@$%' and '&^%?'). As discussed earlier, the two String inputs would undergo floating point conversion in the Complex class before that addition took place. This issue is further demonstrated in the snapshot given in Figure 9.

Evaluating robustness of Java® COTs. Here, Jada (Ciancarini & Rossi 1997), a distributed shared memory implementation of Linda in Java®, was chosen as the second case study for SFIT. The rationale for choosing Jada stemmed from the fact that it was a public domain Java® COTs which was freely accessible for downloading from the internet. Like most other COTs implementation, Jada did not come with source codes although an overview of its methods and functionalities are given in the documentation.

Based on the given documentation and using SFIT as the testing tool, a number of test cases were defined to be used in this case study. The main aim of this case study was to evaluate the suitability of SFIT as a testing tool for assessing Java® COTs. In fact, these experiences were valuable to establish whether or not Jada implementation was robust, and hence could be used for critical safety applications.

Jada is a Java® COTs based on the Linda parallel programming model that was proposed by David Gelernter (1985). Tuple space, essentially a distributed shared memory, is the Jada's mechanism for creating and co-ordinating multiple execution threads. Tuple space stores tuples, where a tuple is simply a sequence of typed fields. Jada defines three operations on tuple space:

- out(t); causes tuple t to be added in the tuple space.
- in(s); causes any tuple t that matches the template s to be withdrawn from the tuple space. The actual values of t are assigned to the formats of s and the executing process continues. If no matching t is available when in(s) executes; the executing process suspends until one is (i.e. blocking). If many matching t's are available, one is chosen arbitrarily.
- read(s); its operation is the same as in(s); expect that the matching tuple is not withdrawn from the tuple space.

Apart from the abovementioned operations, Jada also provided the non-blocking version of out(t), in(s) and rd(s). As no source code was available, it was impossible to know the exact class structure and dependencies of Jada. Nevertheless, the Jada documentation highlighted the Jada class hierarchy, given in Figure 10.

- class java.lang.*Object*
  - class jada.*FloatSerializer* (implements jada.JadaSerializer)
  - class jada.*IntegerSerializer* (implements jada.*JadaSerializer*)
  - class jada.*Jada*
  - interface jada.*JadaItem*
  - interface jada.*JadaNetConst*
  - class jada.net.*JadaNetIO*
  - interface jada.*JadaSerializer*
  - class jada.net.*ObjectServer* (implements java.lang.*Runnable*, jada.*JadaNetConst*, jada.net.*JadaNetOpcodes*)
  - class jada.*ObjectSpace*
    - class jada.net.*ObjectClient* (implements jada.*JadaNetConst*, jada.net.*JadaNetOpcodes*)
  - class jada.*StringSerializer* (implements jada.*JadaSerializer*)
  - class java.lang.*Throwable*
    - class java.lang.*Exception*
      - class jada.*JadaException*
        - class jada.*JadaFormatException*
        - class jada.*JadaIOException*
        - classjada.*JadaItemIsNotStreamableException*
  - class jada.*Tuple* (implements jada.*JadaItem*)
    - class jada. *TupleString*
  - class jada.*VectorSerializer* (implements jada.*JadaSerializer*)

Figure 10. Jada Class Hierarchy.

Although testing all the classes defined in Jada was equally beneficial (see Figure 10), the Jada Object Space class was the focus of this work. The rationale for such a focus was due to the fact that it is the Object Space class that implements the Linda tuple space operations.

It should be noted that although given in the Jada documentation, the methods for manipulating tuple space defined in the Object Space Class could also be discovered automatically using the SFIT Class Inspector (see Figure 11).

Fifteen experiments were devised to evaluate the robustness of Jada operations manipulating the tuple spaces. These experiments are summarized below:

- *Experiment 1: public void out (Object item)*
- *Experiment 2: public void out (Object objects [ ], int n_objects)*
- *Experiment 3: public Object in (Object match)*
- *Experiment 4: public Object in (Object match [ ], int n_objects)*
- *Experiment 5: public Object in (Object match, long timeout)*
- *Experiment 6: public Object in (Object match [ ], int n_objects, long timeout)*
- *Experiment 7: public Object in_nb (Object match)*
- *Experiment 8: public Object in_nb (Object match [ ], int n_objects)*
- *Experiment 9: public Object read (Object match)*
- *Experiment 10: public Object read (Object match, long timeout)*
- *Experiment 11: public Object read (Object match [ ], int n_objects)*
- *Experiment 12: public Object read (Object match [ ], int n_objects, long timeout)*
- *Experiment 13: public Object read_nb (Object match)*
- *Experiment 14: public Object read_nb (Object match [ ], int n_objects)*
- *Experiment 15: public Object read (object match) with max possible test cases of 2500*

With the exception of *Experiment 15* where 2500 test cases were used, at least 500 test cases were employed in each experiment. The complete discussion of each experiment is beyond the scope of this paper; only the summary will be highlighted here. Interested readers are referred to Alang Hassan (2005).

In all of the experiments undertaken, Jada Object Space class methods behaved as expected when the classes

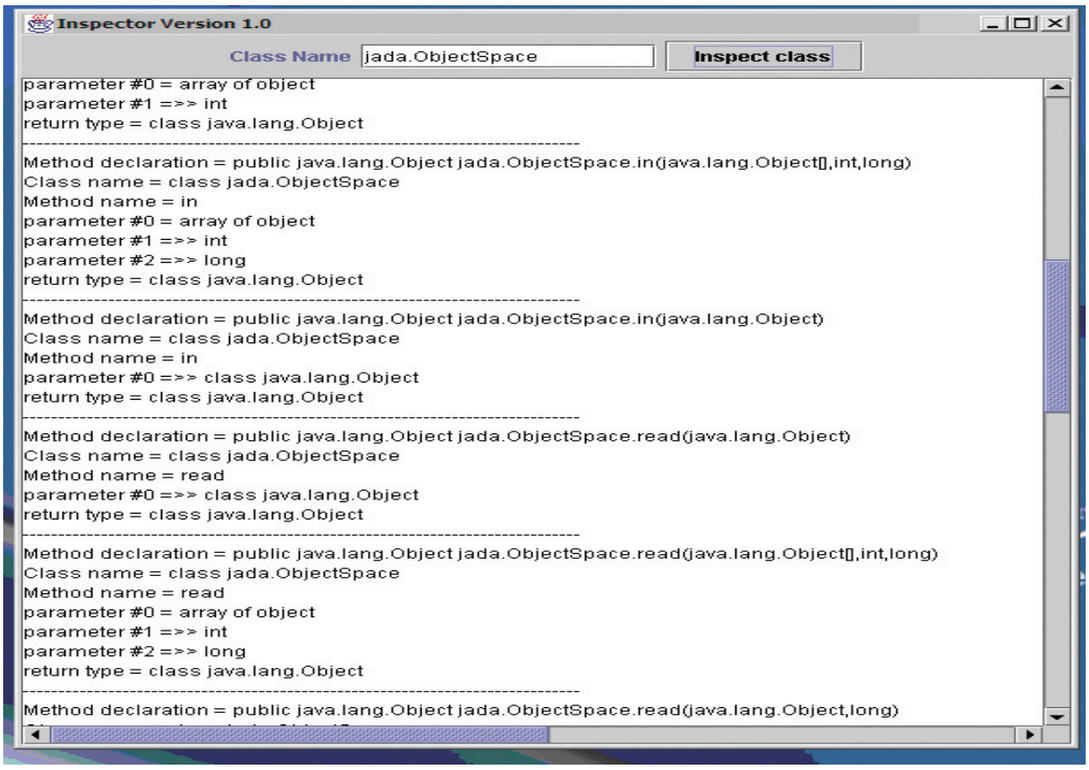


Figure 11. Inspecting Jada Object Space class.

involving String, Integer and Float were used as the passing parameters. Nevertheless, when the Long, Double, and user defined class are used, most methods failed to respond properly. For example, in the experiment involving method *public void out (Object item)*, the method unexpectedly blocked when a Long, Double or a user defined class was used as the passing parameter for the variable item. Similarly, in *Experiment 2* (involving the method *public out (Object [] item, int n_objects)*, the methods also blocked when a Long, Double or a user defined class was used as the passing parameter for the array item. In fact, this observation was true of other experiments as well.

Although defined as objects, the fact that only String, Integer and Float were supported as the valid passing parameters for the object variable in all the methods of the Object Space class raised an issue relating the usefulness of Jada. At a glance, it might appear that Jada implementation might not be sufficiently extensive for manipulating distributed shared memory. Nevertheless, a counter argument suggests that an *ad hoc* approach may be adopted in order to simulate the use of Long, Double and user defined class as passing parameter, for instance, by representing the required passing parameter (e.g. item) as String. Later, a straightforward conversion routine could be developed as required.

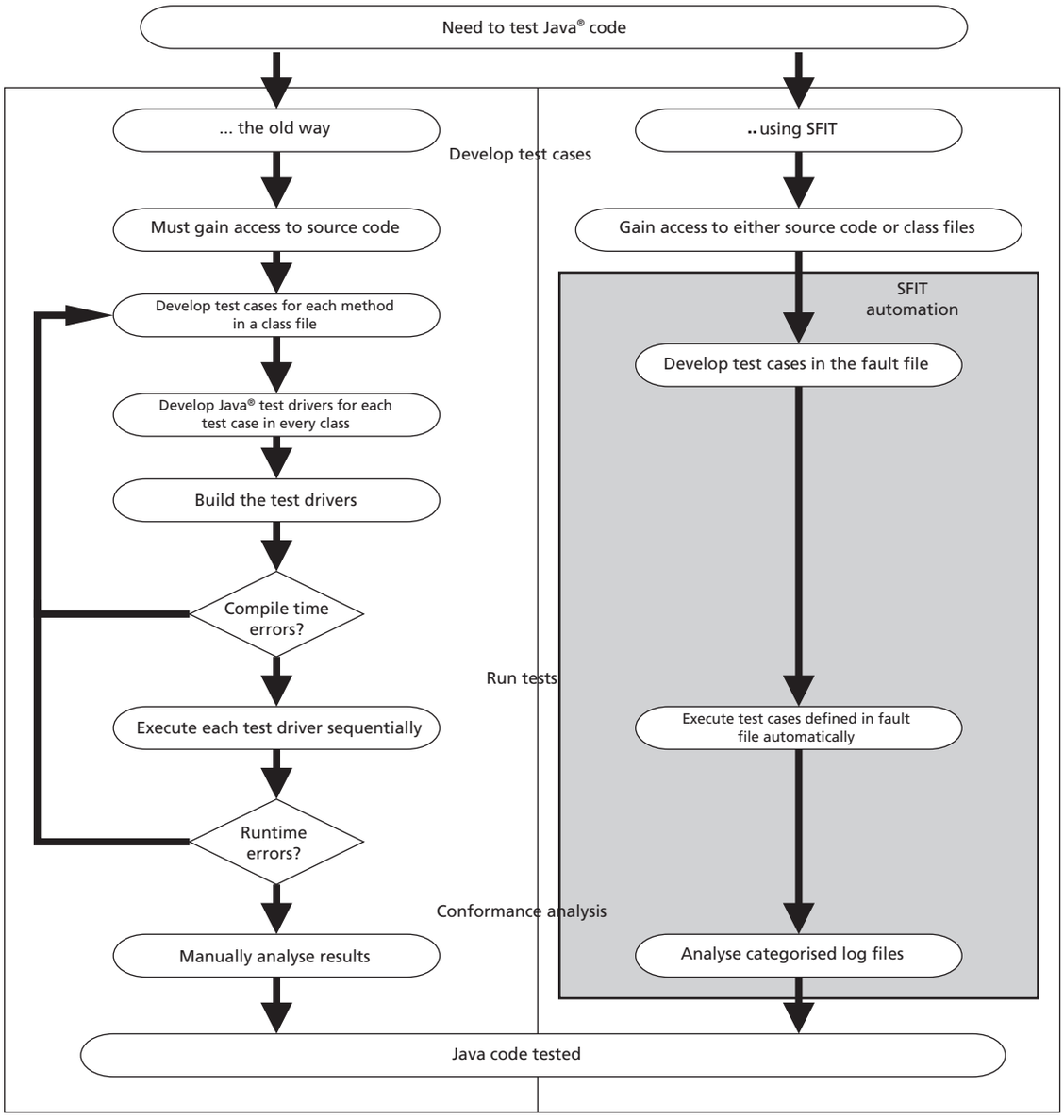


Figure 12. SFIT Automation.

Testing Jada Object Space class with values more than the allowable boundary also caused problems in Jada. For instance, when manipulating extreme operations on Java® pre-defined *Integer.MIN_VALUE, Integer.MAX_VALUE, Float.MAX_VALUE*, and *Float.MIN_VALUE* or any of their combinations in the passing parameters, there was a tendency for all the methods to hang (and never return). This could be seen, for example, in *Experiment 5* involving the method *public object in (object item, long timeout)*. Here, when the variable timeout is given a boundary value, the method unexpectedly hanged. Similar observations could be seen in other methods, for example, involving *Experiment 14*. Here, the method under testing is given as *public Object read_nb (Object match [], int n_objects)*. If the variable *n_objects* used a boundary value (and an out of range value) the method also unexpectedly hanged. Here, rather than the methods to completely hang, a graceful exit mechanism would be helpful for improving the current Jada implementation.

Another observation worth mentioning was on the Jada Object Space methods involving array values as in *Experiment 8*. In this case, the method was defined as *public object in_nb (Object [] match, int n_objects)*. From the Jada specification, the number of values defined in the array of object match must ideally tally with the values of *n_objects*. However, our observation indicates that Jada was flexible enough to accept any values of *n_objects* and yet still gave the expected result provided that the values were within range (see the previous paragraph). Again, similar observation could be seen in all other methods involving array values.

Overall, while useful for manipulating distributed shared memory, Jada appeared to be unsuitable for highly available and critical safety applications. As seen above, Jada lacked robustness, that is, it always failed to behave accordingly when unsupported or out of range input values were used.

DISCUSSION

As discussed earlier, the main issues which are under consideration in this section relate to the applicability of SFIT as an automated software testing tool for Java® program. Such consideration may help to improve SFIT by providing necessary feedback based on the author's practical experiences.

Test automation is the key feature of SFIT. Test automation improves efficiency while reducing the time taken up by this task, thus reducing the cost and increasing the quality of the final product. As comparison, Figure 12 depicts traditional testing with the automation provided by SFIT.

In the absence of source codes, testing is still possible using SFIT. Recall that, SFIT provides an inspector tool for interrogating COTs under question for class name and method interfaces. This information would then be used in order to execute fault through the method interface.

Although the first running experiment with the adder module demonstrated the testing of Java® classes with source code, the same experiment could have been done in the absence of source code (i.e. as the second running experiment involving Jada). The reason for having tested the adder modules with source code was to enable comparison with the expected results with the actual value. In this way, the true behaviour of SFIT could be ascertained.

The SFIT fault file in some ways could be compared to SoftTest's test plan (Childers *et al.* 2003). Here, the information in the test plan was used to instrument the source code of the module under test. In this way, SoftTest could also test specific code branches if necessary. Nevertheless, unlike SFIT, no testing was possible in SoftTest in the absence of source code.

SFIT was also successful for testing on the private method interfaces. We have to recall that in object-oriented languages, private methods are inaccessible to any module other than itself. The fact that SFIT could access the private method reflects the suitability of SFIT to support testing where no source code was available. As discussed earlier, the capability of SFIT to access private methods was actually made possible by the use of computational reflection.

In addition to allowing testing of private methods (and public ones), SFIT also permited testing on protected methods. Conceptually, protected methods were only accessible to the child of the module under tests derived from inheritance relationship. As seen earlier, SFIT could still successfully execute fault into the component under test without the need to rely on inheritance relationship. With such a feature, SFIT appeared to be a useful testing tool for object oriented programs.

Apart from testing private and protected methods, the first running experiments also demonstrated the fact that SFIT could also initiate fault testing based on some user-defined classes. The significance of this capability demonstrated the scalability of SFIT for testing commercial Java® implementations which sometimes do not use standard Java® classes. The ability to keep historical data was also another significant feature of SFIT. This feature permited offline conformance analysis of the test results as well as allowed test archives to be setup for traceability purposes.

Comparatively, the SFIT approach was similar to JACA (Moraes & Martins 2003) in the sense that JACA also used computational reflection in order to execute faults in a Java® program. At a glance, JACA appeared to have all the features of SFIT. Nevertheless, a closer look revealed that, unlike SFIT, JACA required that the test engineer who

performed the testing had substantial knowledge of Java® in order to undertake the testing process, that is, in order to manually write the test driver program. As seen earlier, the driver code for SFIT are automatically generated and executed in a single-click of a button. Furthermore, the testing process in SFIT was highly automated allowing 2500 test cases to be executed at a particular instant. As such, SFIT could be seen as offering a high level of abstraction for testing.

Despite its advantages, SFIT was not without limitations. Preparing fault setting could also be a difficult process. The user had to follow certain rules and formats in order to facilitate the parsing of each test data. It was suggested that improvements be made through GUI to simplify the process of preparing fault setting files. Additionally, a fault setting template would also be useful. In that way, the user only needed to fill in the relevant information within the template.

Another avenue for improving SFIT related to the integration of sensitivity measuring matrix such as the CRASH scale (Pan *et al.* 1999; Ballista Project 2006). The CRASH scale refers to the acronyms which stands for Catastrophic, Restart, Abort, Silent, and Hindering. Catastrophic failures refer to failures that could cause the whole system to stop functioning. Restart failures mean that the system hanged and require user intervention to kill the appropriate tasks. Abort failures refered to abnormal termination of the tester process. Silent failures were false successes that are when errors should have occurred. Finally, hindering failures mean return of incorrect error codes. With the CRASH scale, it was possible to measure how sensitive components under test was in response to extreme input and stressful environment. Furthermore, with such integration, it might be possible to design an automated fault analysis as part of SFIT.

CONCLUSION

This paper has described the design, implementation, and evaluation of an automated Java® testing tool called SFIT. We believe that the development of an automated testing tool like SFIT was crucial in order to assist software engineers at work to promote higher product quality at lower testing costs. Even though SFIT was proved as a useful automated testing tool, it could be enhanced further in order to be a useful and practicable testing tool.

ACKNOWLEDGEMENTS

This research is funded by the eScience Fund — 'Development of a Software Fault Injection Tool to Ensure Dependability of Commercial-off-the-Shelf (COTs) Components for Embedded System Applications' (Project Number: 01-01-05-SF0124).

Date of submission: May 2007
Date of acceptance: November 2007

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ASM Sci. J., **1(2)**, 101–108

Purification and Characterization of an Intracellular Toxic Protein from a Clinical Isolate of *Pseudomonas aeruginosa*

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An intracellular toxic protein of *Pseudomonas aeruginosa* was purified by ion-exchange chromatography on DEAE-cellulose. The purified protein was homogeneous as determined by polyacrylamide disc gel electrophoresis; its molecular mass was determined by gel filtration on Sephadex G-150® and was estimated to be about 62 000 kDa. The purified intracellular toxin appeared to be a dimer and the molecular weights of the subunits were estimated to be 31 000 kDa and 30 500 kDa. The purified protein showed significant toxicity against brine shrimp nauplii and its LC_{50} value was calculated to be 25 µg/ml. The toxic protein was glycoprotein in nature with a neutral sugar content of 4%. It agglutinated red blood cells from albino rats and rabbits and the agglutination was strongly inhibited in the presence of galactose. This intracellular toxin may be an important virulence factor of *P. aeruginosa* and might be involved in the pathogenesis in human infections.

Key words: *Pseudomonas aeruginosa*; intracellular; toxin; protein; purification; characterization; Bangladesh; pathogenesis

Pseudomonas aeruginosa is one of the most virulent organisms among the opportunistic pathogens and has emerged as an important agent of nosocomial infections (Salyers & Whitt 1994). It is the second most frequent gram-negative organism responsible for hospital infections and has the highest case-fatality rate of all hospital-acquired bacteremia (Bryan *et al*. 1983).

The virulence of *P. aeruginosa* is multifactorial, and is determined by a variety of bacterial products. It adheres to the host cell surface, secretes noxious toxins and hydrolytic enzymes at the contact site. It produces a variety of enzymes, toxins including exoenzyme S, exoenzyme T, and exotoxin A (Ohman *et al*. 1980; Nicas & Iglewski 1985; Woods *et al*. 1996a; Galloway 1991). These factors damage the host tissue and may be important for bacterial dissemination.

Identification and characterization of microbial toxins are prerequisites for understanding their role in pathogenesis. No work has been done to determine the virulence factors of *P. aeruginosa* which causes different types of infection in the Bangladeshi population. The present study describes the purification and characterization of an intracellular toxin from *P. aeruginosa* which was isolated from a patient with hospital acquired infection in Bangladesh. This putative intracellular toxin may be used as a marker to detect *P. aeruginosa* capable of causing invasive infection in human.

MATERIALS AND METHODS

P. aeruginosa (Strain no.14) used in the present study was isolated from a patient with hospital acquired infection. The strain was selected because it was multi-drug resistant and associated with invasive infection. It has been identified and characterized systematically in a previous study (Begum 2003). All the chemicals used were of analytical grade and unless otherwise specified, all experiments were performed at 4ºC.

Growth of Bacterial Cells

Three to four colonies of *P. aeruginosa* (Strain No.14) were inoculated aseptically into Mueller-Hinton broth (150 ml – 200 ml) and incubated overnight at 37ºC in a shaking incubator. After incubation, the culture growth

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was clarified by centrifugation at 4000 g for 10 min. The clear supernatant was discarded and the pellet (cell) was collected for biological study. The purity of each colony was determined when the organism was sub-cultured and grown for isolation of protein in broth. Each colony was identified by colony morphology, Gram stain, production of pyocyanin, fluorescein, and dihydrolase, gelatin liquifaction and carbohydrate utilization tests.

Preparation of Crude Protein Extract

Bacterial cells (10 g approximately) were lysed by ultrasonication in cold 0.1 M sodium phosphate buffer, pH 7. The temperature was maintained at 4ºC by keeping the sample container in a plastic bucket containing ice. The suspension was then centrifuged at 10 000 g for 8 min at 4ºC. The clear supernatant was collected after dialysis against 10 mM Tris-HCl buffer pH 7.4 for 24 h at 4ºC and used as crude protein extract.

Purification and Characterization of Proteins

DEAE-cellulose chromatography. The crude protein extract was dialyzed against distilled water for 12 h and against 10 mM Tris-HCl buffer, pH 8.4 for 18 h at 4ºC and then loaded onto the DEAE-cellulose column (Sigma, USA) previously equilibrated with the same buffer. The protein was eluted from the column with the same buffer containing different concentrations of NaCl. The fractions were collected with an automatic fraction collector and the protein was monitored by UV-spectroscope at 280 nm.

Polyacrylamide disc gel electrophoresis. The homogeneity of the protein was judged by polyacrylamide disc gel electrophoresis conducted at room temperature, pH 8.5 in 7.5% gel as described by Ornstein (1964). The gel was stained with 1% Amido black 10B in 7.5% acetic acid for an hour at room temperature and destaining was performed by washing the gel in 7% acetic acid (v/v) solution.

Molecular mass determination by gel filtration. The molecular mass of the protein was determined by gel filtration on Sephadex G-150® (Sigma, USA) as described earlier (Andrews 1965) using β-galactosidase from *Escherichia coli* (Mr 116 000), bovine serum albumin (Mr 66 000), α-amylase from *Bacillus subtilis* (Mr 58 000), ovalbumin (Mr 46 000), trypsin inhibitor from corn kernels (Mr 20 000) and lysozyme (Mr 14 000) as reference proteins.

Molecular mass determination by SDS-PAGE. SDS-PAGE was performed with 10% polyacrylamide gel (Weber & Osborn 1969) and the marker proteins used were the same as those used in molecular weight determination by gel filtration. Dissociation and reduction of proteins were performed by heating for 5 min at 100ºC in 0.1% SDS with 0.1% 2-mercaptoethanol and the proteins were stained with Coomassie Brilliant Blue R-250.

Protein content and estimation of sugar. The concentration of protein was measured by the method described by Lowry *et al*. (1951) using BSA as the standard. The protein in eluted fractions from the column fractions was also monitored with UV-spectroscope at 280 nm. The total neutral carbohydrate content of the purified protein was determined by the phenol-sulphuric acid method using D-glucose as the standard (Dubois *et al.* 1956).

Brine shrimp lethality bioassay of purified intracellular toxic protein. Brine shrimp (nauplii) lethality bioassay was used to test toxicity of intracellular protein purified from *P. aeruginosa* (Meyer *et al.* 1982; McLauglin *et al*. 1991). The protein sample was dialyzed against distilled water for 3 h at 4ºC and collected in different vials so that the concentrations of the toxin were 10, 20, 40, 80 and 120 µg/ml in different vials. The volume of the vials containing 10 brine shrimp nauplii, were made up to 5 ml with sea water. Three vials were used for each concentrations and a control was used containing 10 nauplii in 5 ml of sea water only. After 24 h, the vials were observed and the number of survivors in each vial were counted and noted. From this data, the percentage of mortality of the nauplii was calculated at each concentration.

Haemagglutination study of purified intracellular toxin. Haemagglutination activity of the purified intracellular toxin was determined by using albino rat and rabbit red blood cells (Lin *et al.* 1981). The agglutinating activity was expressed as the titre defined as the reciprocal of the highest dilution at which minimum agglutination could be detected. The specific activity was expressed as titer/mg of protein.

Haemagglutination-inhibition study. The haemagglutination-inhibition test was performed in presence of six different sugars. Protein solutions (0.1ml) containing minimum concentration of protein needed for visible agglutination were added to 0.1 ml of increasing concentrations of sugar solutions and mixed gently. Then 0.2 ml of 4% RBC in phosphate buffer saline (pH 7.2), either from albino rat or rabbit, was added. It was mixed gently and incubated at 37ºC for an hour. In the mixture, the concentration of the purified intracellular crude toxin was maintained at appropriate concentration. On the other hand, the concentration of sugars used was 20 mM to 250 mM. Absence of agglutination in the presence of minimum concentration of sugar was considered as positive reaction while presence of agglutination was considered negative.

RESULTS

Purification and Characterization of Intracellular Toxin

Ion-exchange chromatography on DEAE-cellulose. The crude protein extract after dialysis against 10 mM Tris-HCl buffer pH 8.4 at 4ºC for 24 h was applied to a DEAE-cellulose column at 4ºC, previously equilibrated with the same buffer and the column bound protein was eluted by a linear gradient of NaCl from 0 M to 0.4 M in the buffer. The bound proteins were eluted as a single but broad peak, indicating the presence of more than one component (Figure not shown). In order to separate these components, the elution was carried out stepwise with increasing concentrations of NaCl in the same buffer. As shown in Figure 1, the components of crude cell extract were separated into five major peaks: F-1; F-2; F-3; F-4 and F-5. Of these fractions, F-1 was eluted by the buffer only while F-2, F-3, F-4 and F-5, were eluted by the buffer containing 0.05 M, 0.11 M, 0.22 M, and 0.4 M NaCl, respectively. Only F-2 fraction (as indicated by solid bar in Figure 1) containing toxic activity was pooled and used for further purification process. The remaining fractions were not used for experimental purposes, as they exhibited no noticeable toxic property.

Re-chromatography of F-2 Fraction on DEAE-cellulose

Although the fraction F-2a was eluted from DEAE-cellulose column as a single sharp peak it was again re-chromatographed on a DEAE-cellulose column under identical conditions. After overnight dialysis of the F-2 fraction against 10 mM Tris-HCl buffer, pH 8.4, it was applied again onto a DEAE-cellulose column under identical conditions. As shown in Figure 2a, the components of F-2 were eluted from the column mainly as one sharp peak, F-2a which was eluted by buffer

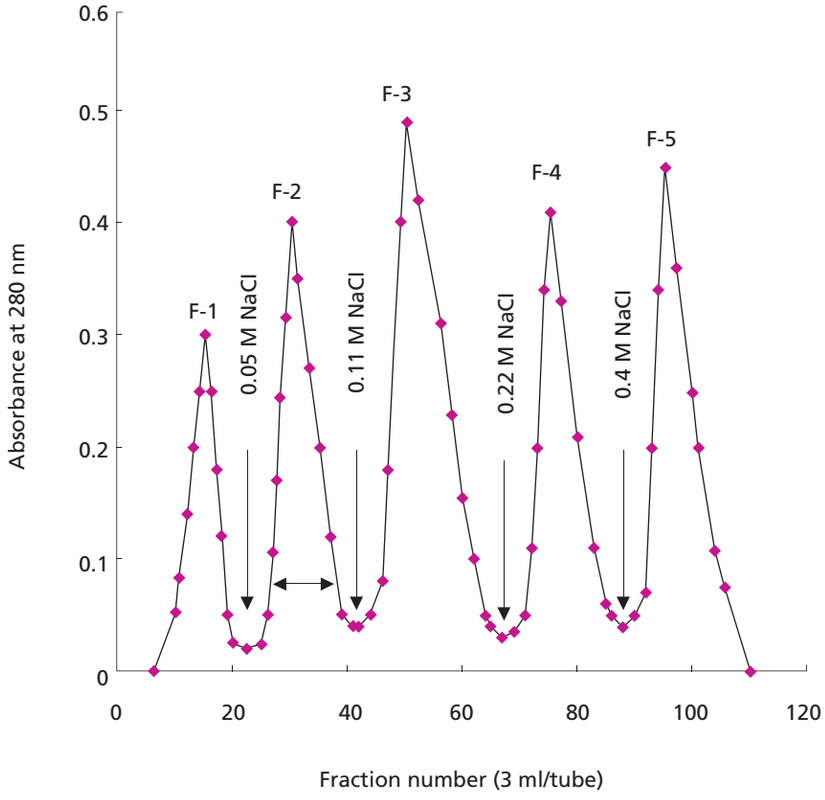

Figure 1. Ion-exchange chromatography of crude protein extract on DEAE-cellulose. The crude extract solution (40 mg) was applied to the column (2.1 cm × 20 cm) pre-equilibrated with 10 mM Tris-HCl buffer, pH 8.4 at 4ºC and eluted by stepwise increase of NaCl concentrations in the same buffer. Flow rate: 45 ml / hour.

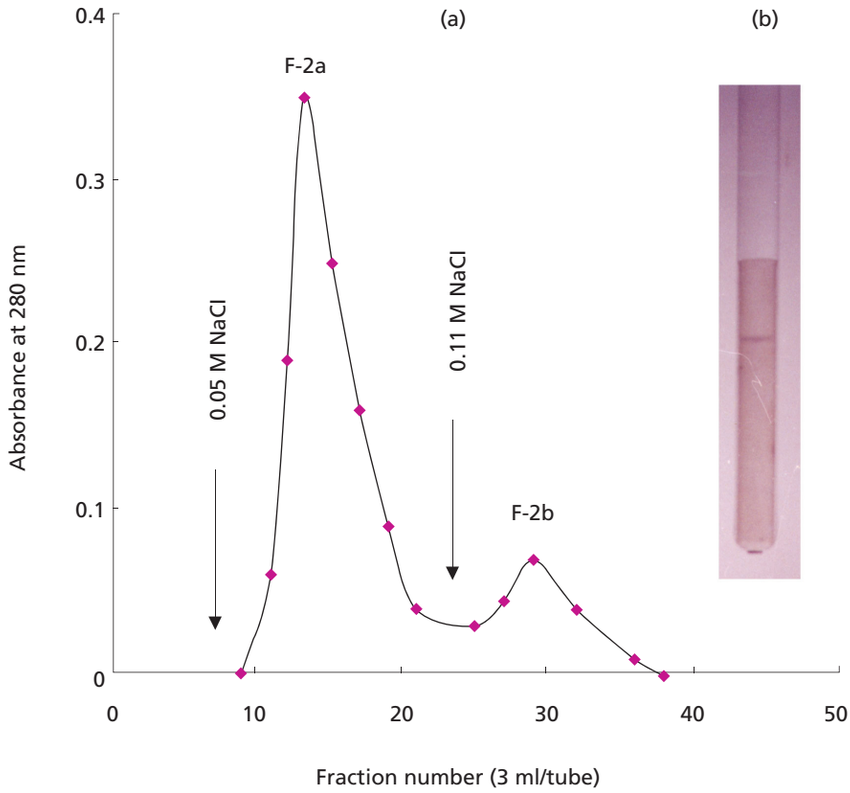

Figure 2. (a) DEAE-cellulose re-chromatography of F-2 fraction obtained from ion-exchange chromatography on DEAE-cellulose. Fraction F-2 (4 mg) was applied to the column (1.5 cm × 10 cm) pre-washed with 10 mM Tris-HCl buffer, pH 8.4 at 4°C and eluted by stepwise increases of NaCl concentrations in the same buffer. Flow rate: 45 ml / hour. (b) Polyacrylamide disc gel electrophoretic pattern of purified toxin (F-2a fraction) on 7.5% polyacrylamide gel.

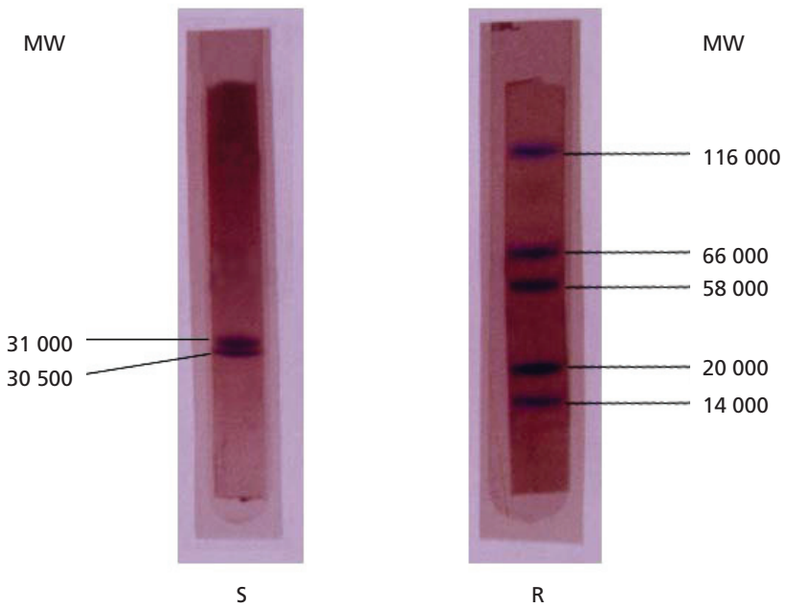

Figure 3. SDS-polyacrylamide disc gel electrophoretic patterns of marker proteins (R) and purified protein in the presence of 0.1% 2-mercaptoethanol (S) in 10% gel.

containing 0.05 M NaCl and another small peak, F-2b which was eluted by buffer containing 0.11 M NaCl. Further it was found that only the fraction, F-2a, contained toxic property. The purity of this fraction was checked by polyacrylamide disc gel electrophoresis.

Polyacrylamide Disc Gel Electrophoresis

The electrophoretic pattern of F-2a fraction has been shown in Figure 2b and the fraction contained pure protein as it gave a single band on polyacrylamide gel electrophoresis. The data pertaining to the purification of toxin from *P. aeruginosa* has been summarized in Table 1. Although the activity as well as yield of the protein decreased at each subsequent purification step, their purification fold increased and finally the purification of toxin increased to about nine-fold.

Molecular Weight of the Toxin

The molecular weight, as estimated by gel filtration on Sephadex G-150®, was found to be about 62 000 kDa (Figure not shown). It was determined from the standard curve that was constructed by plotting the molecular weight of standard reference proteins against their elution volume.

Subunit Structure of the Toxin

The subunit structure of the toxin was determined by SDS-polyacrylamide gel electrophoresis with and without β-mercaptoethanol. The toxin gave two close bands which might be due to two proteins of almost similar molecular weight (Figure 3). The molecular weights of the subunits were calculated to be about 31 000 kDa and 30 500 kDa (Figure 3). By comparing with the molecular weight of the native toxin, as determined by gel filtration, it could be concluded that the purified toxin was a dimer in nature which were held together by non-ionic hydrophobic interactions.

Glycoprotein Test and Sugar Content

The purified intracellular toxic protein gave a yellow-orange colour in the presence of phenol-sulphuric acid, indicating that it contained sugar. The concentration of neutral sugar present in the protein was found to be 4%.

Optical Density *versus* Concentration of the Purified Toxin

The optical absorbance of 1.0 at 280 nm for the toxin was found to be equal to 0.65 mg of protein, as determined by

Table 1. Purification of intracellular toxin of *P. aeruginosa.*

Steps of purification	Total protein (mg)	Total haemagglutination activity (titre)	Specific activity (titre/mg)	Yield (%)	Purification fold
Crude cell extract	40	72	1.8	100	1.00
DEAE-cellulose	4	44	11	61.1	6.11
DEAE-cellulose rechromatography	2	32	16	44.4	8.9

Table 2. Haemagglutination inhibition assay of purified intracellular toxins of *P. aeruginosa* using rat and rabbit red blood cells with various sugars.

	Sugar added	Red blood cell source	
		Rat	Rabbit
Purified intracellular toxin	D-glucose (Conc. 250 mM)	NI	NI
	D-mannose (Conc. 250 mM)	NI	NI
	D-galactose (Conc. 110 mM)	I	I
	N-acetyl-D-glucosamine (Conc. 250 mM)	NI	NI
	Methyl-α-D-galactopyranaside (Conc. 110 mM)	I	I
	Methyl-β-D-galactopyranaside (Conc. 110 mM)	I	I

Note: NI = No inhibition of agglutination; I = Inhibition of agglutination.

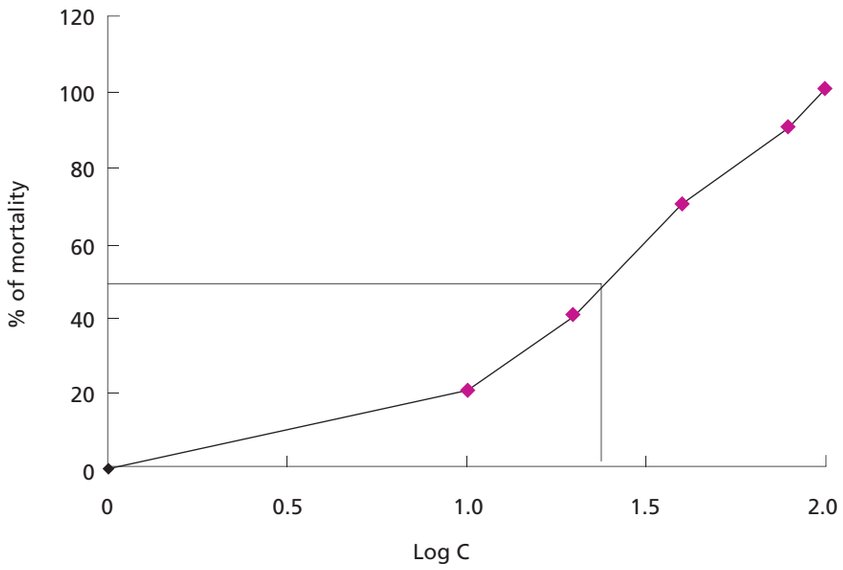

Figure 4. Determination of LC_{50} value of the purified toxin by brine shrimp lethality bioassay. Log C: Log concentration of the purified protein.

the Lowry method using BSA as standard. The value was slightly higher (0.7 mg) when the amount of protein was determined after drying the protein solution by heating under vacuum.

Cytotoxicity Assay of Intracellular Toxin

In the brine shrimp lethality bio-assay, the protein showed a positive result indicating that the purified intracellular protein F-2a was cytotoxic in nature. The mortality rate of brine shrimp nauplii increased with the increase in concentration of the sample and a log plot of concentration *versus* percentage of mortality gave an almost linear correlation (Figure 4). The LC50 (concentration at which 50% mortality of the brine shrimp nauplii occurred) was determined from the graph by extrapolation and the LC_{50} value of the protein was calculated to be 25 µg/ml.

Haemagglutinating Activities of Toxin

The purified intracellular toxin from *P. aeruginosa* agglutinated specifically the rabbit and albino rat red blood cells. The minimum protein concentration needed for visible agglutination was taken as the minimum haemagglutination dose and was calculated to be 0.015 mg/ml and 0.029 mg/ml for rat and rabbit red blood cells, respectively. It was evident from the results that the toxins agglutinated albino rat red blood cells at a lower concentration as compared to that of rabbit red blood cells.

Haemagglutination Inhibition Studies

Haemagglutination inhibition assay using rat and rabbit red blood cells was performed in the presence of different sugars. As presented in Table 2, the haemagglutination activity of purified toxic protein was inhibited specifically with 110 mM of galactose and galactose containing saccharides. No inhibition was observed with other sugars even with a concentration up to 250 mM.

DISCUSSION

The authors have purified an intracellular toxin from a clinical isolate of *P. aeruginosa* by ion-exchange chromatography on DEAE-cellulose followed by re-chromatography on the ion exchange matrix under identical condition. The molecular weight of the intracellular toxin was calculated to be about 62 000 kDa by gel filtration on G-150 Sephadex® and its subunit structure was determined by SDS-polyacrylamide gel electrophoresis. The toxin gave an almost overlapping band under denaturing as well as reducing conditions. It might be concluded from the pattern of gel that the toxin was a dimer and the molecular weight of the subunits was almost similar and were calculated to be about 31 000 kDa and 30 500 kDa. From this observation it could be indicated that the subunits were held together by non-ionic hydrophobic interactions. Like our isolated protease (Begum *et al.* 2007), the purified intracellular toxin was also a glycoprotein as it gave a yellow-orange colour with

phenol-sulphuric acid. We believe that the toxic protein that we isolated was a cytoplasmic intracellular protein and was not an outer membrane protein (OMP) or associated with cell surface because the OMP and surface components were removed after sonication by centrifugation. The purified toxin was tested on animal models to determine its role in pathogenecity in a separate study. We found that the purified toxin was able to induce inflammation and necrosis in tissue which indicated its cytotoxic property. However, it needs to be seen whether antitoxin to this intracellular protein can neutralize it and thus reduce the virulence of the organism.

P. aeruginosa produces several exoenzymes, namely exoenzyme U, Y, S and T. Exoenzyme U is a phospholipase (Hauser *et al.* 1998; Sato *et al*. 2003), and ExoY is an adenylate cyclase (Yahr *et al*. 1998). Exoenzyme S and T are highly homologous to each other and have ADP-ribosyltransferase and GTPase-activities (Goehring *et al.* 1999; Krall *et al.* 2000; Radke *et al.* 1999; Sun *et al.* 2003). It has been reported that *P. aeruginosa* produces an exotoxin A, a cytotoxin having molecular weight of 66 kDa which kills cells by inhibiting protein synthesis (Me´re´ *et al.* 2005; Leppla 1976). The organism also produces a 28 kDa and a 56 kDa cytotoxin (Sliwinski-Korell *et al.* 1999). However, these exoenzymes and toxins are different from our intracellular purified toxins in characters and locations.

P. aeruginosa produces two carbohydrate binding lectins, LecA and LecB with cytoxic properties (Tielker *et al.* 2005; Gilboa-Garber 1982). The bindings of these lectins are inhibited by mannose and fucose, respectively. Our purified intracellular toxin might be a type of galactophilic lectin with cytotoxic properties as has been shown by the brine shrimp lethality assay and haemagglutination inhibition assay. However, the intracellular toxin that we have isolated and purified is distinct from the above mentioned cytotoxic lectins as its activity has not been affected by either mannose or fucose.

It appears that our purified protein is an intracellular galactophilic toxin with cytotoxic properties. This toxin might be an important virulence factor of *P. aeruginosa* and might play a role in pathogenesis and tissue damage in infected persons.

Date of submission: July 2007
Date of acceptance: November 2007

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ASM Sci. J., **1(2)**, 109–128

Global Colour Scale for Timeline Events in Ion Dynamics

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Spatio-temporal datasets are a collection of datasets where data can vary in both space and time. Theoretically, such datasets can be considered as continuous and discrete. For example, specification of the function, F: $E^d \times T \rightarrow R^n$, where E^d denotes d-dimensional Euclidean space, $T = R^* \cap \{\infty\}$ the domain of time and R^n an n-dimensional scalar field. Examples of such data sets include time-varying simulation results, film and videos, time-varying medical datasets, geometry models with motion or deformation, meteorological measurements, and many more. It is therefore highly desirable to use visualisation to summarize meaningful information in higher dimensional spatio-temporal datasets. Our aim is to conceive an efficient visual study to facilitate scientists in identifying temporal association among complex and chaotic atom movements in ion trajectories. An application that uses a streamline for spatial motion of ion trajectories and Colour Number Coding Scheme for temporal encoding of high degree of timeline events among mobile ions is proposed. With an anthology of the visual examples, it was revealed that this application would be beneficial for scientists to visually mine any 3D spatio-temporal dataset.

Key words: spatio-temporal applications; ion dynamics; streamlines; colour scale; coding theory; visual representation; zooming; transparency; depth-cueing; halos; opacity; depth

The transport of ions within periodic glass structures has remained an enigma for many years, the resolution of which will be critical for explaining the huge versatility of glass in technology; including its homogeneity, its electrical, mechanical and chemical characteristics. Physicists have proposed a variety of ionic conduction models, ranging from the correlated forward and backward hopping of single cations (Funke 1993), to collaborative process involving the transport of many mobile cations (Ngai 1993; Smith *et al*. 1995; Ngai *et al*. 1998).

Experimentally, the collaborative character of ion trajectories in glass can be inferred from dielectric and ion transport properties. The existence of such collaborative phenomena was indicated by examining ionic conductivity data, tracer diffusion measurements and dielectric data collected from experiments (Greaves & Ngai 1995; Ngai *et al*. 1998; Ngai *et al*. 2002). However experimental data, which measures macroscopic properties and lacks in structural periodicity, does not provide any description of the atomic structure and trajectories. Any detailed observation of spatio-temporal collaboration in ion trajectories is not possible at this moment. The glass structure and trajectories over the spatial and temporal scales relevant to diffusion processes therefore remain undetermined from the experiments.

With the advance of computational science, large-scale simulation of molecular trajectories, followed by statistical analysis, have resulted in a better comprehension of ion trajectories in glass. These approaches have established the clustering of alkalis (Oviedo & Sanz 1998; Sunyer *et al*. 2002; Meyer *et al*. 2004), and identified both localized hopping and long-range collaborative jumps (Habasaki & Hiwatari 2002). Collaborative transport is less likely at low temperature or at low and in mixed alkali compositions (Rao & Balasubramanian 1995; Smith *et al*. 1995; Greaves 1998). This latter phenomenon is known as the mixed-alkali effect and has been interpreted by involving an energy penalty which inhibits hops to sites previously occupied by a different alkali type (Maass *et al*. 1995). Many of these ideas beg the question of visualisation to clarify the relationship between glass structure and ion trajectories at the local level.

In a comprehensive study of single and mixed alkali glass, 1080 atom models of composition $(Na_{(1-x)}\ K_x)_2\ Si_2O_5$ were calculated using the Molecular Simulation Package. In these models (Smith *et al.* 2007), Si (silicon) and 0 (oxygen) atoms form the silicate network, which hosts alkali Na (sodium) and K (potassium) ions in a number of suitable spatial domains. The short-range Van der Waals interactions are modelled by the Buckingham potential :

$$U(r_{i,j}) = \mathrm{A}\ \exp\left(-\frac{r_{i,j}}{\rho}\right) - \frac{C}{r_{i,j}^6} \qquad (1)$$

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where U and $r_{i,j}$ denote the energy and the interatomic distance for the pair of atoms i and j, respectively. The long-range Coulomb interactions are handled *via* the standard Ewald sum.

In order to form the silicate network, the model potential for the 0-0, 0-Si interactions is based on that of Vessal *et al*. (1989), and three-body components are used to control the 0-Si-O and Si-O-Si angular distributions U ($\theta_{i,jk}$) where $\theta_{i,jk}$, is the angle formed by atoms *i, j* and *k*.

Simulations of the trajectories have been performed at the fixed temperature of 1800 K and over a duration of 20 ps – 100 ps. They involve the integration of Newton's equations of motion for each time step for each atom which allow the calculation of the individual atomic trajectories over time. At this temperature, a fraction of the alkali Na and K ions can be mobile, travelling through a comparatively frozen silicate network.

Studying the complicated events that result in ion migration from statistical functions, however, has proved elusive in the past. Most ions stay close to the same position over time, but some can move a considerable distance, typically within about 10^{-11} seconds. The latter events have been interpreted as collaborative (Habasaki & Hiwatari 2002) and the analysis of time series events has also been conducted (Habasaki *et al*. 2005).

Using visualisation, it becomes possible for us to probe these complex compositional dependent processes by looking at the choreography of neighbouring ions. The distinction of different mobility of ions can be clearly seen in Figure 1 which shows the movements of neighbouring Na (blue), 0 (cyan) and Si (green) ions in disilicate glasses. Ion tracks are reduced to attractors using the Ruelle-Taken formalism. These are mainly roughly spherical in shape, ion motion being contained within a short distance ($< 10_{10}$ *m*), but the mobile Na ions in the lower half clearly travel much further.

The simulation results include various thermodynamic properties of the simulated ensemble average, the positions of the bonds between atoms and the trajectories of ions as time-varying series of 3D points which can be forwarded to the visualisation process. In this work, we are particularly

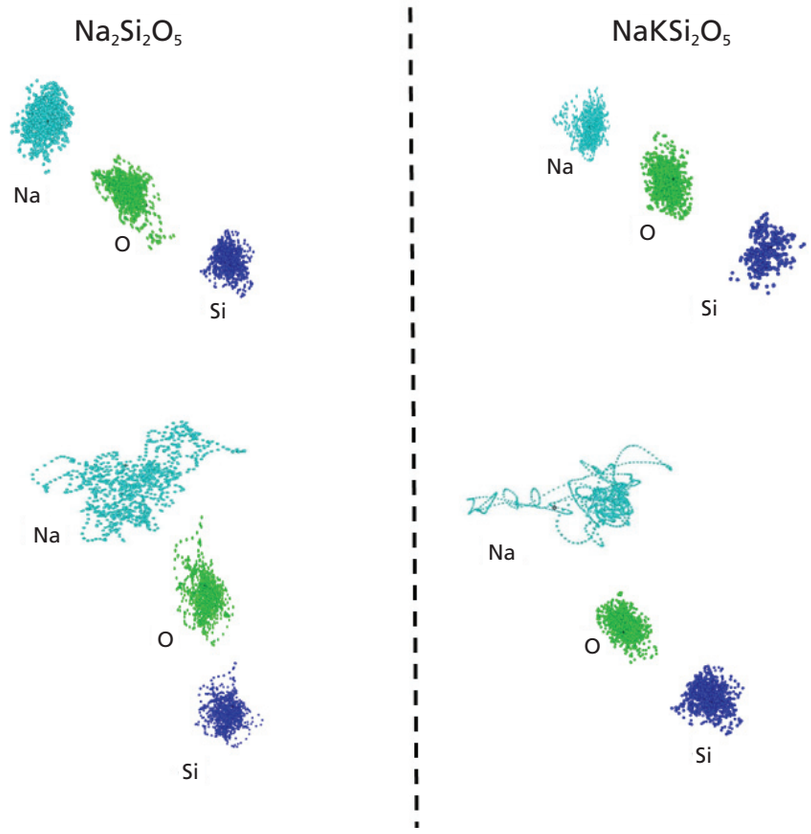


Figure 1. Attractors for neighbouring ions are shown for $Na_2Si_2O_5$ (left) and $NaKSi_2O_5$ (right) glasses. Sodium (Na) attractors appear to be more mobile than others, indicating their possible involvement in spatio-temporal collaboration.

interested in the identification of time series events and collaborative activities from a given collection of such trajectories for ions *a,b*,…. :

$$P_{a,0}, P_{a,1} \ldots, P_{a,n}; \quad (2)$$

$$P_{b,0}, P_{b,1} \ldots, P_{b,n}; \quad (3)$$

In the rest of this paper, we will first give a description of the application concerned, the scientific background which will be followed by the method that we used in our study. This section is divided for two concrete issues: firstly, we would be representing timeline events of ion trajectories and secondly, we enumerate a method for collaboration events. In the following section, a discussion will takes place before we conclude.

COLOUR SCALE

In colour science, colour scale is a series of the ordered numbers which represents observable gradations of an attribute or combination of attributes of colour perception. Colour scale visualisation is commonly used to represent numerical information (Robertson 1988; Levkowitz & Herman 1992; Hall 1993; Cossu 1995; Johannsen 1995). Normally, a sequence of N distinct numerical values v_0, v_1, ..., v_N can be respectively represented by the colours c_0, c_1, ..., c_N, which can comprise as steps of an attribute.

We have conducted several analytical tests to observe which colour scale can possibly depict a timeline in the series of events. In this section, we present a visual study of six ions, including three sodium and three oxygen ions. In the beginning, no assumption had been made for co-operation because we wanted to evaluate the effectiveness of global and local colour scales. The reason is for viewers to be able to observe the timeline for example $t = 0$, $t = 1$ and so on.

Data visualisation is commonly used to convey a wide variety of information. Generally, every scientific visualisation needs colour to enhance the ability to analysis, evaluate, assess and examine large datasets (Helman & Hesselink 1989; Haber 1990; Dovey 1995; Pang & Alper 1995; Shen *et al*. 1996; Crossno *et al*. 2001). In time-varying visualisation, colour has also become popular lately, to achieve needed objectives (Silver & Wang 1997; Becker & Rumpf 1998; Ellsworth *et al*. 2000; Wang & Shen 2003; Shimabukuro *et al*. 2004). Wong and Bergeron (1997) used a colour scale in wavelet-based data visualisation for error tracking applications.

Rheingans (Rheingans & Tebbs 1990; Rheingans 1992; Rheingans 1997; Rheingans 1999) introduced a colour scale which can be useful for univariate, bivariate or multivariate data. Colour scales also has been used extensively in many applications, including automotive (Seidenberg *et al*. 1992), medical (Vos & Spoelder 1998; Stokking *et al*. 2001; Wunsche 2003; Nattkemper 2004), topography (Treinish 1993; Eddy & Mockus 1994; Wijk & Telea 2001; Poonam 2005; Saalbach *et al*. 2005) and fluid mechanics (Saunders *et al*. 2004).

In perceptual view, Healey and Enns (1996) presented perceptual colour scale algorithm based on variety of colour models such as Munsell, CIELUV and RGB or CIEXYZ. Healey (2000), the same author again proposed an architecture for perceptual visualisation. He extended previous works with combinations of colour and texture to visualise scientific datasets like plankton densities. Bertini and Santucci (2005) also helped users to perceive density differences in 2D scatter plots. While, Seidenberg *et al*. (1992) described how to choose a set of colours with perceptually uniform spacing and also showed the usefulness of a logarithmic scale for relating curvature to colours. Meanwhile, Stokking *et al*. (2001) applied the normal fusion technique with the HSV color model to display integrated 3D visualisation of anatomical surfaces and functional data. They were also concerned with perceptual issues on surface rendering of the human brain. They came out with their own table manipulation and evaluated their method using three clinical cases of different modality combinations. Rogowitz *et al*. (Rogowitz & Treinish 1993; Rogowitz & Kalvin 2001) were also interested in perceptual issues of color mapping. They produced architecture and applied a colour scale onto intensity values of digitized photographs of a face and asked observers to rate each of the images. Kalvin *et al*. (2000) used the method for visualising interval data. Levkowitz (Levkowitz & Herman 1992; Levkowitz 1996; Levkowitz 1997) presented a method and algorithm for derivation of colour scales with perceptual properties.

Some researchers use a colour scale for visual representation purposes. Like Baker and Eick (1994) they used a colour scale in their technique to visualise the statistics of the source code with its code structure, complexity and evolution. Graham *et al*. (2000) used a colour scale in their graph visualisation. Meanwhile, Elmqvist and Tsigas (2003) used a straightforward non-continuous distribution of RGB spectrum for their graphical representation of causal relations and information flow in a system of interacting processes. Wunsche (2003) and Wunsche & Lobb (2001) showed how concepts from human visual perception and cognitive science could be used in visualisation scientific datasets. However, Keim (1994; 2000; 2002) introduced a pixel-based visualisations map with an attribute value of pixel to a pixel on the screen, that is coloured according to a pre-defined colour map.

Chuah and Eick (1997) used a rainbow colour scheme to encode the attributes of objects in a circular shape for managing a large software project. Gall *et. al* (1999) modified the rainbow scale to 21 colour scales that were

used in 2D and 3D graphs. However, Vos and Spoelder (1998) decided rainbow colour scales would lead to misinterpretation in distinguishing or visualising corneal shape. We would like to introduce our scheme that uses a rainbow colour scale as a core idea but we manipulate it in different ways for visualising timeline events in ion dynamics (Sharif *et al*. 2006). Our method consists of two time scales which are a global and a local colour time scale. At the moment we would like to discuss about the global colour time scale as shown in Figure 2.

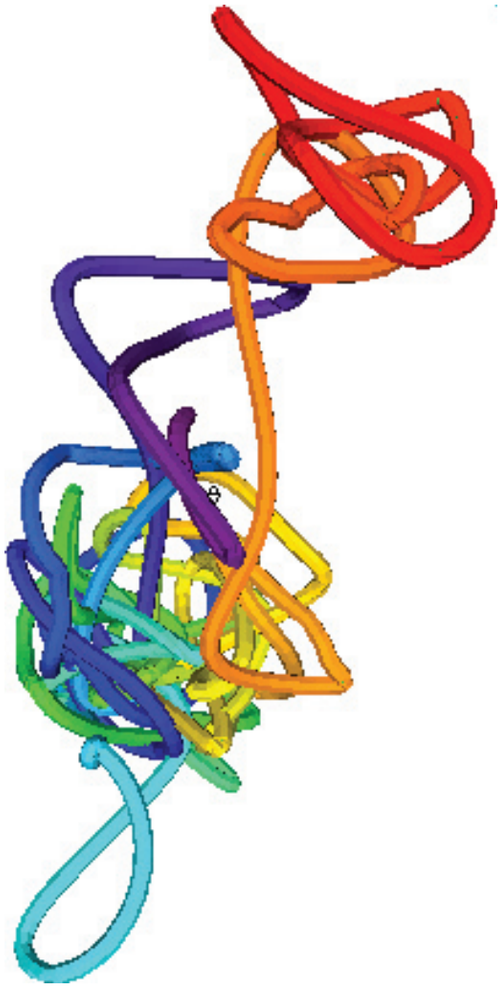


Figure 2. Global time scale for sodium #169 trajectory with seven key colours of a rainbow colour scale.

SPATIAL ORIENTATION

In this section, we will first examine the more challenging task of visualising temporal information in order to identify the series of events. We will discuss the use of glyph, colour and opacity in our visual representations and present the methods for constructing and rendering composite visualisation, that conveys a rich collection of indistinguishable visual features for assisting in data mining processing.

Given an ion trajectory as a series of $n + 1$ points, $p_0, p_1, ..., p_n$, we have n consecutive vector segments, $v_0, v_1, ..., v_n$, where $v_i = (p_i - p_{i-1})$. One can visualise such a trajectory using streamlines or vector glyphs.

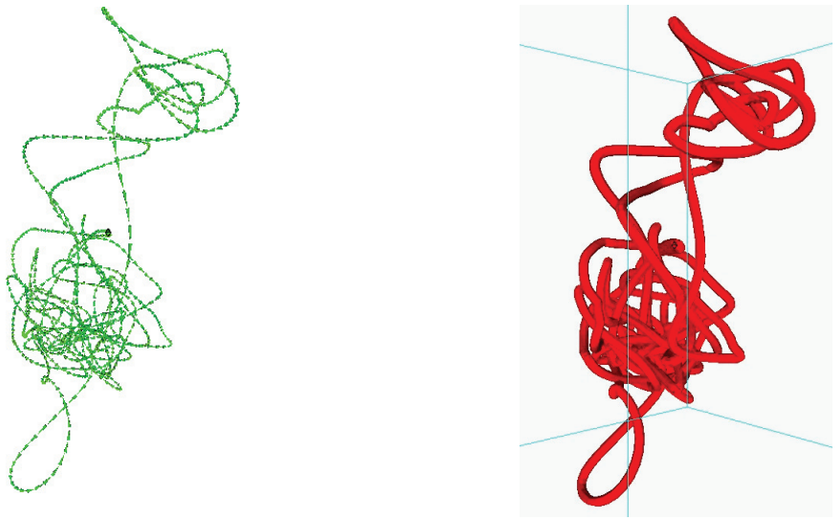
In Figures 3a and 3b, even though each image which represents a vector segment, depicts the instantaneous velocity at a given time interval with its length or direction of motion with its pointer, it does not much help to visualise a time series event in ion dynamics. Probably with this method the viewer might know which ion is moving or static as shown in the Figure 1. In the next section, we will highlight a method that can give a more understandable view about time series events in ion dynamics.

With streamlines, it is impossible to tell the difference between the top and bottom trajectories, even though they are representing motion in opposite directions and at different speeds. Each conical glyph, which represents a vector segment, depicts the instantaneous velocity at a given time interval with its length and the direction of the motion with its pointer. An example of sodium trajectory is shown in Figure 2. Considering the complexity of the movement, it is almost essential for viewers to be able to observe the motion direction and speed in a visual data mining process.

TEMPORAL INFORMATION

When involving a sequence of timeline events, the complexity of the task is to reveal the time of an event and the classification of corresponding parties which participate in collaboration. The issues of co-operation or collaboration will not be discussed at this moment. At the same time, this task will turn tremendously complicated if there are hundreds or thousands of collaborative events occuring. Given an ion trajectory as a series of $n + 1$ points, $p_0, p_1, ..., p_n$, we have n consecutive vector segments, $v_0, v_1, ..., v_n$, where $v_i = (p_i - p_{i-1})$.

Through streamlines itself, it is difficult to differentiate between the top and bottom trajectories, even though they are presenting motion in opposite directions. In the complexity of movement, at the global level, the viewer should be able to observe a global time frame of the ion trajectory before going into a high degree of temporal information. As mentioned above, the purpose of a global colour scale had been used because it would help the viewer to determine a global time frame for the events. Here, are a few schemes that could be possible before we choose a suitable scheme for global time frame.



(a) Glyph (b) Tube

Figure 3. Streamlines of trajectory sodium #169.

Single Colour

Select any colour from RGB, such as c_1 and assign to each of the vectors as shown below :

$$v_1 \;\; v_2 \;\; \ldots \;\; v_n \tag{4}$$

$$c_1 \;\; c_1 \;\; \ldots \;\; c_1 \tag{5}$$

where n is the total of vectors. Figure 4 represents a red colour as a single colour scheme for the ion trajectory. However, this scheme does not give any meaning, according to timeline events.

Discrete Colour Cycle

This scheme is originated from Shoup (1979) and is for enhancement of the usefulness of the real-time animation capability. Many researcher have borrowed from this scheme to solve their problems. In our work, we applied each of the vectors that show the ion trajectories as probably it might help us to uncover temporal issues in ion trajectories. Given a series of colours, $c_1, c_2, \ldots, c_n$ $(k > 1)$ we assigned a colour to each vector segments as :

$$v_1 \;\; v_2 \;\; \ldots \;\; v_k \;\; v_{k+1} \;\; v_{k+2} \;\; \ldots \;\; v_n \tag{6}$$

$$c_1 \;\; c_2 \;\; \ldots \;\; c_k \;\; c_1 \;\; C_2 \;\; \ldots \;\; c_w \tag{7}$$

where w could be determined arithmetically. Figure 4 shows an example of using three colours as a circular pattern or cycling colour. It is hard to represent the series of events along the timeline because it repeats the same colour.

Continuous Colour Spectrum

Given a series of colours in RGB, $c_1, c_2, \ldots, c_k$ $(k > 1$ *and normally* $k < n)$, we assigned colours to each points as :

$$p_1 \;\; p_2 \;\; \cdots \;\; p_{k-1} \;\; p_k \;\; p_{k+1} \;\; \cdots \;\; p_n \tag{8}$$

$$c_1 \;\; c_2 \;\; \ldots \;\; c_{k-1} \;\; c_k \;\; C_1 \;\; \ldots \;\; c_w \tag{9}$$

where w could be determined arithmetically. To maintain a continuous visual effect, each vector segment v_i was drawn using linear interpolation between two consecutive colours associated with p_{i-1} and p_i. However, in this case, smooth interpolation was unnecessary and does not serve well the purpose of showing the timeline. In the next scheme, we applied the same scheme but for the vector, not for the points itself.

Key Colours

In order to show the global timeline events of ion trajectory, we introduced the *Global Key Colours Scale*. In this scheme, we used a small set of colours, $c_1, c_2, \ldots, c_k$; $(k > 1)$, then we assigned a colour to a specific vector in the vector series :

$$v_1 \;\; v_u \;\; \ldots \;\; v_v \;\; \ldots \;\; v_n \tag{10}$$

$$c_1 \;\; c_2 \;\; \ldots \;\; c_i \;\; \ldots \;\; c_k \tag{11}$$

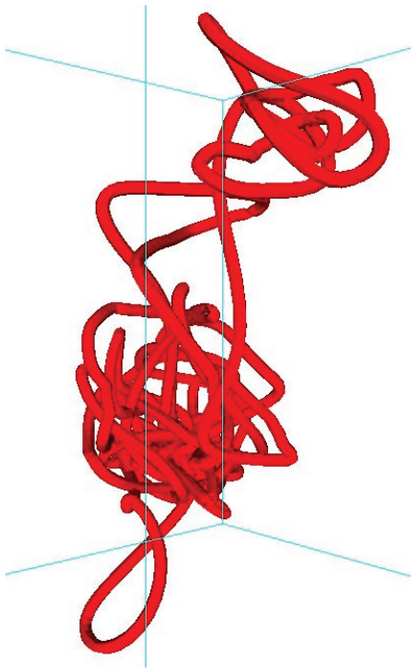


Figure 4. Determination of LC_{50} value of the purified toxin by brine shrimp lethality bioassay. Log C: Log concentration of the purified protein

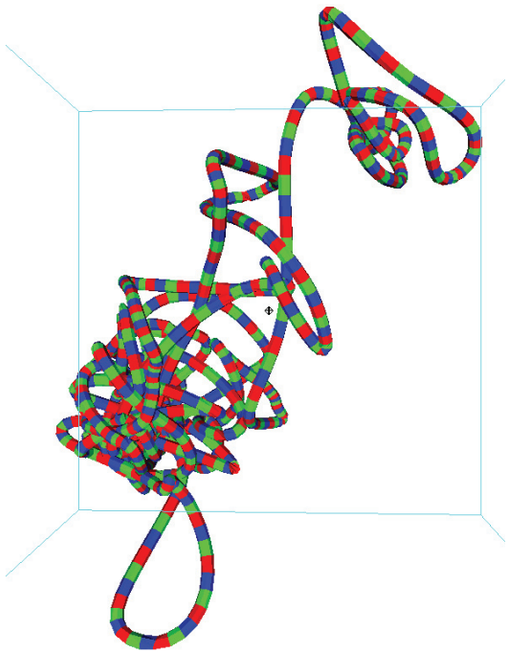


Figure 5. Discrete colour cycle.

where indices such as u and v are pre-determined. For each vector that was not assigned a colour, we obtained a colour by interpolating the two nearest neighbours with the specified key colours in each direction. This scheme allowed a viewer to determine a time frame at a global scale with the help of key colours as shown in Figure 5.

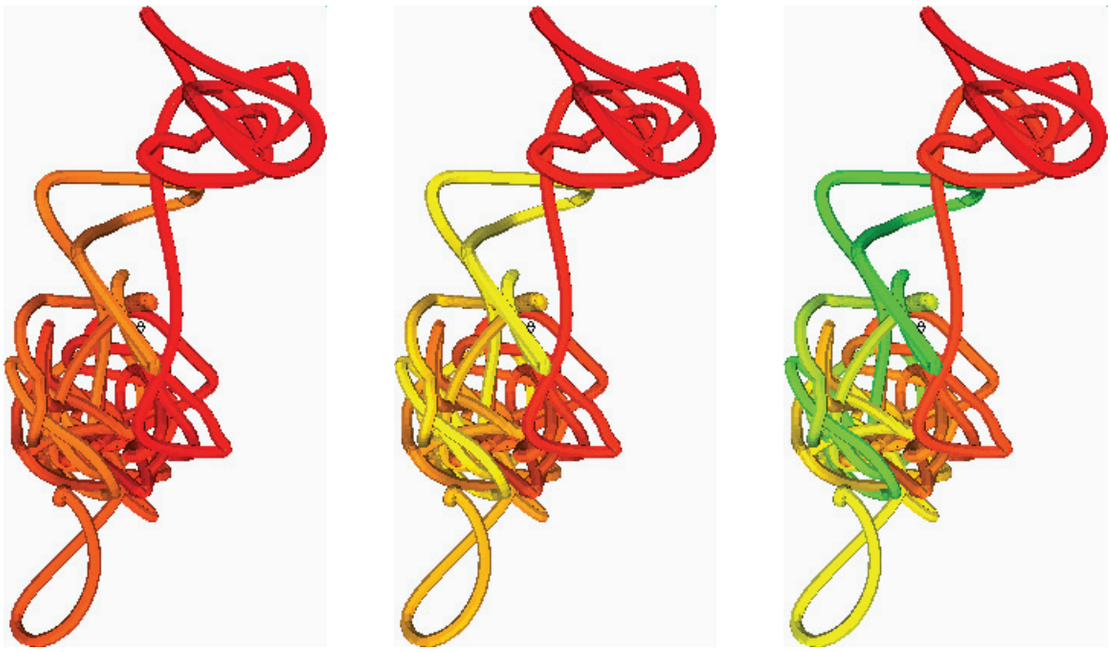
GLOBAL COLOUR TIME SCALE

In Figure 6, we show two to seven key colours images which used a rainbow colour scale to visualise a global scale of timeline events. Moreover, it is possible to have the same or similar interpolated colours between different sets of consecutive key colours. There is a colour scale that uses 256 colours (Levkowitz & Herman 1992; Levkowitz 1996; Levkowitz 1997; Shimabukuro *et al*. 2004) but its hard to distinguish between two consecutive key colours as shown in Figure 6. That is why we have proposed a *Global Key Colour Scheme* so that based on these we would be able to use any colour model as long there is a colour existing in between two colours if interpolation process takes place (Hurvich 1981).

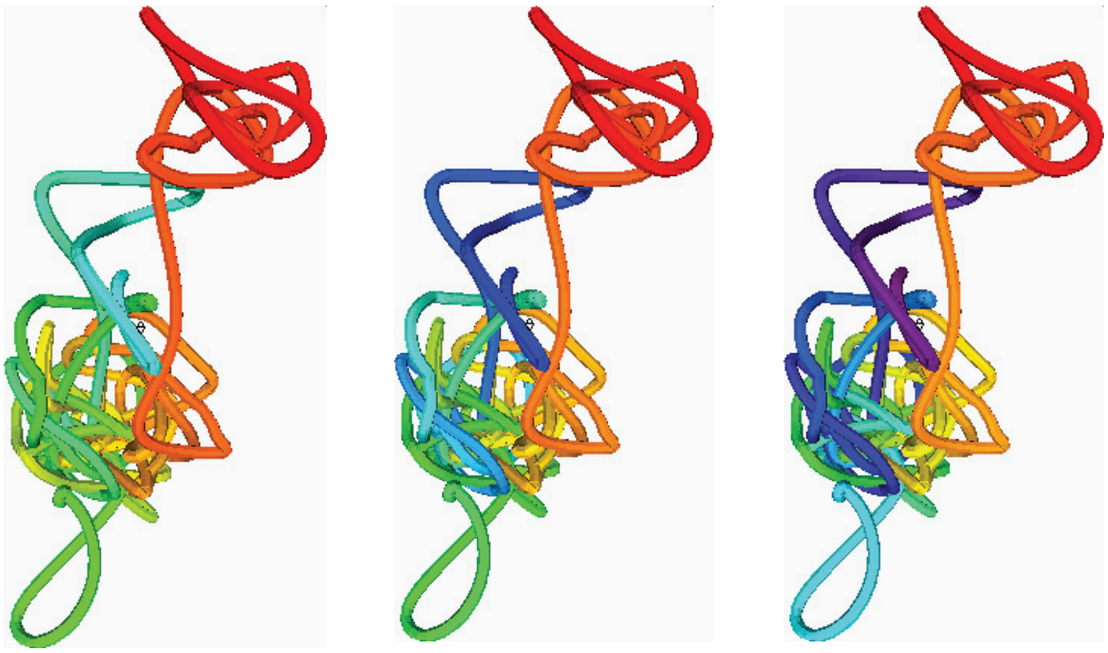
Moreover, we used a linear interpolation function to generate colour among two consecutive key colours. If n is the total number of vectors so that it can represent a time frame of ion trajectory, then we need to find the time frame t between key colours, k that satisfies :

$$t \approx \frac{n}{k-1} \; ; k > 1 \qquad (12)$$

Let us say n = 1000, if we using two key colours k = 2, then we need t = 1000 for the time frame between two consecutive key colours. We have t = 500 if k = 3, t ≈ 333.33 if k = 4, t = 250 if k = 5, t = 200 if k = 6 and t ≈ 166.66 if k reaches 7 or maximum key colours if possible. All the above correlations between colour and number of ions have been represented in Figure 7. We understand from the result represented in Figure 7 which shows us the time frame of ion trajectories between two consecutive key colours of each of the scheme. We thought, by increasing the number of key colours we would enhance the ability of distinguishing for viewers in differentiating the accuracy of representing timeline events at low level. According to Figure 2, we choose the existing colour scale with 256 colours for sodium #169 trajectory. As a result, it is easy for the viewers in helping them to distinguish timeline events at high level or global time frame instead of low level or local time frame. In perceptual point of view, the reason for this case is one or more ions will have the same or similar interpolation colour. In the following section, we



(a) 2 colours (b) 3 colours (c) 4 colours



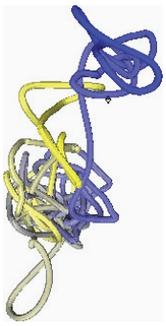
(d) 5 colours (e) 6 colours (f) 7 colours

Figure 6. Global key colours.

(a) Heated object

(b) Optimal colour scale

(c) Blue to cyan

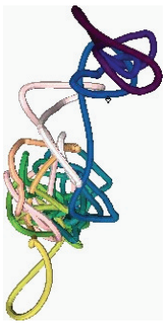


(d) Blue to yellow

(e) Magenta scale

(f) Red saturation

(g) Gray scale



(h) Rainbow scale

Figure 7. Existing colour scale (Levkowitz & Herman 1992).

will introduce a scheme of such a high degree which can denote a timeline event at local scale accurately.

Interpolation

To find the colours among two consecutive key colours we used the linear interpolation function as stated in Equation 13:

$$C_{vi} = (1 - t_f)\, C_{i-1} + t_f\, C_i \qquad (13)$$

where: C_i = destination colour
C_{i-1} = origin colour
C_{vi} = current interpolation colour
t_f = current fraction $\left(\frac{t_i}{t}\right)$
t_i = current time event.

Firstly, we needed to decide how many key colours k that we would want if $n = 1000$, for example two colours, thus $k = 2$. From Equation 12, we can find t; t will denote how big a time frame can be occupied with key colours. Then, k = 2 and t ≈ 1000.

Once we had got all these parameters for Equation 13, we calculated the value for the interpolation colour. Before that, we needed to choose a colour whose interpolation could exist in between those colours (Hurvich 1981; Wyszecki & Stiles 1982). In our case, we decided to borrow a colour from the rainbow colour scale which consisted of seven colours and the blending or interpolation was existing among all these colours. For the time being, we choose the first two colours, which are red and orange. According to colour in computers (Hearn & Baker 2004) there are three values to represent each of the colours in the computer screen, its so called RGB value. Below is the table for RGB value for seven key colours in rainbow scale.

Table 1. RGB values for rainbow colour scale.

Colour	RGB value (x,y,z)
Red	(1.0, 0.0, 0.0)
Orange	(1.0, 0.5 ,1.0)
Yellow	(1.0, 1.0, 0.0)
Green	(0.0, 1.0, 0.0)
Cyan	(0.0, 1.0, 1.0)
Blue	(0.0, 0.0, 1.0)
Purple/indigo	(0.5, 0.0, 0.5)

In Figure 9, we show the steps to calculate the correlation value for colour interpolation. The explanation starts with assigning correlation vector segments with appropriate interpolation colour between key colours. Each of the values for RGB were calculated as it is shown. At the end, we render these values on tubes of the ion trajectories to represent our global colour time scale as shown in Figure 6.

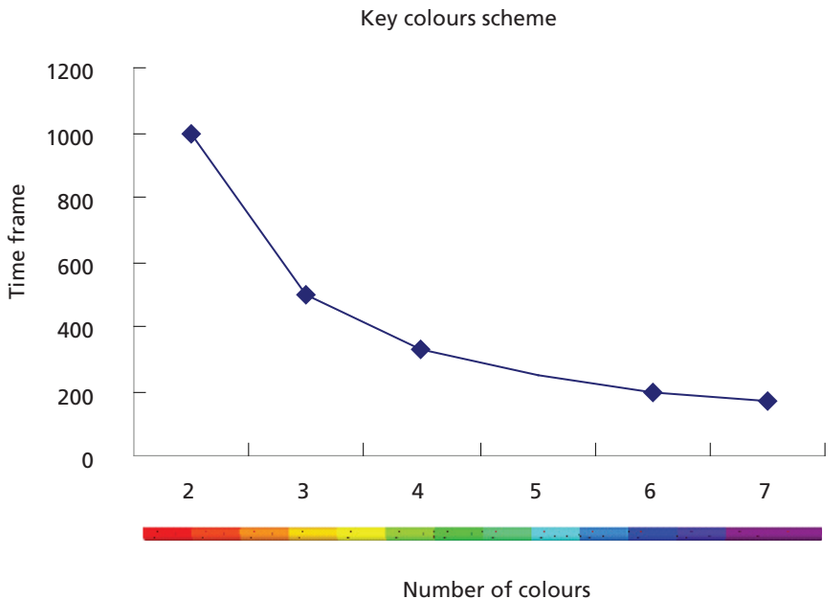


Figure 8. Global colour time scale between 2 and 7 key colours.

v_0, v_1, ...,
Let k = 2; red and
$C_{0_{red}}$ ..... $C_{1000_{orange}}$

Use this equation to find:

$$C_{v_i} = (1 - t_f)C_{i-1} + t_f C_i \quad \text{(Equation 13)}$$

where: C_i = destination colour
C_{i-1} = origin colour
C_{v_i} = current interpolation colour

t_f = current fraction $\left(\frac{t_i}{t}\right)$

t_i = current time event.

So,

C_i = orange (1.0, 0.5, 1.0)
C_{i-1} = red (1.0, 0.0, 0.0)
$t = \frac{n}{k-1}$; $\frac{1000}{2-1}$; 1000 (total time frame) (Equation 12)

t_f = current fraction $\left(\frac{t_i}{t}, \frac{t_1}{t}, \frac{t_2}{t}, ..., \frac{t_{1000}}{t}\right)$

t_i = current time event.

Example:

v_0, v_1, ..., v_{1000}
$C_{0_{red(1.0,\ 0.0,\ 1.0)}}$, ..., $C_{1000_{orange\ (1.0,\ 0.5,\ 1.0)}}$

$C_{v_i} = (1 - t_f)C_{i-1} + t_f C_i$

$C_{v_i} = \left(1 - \frac{1}{1000}\right)C_{(x,y,z)i\text{-}1} + \frac{1}{1000} C_{(x,y,z)i}$

$C_{v_{1_x}} = (1 - 0.001)\ 1.0 + 0.001\ (1.0)$

$C_{v_{1_x}} = 0.999 + 0.001 = 1.0$

Figure 9. Steps towards interpolation colour.

LOCAL COLOUR TIME SCALE

As mentioned previously, the global colour scale would be able to visualise global time frames only instead of local time frames. In Figure 10 we show a comparison between global and local colour time scale.

At the local level, the interpolation can make different vector segments indistinguishable. Here, we show vector glyphs and *Colour Number Coding Scheme* in our visualisation. Given a small set of key colours, c_1, c_2, ..., c_k ($k > 1$) and distinctive interval-colour (e.g., white, black or grey depending on the background colour), we coded a group of consecutive m vectors as a k-nary number, terminated by a vector in the interval-colour. Given n as the total number of vectors, and we always assign the interval-colour to the first vector, we needed to find the smallest integer m that satisfies Equation 14:

$$(m + 1)\ k^m \geq n \quad \text{(Equation 14)}$$

For instance, when n = 1000, using two key colours, say red and green, we need m = 7 colour digits. We have m = 5 for k = 3, m = 4 for k = 4, and m = 2 when k reaches 19. The selection of m and k needs to address the balance between a smaller number of colours or a smaller number of colour digits in each group of vectors. The former ensured more distinguishable colours in visualisation, and the alteration reduced the deductive effort for determining the temporal position of each vector. Figure 11 shows a quaternary colour coding scheme for ion tracks with 1000 vectors.

In this paper we have chosen a quaternary colour coding scheme for the local colour scale, which is k = 4, for our comparison with the global colour scale. According to our results that are shown in Figure 10, we believe the local colour scales will help the viewer to distinguish each timeline event in ion trajectories and the purpose of the global colour scale is to summarize all the timeline events or show the global time frame in ion trajectories.

In the following section, the composition method will be elaborated. The main concern of this particular section is to show the visual representation of global and local colour time scale to help the viewer in analysing timeline events. Moreover, it will be a tool for them in analysing any scientific datasets, especially in time-varying datasets.

COMPOSITING RENDERING

Through combination of the two above-mentioned colour scales, we have provided an effective visual representation for visualising spatio-temporal ion trajectories. To simplify the clarification about colour scale we have constructed testing trajectories as shown in Figure 12. The top trajectory represents an object travelling from left to right at a constant velocity, the center one travelling in a circle at a constant speed and the bottom one travelling from right to left at a steadily increasing speed.

In Figure 12(a), a streamline had been coloured by Global Colour Scale. Even though, it can differentiate between the top and bottom trajectories and represents the motion in opposite direction at a different speed, it is for global scale viewing only.

Figure 12(b) shows a conical glyph, which represents a vector segment with Local Colour Scale, depicts instantaneous velocity at a given time interval with its length and the direction of the motion with its pointer. The combination of methods in Figures 12(a) and 12(b) are shown in Figure 13.

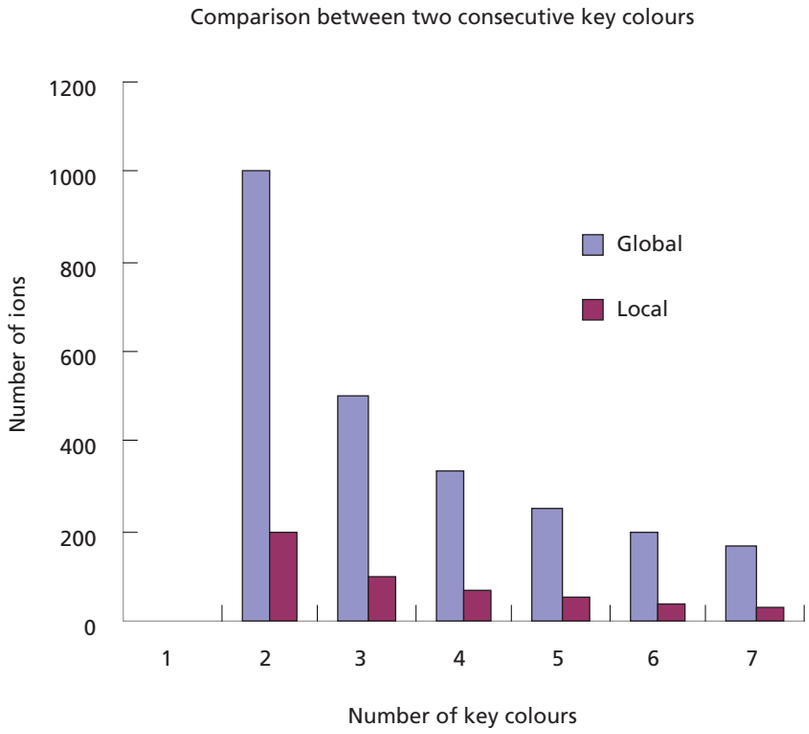


Figure 10. Comparison between global and local colour scale.

Initially, the viewers will be able to only visualise the global scale. To let the viewers look at the local scale, the viewers must move close to the trajectory and they will see the local scale inside the global scale. Figure 13 shows the local colour scale when the viewers come close to the ion trajectories.

ZOOMING EFFECT

Without this section, we cannot complete our visual representation. This is another issue that we think we should include in this part because it supports our objective. Initially, we want to show the effect of the zooming techniques which are used in our study. We begin the discussion with the effect of zooming before co-operation occurs. Before that, it is good to discuss about the transparency scheme and depth-cueing techniques.

Transparency Scheme

To help the viewers view the Local Colour Scale inside the tube, we need to control the opacity of the tube with the basic transparency model. First of all, we set the boundary of the zooming effect, here we chose $d_{\min}$ and $d_{\max}$. When the ions are hit by $d_{\max}$, the calculation of opacity would begin with Equation 15. It happened when the camera was moving close to the object. The image of this scheme can be roughly seen in Figure 15.

$$f_{\text{depth}_i} = \frac{d_{\max} - d_i}{d_{\max} - d_{\min}} \tag{15}$$

where d_i is the distance of a point between zooming effect boundary. As a result, the nearer ions are displayed with a higher value of transparency and the ions at the maximum depth or farthest have a higher value of opacity, f_{depth_i}.

We assign parameter f_{depth_i} a value between 0.0 and 1.0, to specify the distance of the ions from the viewplane. Thus, we calculate the opacity of the tube between maximum opacity $O_{\max}$ and minimum opacity $O_{\min}$ using depth coefficient f_{depth_i} using the linear interpolation function as Equation 16.

$$O_{v_i} = (1 - f_{\text{depth}_i})\, O_{\max} + f_{\text{depth}_i}\, O_{\min} \tag{16}$$

All the explanations can be simplified, according to Figure 14. From this figure, we will do some analytical discussions to determine optimum setting for the opacity control. To achieve a high degree of visual representation we need another feature like depth-cueing technique for improving our transparency scheme in ion trajectories.

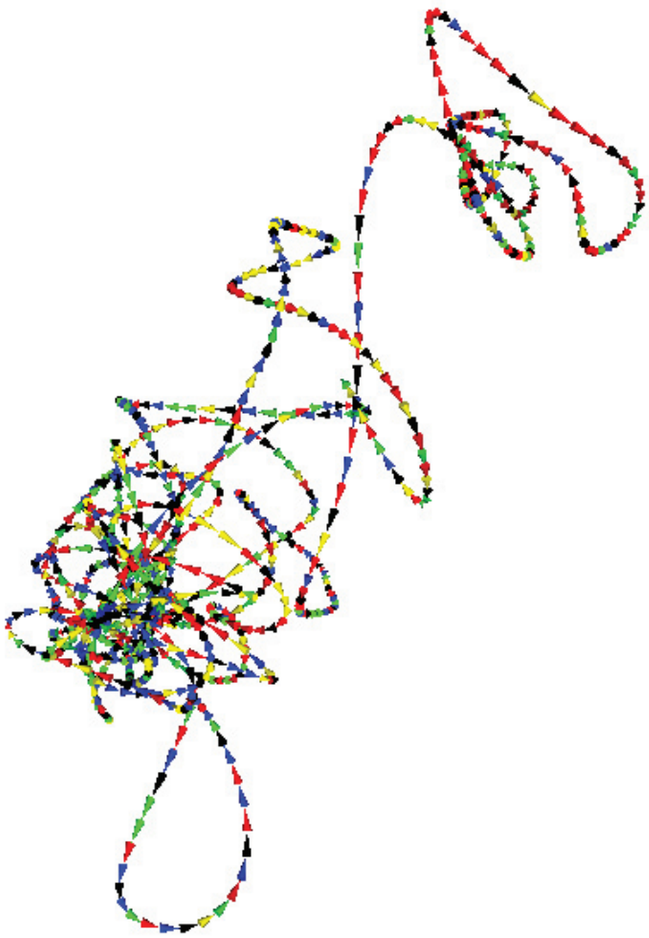
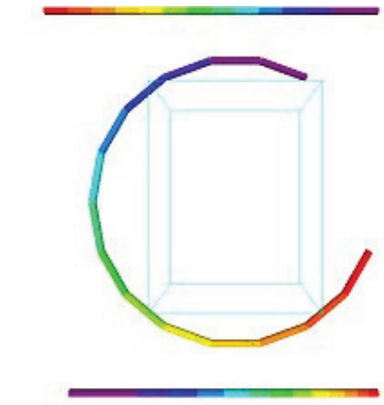
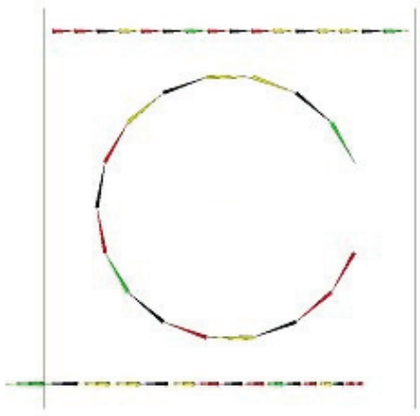


Figure 11. Quaternary colour coding scheme for trajectory of sodium #169.



(a) Global colour scale — *n* key colours.



(b) Local colour scale — *colour number coding scheme*.

Figure 12. Time coding colour scale.

Depth-cueing

Depth-cueing is a way to enhance depth impression. With the transparency scheme itself, it does not much help represent cueing of trajectories. To achieve this, we have to sort the object, from furthest to the nearest first, as when the rendering process had occured. Thus, we incrementally obtain contributions from all the transparent layers in the scene.

In our case, the viewer would have to move around if they want to do some analysis on trajectories. Here, we need to keep updating the depth-cueing of the trajectories before the rendering process.

In the next section, we did analytical testing to find the optimum setting for the transparency scheme in relation to finding the best correlation for the transparency parameter between the global and the local colour scale.

Halos

Halos are easily implemented for illuminated streamlines using OpenGL. We first render a streamline, then we draw a black streamline with greater line width exactly on the same vertex positions. Fragments with equal depth that come second are rejected and so the pixels of the black streamline are drawn only left and right of the original streamline, acting as a black border on each side that are always parallel to the screen from every viewing angle. With this border region across another streamline in the foreground, the halos appear on the background streamline. Besides enhancing depth impression, the halos give a more plastic 3D look to

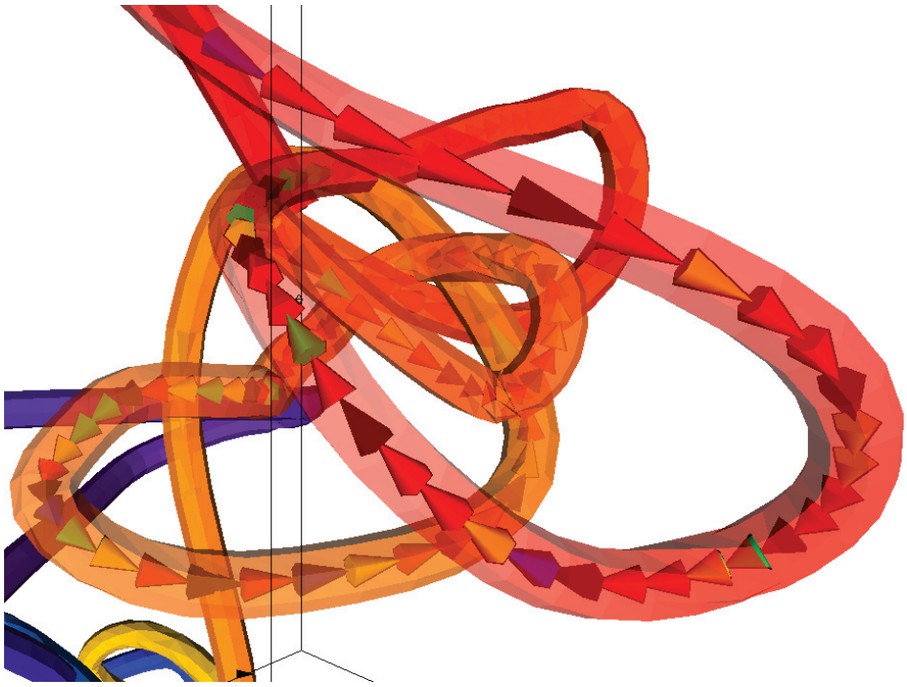


Figure 13. Zooming effect when viewer come closer.

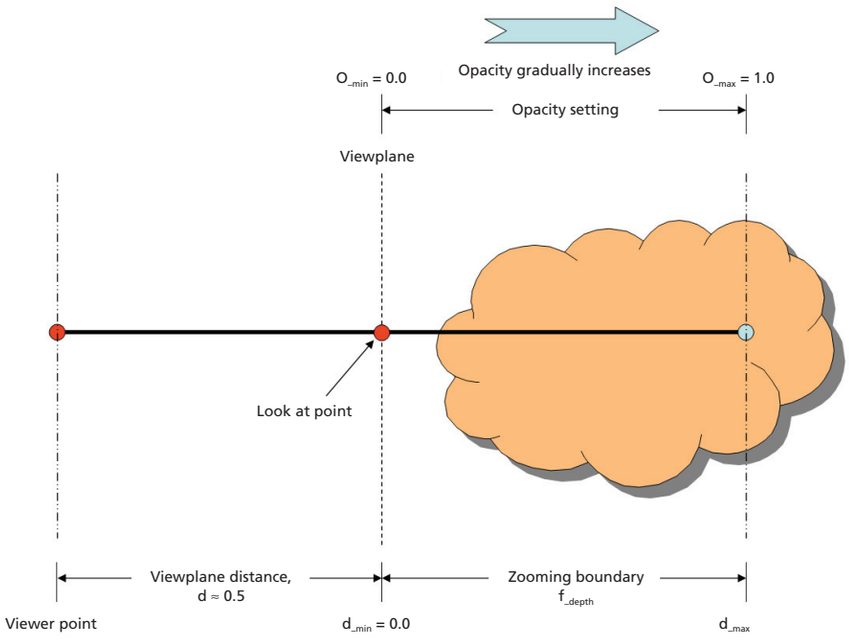


Figure 14. Transparency scheme.

the streamlines. This is similar to silhouette drawing in non-photo realistic rendering (Raskar 2001). If streamlines are drawn semi-transparent, the halo is drawn with the same transparency value. This technique was implemented in our local colour scale. See Figure 15 for the difference between streamlines with and without halos.

Zooming Scheme

We developed three different schemes for implementing correlation between the global and the local colour scale. We describe these scheme in the following subsection.

Standard scheme. In this scheme, we moved the viewplane only towards the object. As according to Figure 16, we fixed the O_{min}, O_{max}, d_{min} and d_{max}. In this case, we just moved the camera or viewplane to the target area. For example, we were looking for $t = 0$ in the ion trajectories. This was the standard technique in our transparency scheme without modification of parameters. We were thinking that modifications of parameter values would help to find the optimum opacity setting in correlation between the global and the local colour scales.

Opacity scheme. In order to obtain enhancement in global and local colour scale correlation, we used opacity scheme, where d_{min} and d_{max} will be fixed at one value only such as $d_{min} = 0.0$ and $d_{max} = 1.0$. This scheme will be used accordingly in Figure 17. In the analysis section, we place the variety of O_{min} and O_{max}.

Depth scheme. For the purpose of comparison, we have also considered depth scheme, which takes consideration of variety of depth with fixed value of opacity. This scheme is shown in Figure 18.

ZOOMING OPTIMUM SETTING

We conducted several analytical tests to observe the correlation between the global and the local colour scales of these three zooming schemes. Firstly, we found $t = 0$ then we looked into the first two key colours at the global scale. Once we had found it, the local colour scale was inside the global colour scale. We have to move the camera close to the target area such that $t = 0$. Once we had moved the camera, the transparency scheme would take place until we could see the local colour scale clearly. Figure 19 shows the images of local colour scale from global colour scale using the standard scheme.

The advantages of the standard scheme is that viewers would not have to worry about the optimum setting for depth and opacity value. In relation to our problem, we needed to find the optimum setting for depth and opacity parameters between the global and the local colour scales. The disadvantages of the standard scheme is when the viewers move the camera close to the target area, like $t = 0$, the whole ion trajectories of two key colours would not included in the screen. That is why we have came out with the depth and opacity scheme for this problem. In the next section, we will determine the optimum setting for depth and opacity value.

According to Figure 20, the depth scheme is better than the standard scheme because the viewer would be able to see the whole two consecutive key colours compared to the standard scheme which would eliminate some of the ions in the global colour scale. In the depth scheme, d_{min} and d_{max}. would play the main role in improving the opacity of global colour scale, while O_{min} and O_{max} remain unchanged. In the depth scheme we would see O_{min} and O_{max} play the main role as d_{min} and d_{max} would remain unchanged.

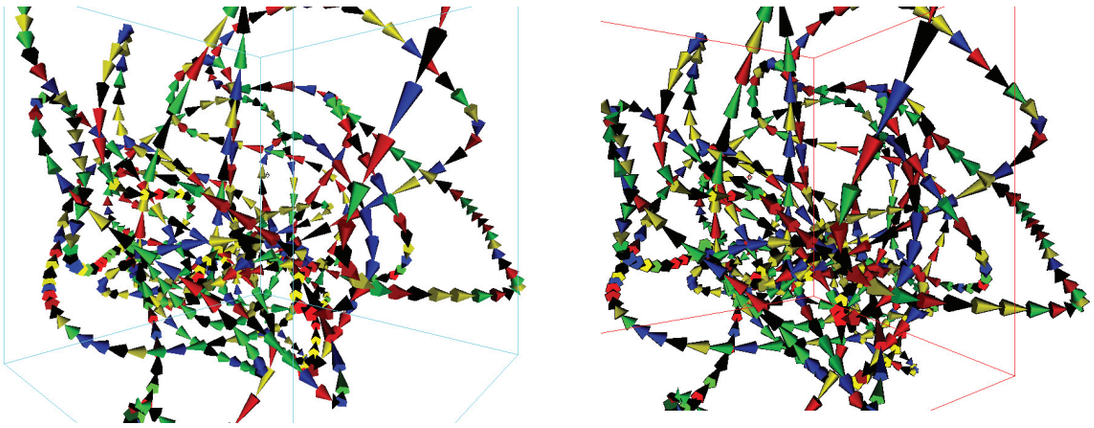


Figure 15. Local colour scale without halos (left) and with halos (right).

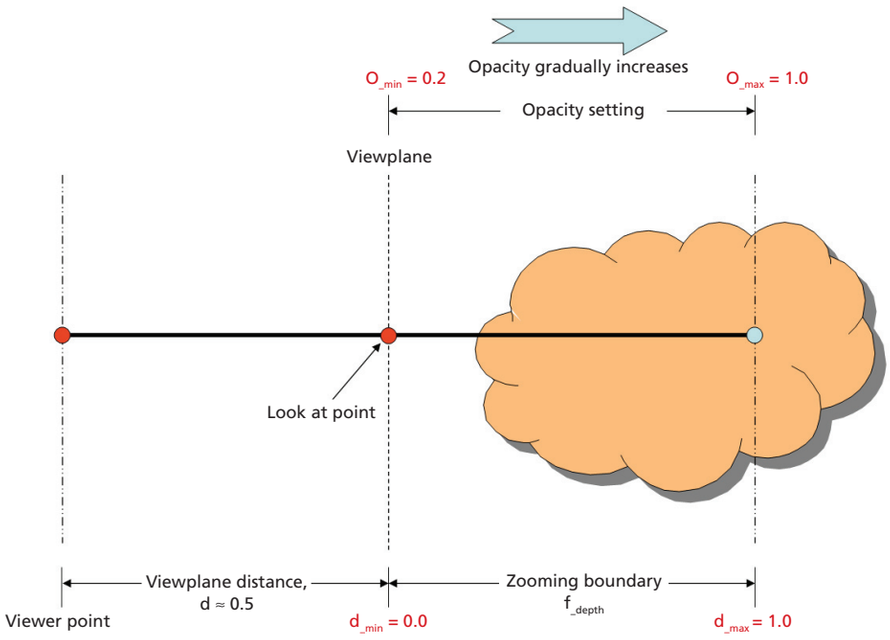


Figure 16. Standard scheme.

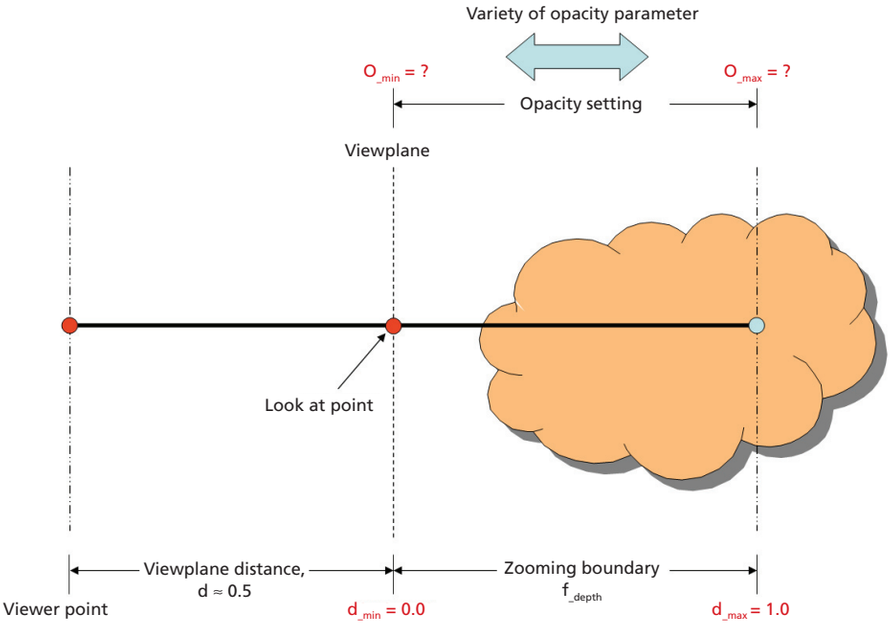


Figure 17. Opacity scheme.

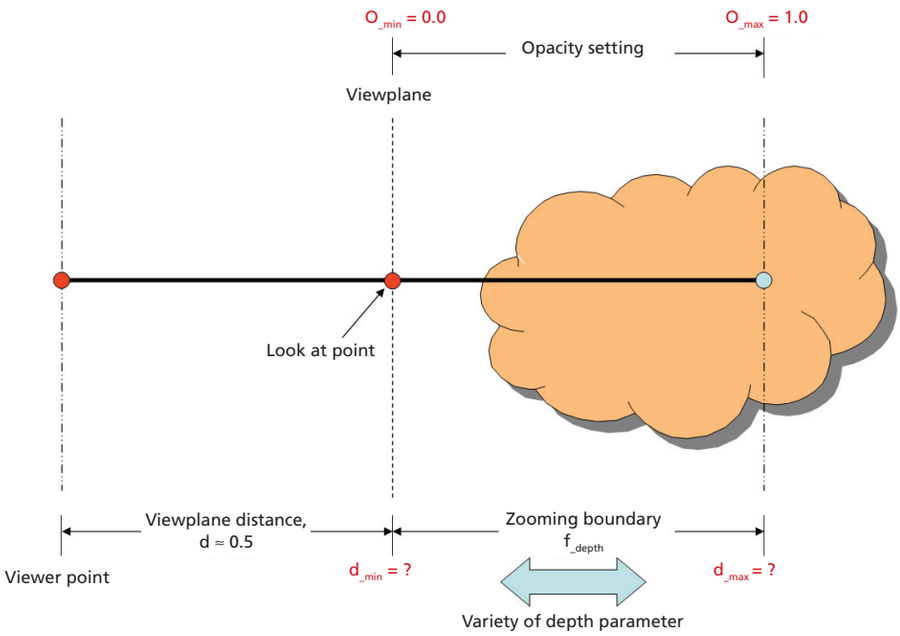


Figure 18. Depth scheme.

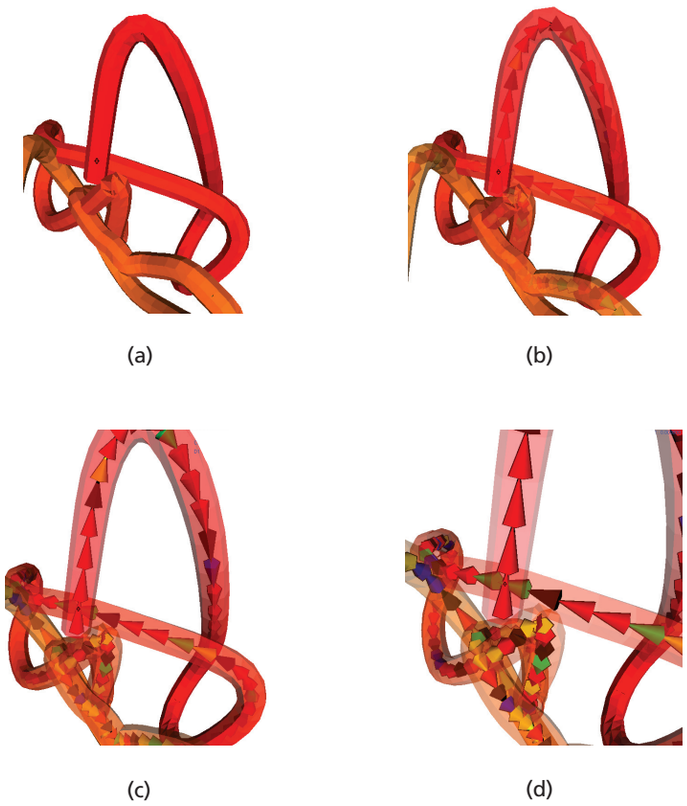


Figure 19. Zooming effect with standard scheme.

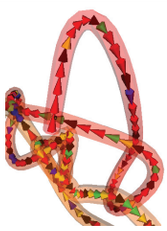
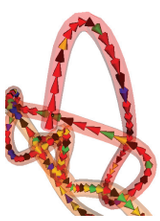
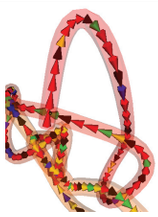
D_{min} D_{max}	0.0
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	

Figure 20. Zooming effect with depth scheme.

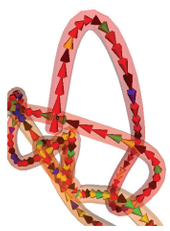
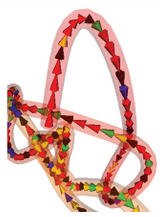
O_{min} O_{max}	0.0
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	

Figure 21. Zooming effect with opacity scheme.

The result of the opacity scheme is almost the same as with the depth scheme as shown in Figure 21. Here, the opacity scheme is supportive of the depth scheme and it can be adjusted together with the depth scheme. In another words, the opacity scheme complements the zooming effect method.

CONCLUSION

The results showed that our Colour Number Coding Scheme could be used to allow viewers to determine time. Traditionally for lower dimensional spatio-temporal datasets, investigation is done using line graphs, bar charts or other pictorial representations of a similar nature and animation. All of this require time-consuming and resources-consuming processes. However, our results indicated that the Colour Number Coding Scheme could be used to visualise timeline events without line graphs, bar charts etc. thus enabling the real time imaging of ion dynamics. Our work also convey temporal information to a high degree of certainty and effective deployment of visualisation in complex spatio-temporal datasets. This enabled us to form the basis of visual mining tools for time-varying visualisation.

Date of submission: October 2006
Date of acceptance: January 2008

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ASM Sci. J., **1(2)**, 129–133

An Erbium/Ytterbium Co-doped Fibre Amplifier Using 1058 nm Pumping

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This paper demonstrates an erbium/ytterbium co-doped fibre amplifier (EYDFA) which used a pumping wave-length of 1058 nm, whereby the amplification was assisted by the energy transfer between Yb and Er ions. The energy transfer increased the erbium doping concentration limit that was imposed by concentration quenching in erbium-doped fibre. The optimum length was obtained at 4m~6m for erbium/ytterbium co-doped fibre with Er ion concentration of 1000 p.p.m. This enabled the development of a compact amplifier with a shorter gain medium compared to erbium-doped fibre amplifiers which use a gain medium of up to 15 m. A 1058 nm pumping wave-length was used for the EYDFA, as 1480 nm pumping resulted in severely degraded gain and noise figures because the energy transfer could not be achieved. The use of the optical isolator improved the small signal gain and noise figure by about 4.8 dB and 1.6 dB, respectively. Without the isolator, gain saturation and a noise figure penalty were observed due to the oscillating laser which was created at around 1534 nm by spurious reflection. This showed that the usage of optical isolators was an important aspect to consider when designing an EYDFA.

Key words: erbium/ytterbium; fibre; amplifier; pumping; wave-length; energy transfer; Yb; Er; optical isolators

The demand for bandwidth capacity has been increasing every year due to Internet and other new services. Capacity expansion has been achieved both by increasing the number of channels and by expanding the transmission band. Expansion of wave-length division multiplexing (WDM) transmission systems thus makes the capacity and bandwidth of fibre-optic amplifiers the key aspects of the system. Increasing the number of channels of a WDM transmission system requires an increase in total input signal power, resulting in the need for higher output power from erbium-doped fibre amplifier (EDFA). This amplifier necessitates a higher erbium ion concentration in the medium. However, the concentration is limited in erbium-doped fibre due to concentration quenching (Wagener *et al*. 1993, p. 2014; Myslinski *et al*. 1997, p. 112).

To overcome this limitation, an Er-Yb doped fibre (EYDF) which is fibre co-doped with Yb as well as Er, can be utilized to increase the limit of erbium doping concentration. EYDF is also attractive as it exhibits an intense broad absorption between 800 nm and 1100 nm, spanning several convenient pump wave-length source options. In EYDF, energy transfer from the excited states of Yb to that of Er is utilized to form a population inversion between lasing levels of Er. In previous studies, a 1064 nm Nd:YAG laser and an Nd-doped double-clad laser were used as the pumping source (Grubb *et al*. 1992, p. 553; Park *et al*. 1996, p. 1148).

In this paper, an efficient Er/Yb-doped fibre amplifier (EYDFA) is demonstrated using a laser diode as the pumping source. The pumping range of EYDFA is wider (800 nm ~ 1100 nm) compared to an EDFA which requires pumping at either 980 nm or 1480 nm. The proposed EYDFA uses a pumping wave-length of 1058 nm which coincides with the pumping range of the EYDF. Additionally, laser diodes were made recently available at this wave-length region which lies above the cut-off wave-length of the EYDFA. The amplifier's performance was also compared with 1480 nm pumping which is within the Er and outside the Yb ion absorption region. The effect of spurious reflection on the amplifier's performance was also investigated.

EXPERIMENT

Figure 1 shows the configuration of the EYDFA. The EYDF with a cut-off wave-length of 1532 nm was used as a gain medium. The pump power was provided by a 250 mW laser diode operating at 1058 nm using a forward pumping scheme. A wave-length selective coupler (WSC) was used to

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combine the pump light with the test signal. Isolators were incorporated at both input and output ends of the amplifier in order to avoid spurious reflection. A tunable laser source (TLS) in conjunction with an optical spectrum analyzer (OSA) was used to evaluate the amplifier's performance. The performance result was also compared with similar EYDFA's configuration by using a 1480 nm pumping wavelength. The gain and noise figure was also characterized for the amplifier configured without optical isolators.

Figure 2 shows a model of the energy levels in an Er-Yb system. In an EYDF, Yb ions were excited by pumping light of 800 nm – 1100 nm to the $^2F_{5/2}$ state, after which Er ions were excited to the $^4I_{11/2}$ state through energy transfer from the Yb ions, while the Yb ions reverted to the $^2F_{7/2}$ state. The Er ions that were excited to the $^4I_{11/2}$ then made a transition to $^4I_{13/2}$ by a non-radiative process, forming a population inversion between the $^4I_{13/2}$ and $^4I_{15/2}$ states and amplifying the incident optical signal by stimulated emission. Yb ions as well as Er ions have low solubility to a silica host, and since both have about the same ionic radius, they cluster together. Thus the distance between Yb ions and Er ions was reduced and energy transfer proceeded with good efficiency (Federighi *et al*. 1995, p. 303). This means that if a number of Yb ions surround Er ions to form a cluster, the distance separating the Er ions from each other would increase, and this should produce a reduction in the pair-induced quenching occurring between Er ions. This can increase the limit of Er doping concentration that is imposed by concentration quenching in EDF. The EYDF used in this experiment had an Er and Yb concentration of 1000 p.p.m. and 45 000 p.p.m., respectively.

RESULTS AND DISCUSSION

Figure 3 shows the forward amplified spontaneous emission (ASE) spectrum of the EYDFA at different EYDF lengths. The pump power was fixed at 120 mW and EYDF length was varied from 3.4 m to 13 m. Inset of Figure 3 shows the peak ASE against EYDF length. As illustrated in the figure, the optimum length of the EYDF should be in the range from 4 m to 6 m. The highest peak of –4.5 dBm is obtained at 1535 nm with the EYDF length of 5 m. The ASE level started to decrease as the fiber length exceeded this length. In comparison to an EDFA, the ASE spectrum of an EYDFA rose more steeply around the 1534 nm region as depicted

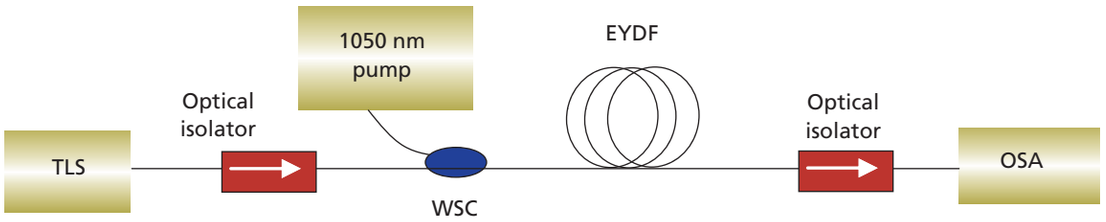


Figure 1. Experimental setup.

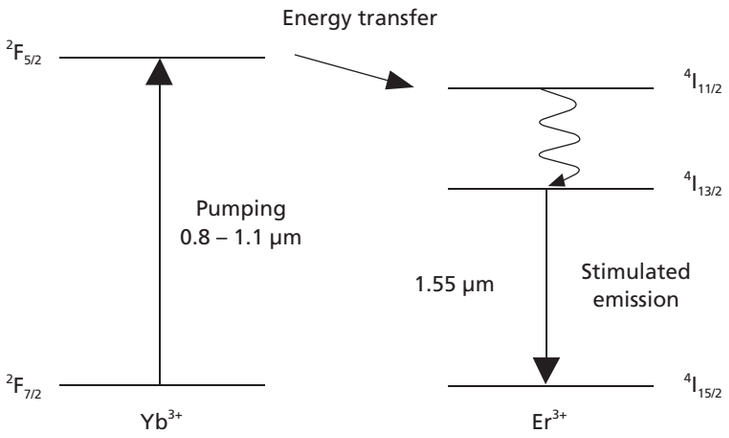


Figure 2. Model of energy levels in an Er-Yb system.

in Figure 3. Therefore, lasing was easily achieved in this region in the presence of spurious reflection.

Yb has an absorption band from 800 nm to 1100 nm. Thus, the EYDF must be pumped using a light source with a wave-length matching the absorption band of Yb, so that the energy transfer from the $^2F_{5/2}$ state of the Yb ions to the $^4I_{11/2}$ state of Er ions takes place. For comparison purposes, experiments were also carried out on pumping of EYDF using a 1480 nm laser diode which is unaffected by Yb absorption. Figures 4 (a) and (b) shows the gain and noise figures, respectively as functions of wave-length for both pumping wave-lengths of 1058 nm and 1480 nm. As shown in the figures, the gain and noise figures for 1058 nm pumping were much better compared with 1480 nm pumping. For instance, at a small input signal of –30 dBm, a gain enhancement of approximately 20 dB was observed at the wave-length of 1536 nm. The corresponding noise figure was also improved by about 11 dB. This showed that the Yb ion was virtually inactive optically with 1480 nm pumping and energy transfers from Yb ions to Er ions could not be utilized.

The optical isolators are incorporated at both input and output ends of the amplifier to eliminate spurious reflections as shown in Figure 1. This technique is well known for an EDFA to prevent unwanted oscillation, improving the amplifier's efficiency and lowering noise figure (Rapp 2006, p.381). The effect of spurious reflections on the performances of EYDFA was investigated by comparing gain and noise figures of the amplifiers configured with and without optical isolators. Figure 5 compares the gain and noise figures against input signal power for both amplifier configurations. As illustrated in Figure 5, the small signal gain was improved by about 4.8 dB with the incorporation of optical isolators. Without the isolators, an oscillating light (laser) was created at around 1534 nm due to the spurious reflections. This laser saturated the gain at around 26.5 dB for input signal powers lower than –15 dBm. At high input signals (above –15 dBm), the amplified signal power drowned out the oscillating laser power. Hence, the oscillating laser was suppressed, and the gain was not enhanced at these input signal powers as shown in Figure 5.

On the other hand, the noise figure improved at all isolator incorporated input signal powers tested as shown in Figure 5. The maximum noise figure improvement of 1.6 dB was obtained at the input signal power of –30

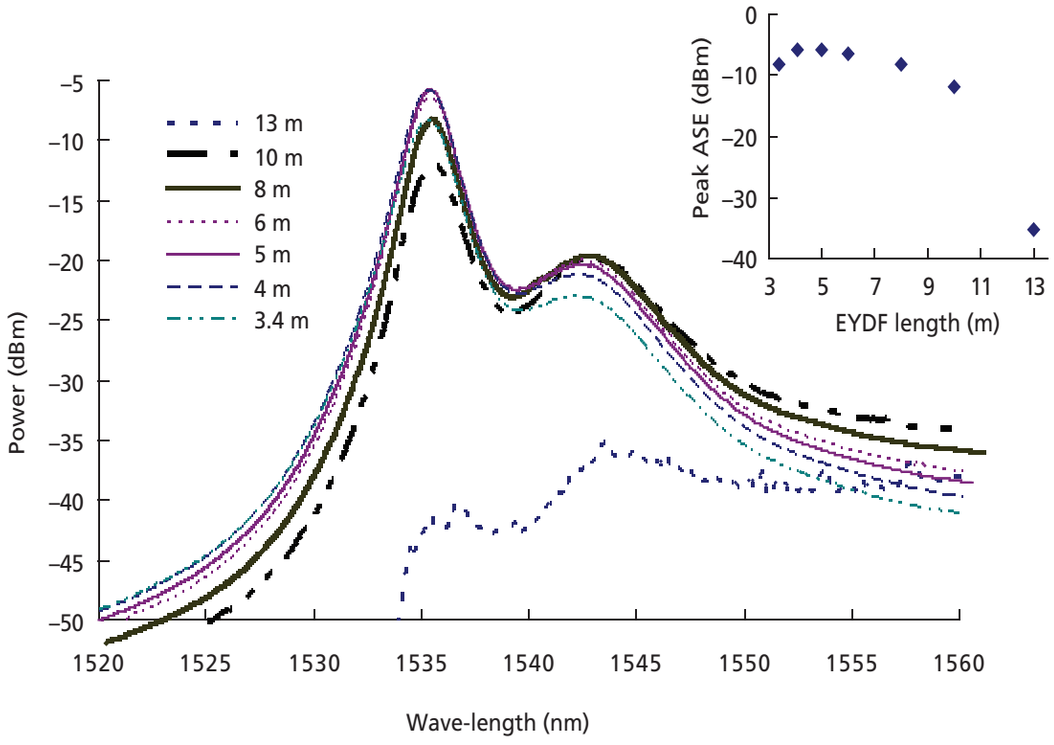
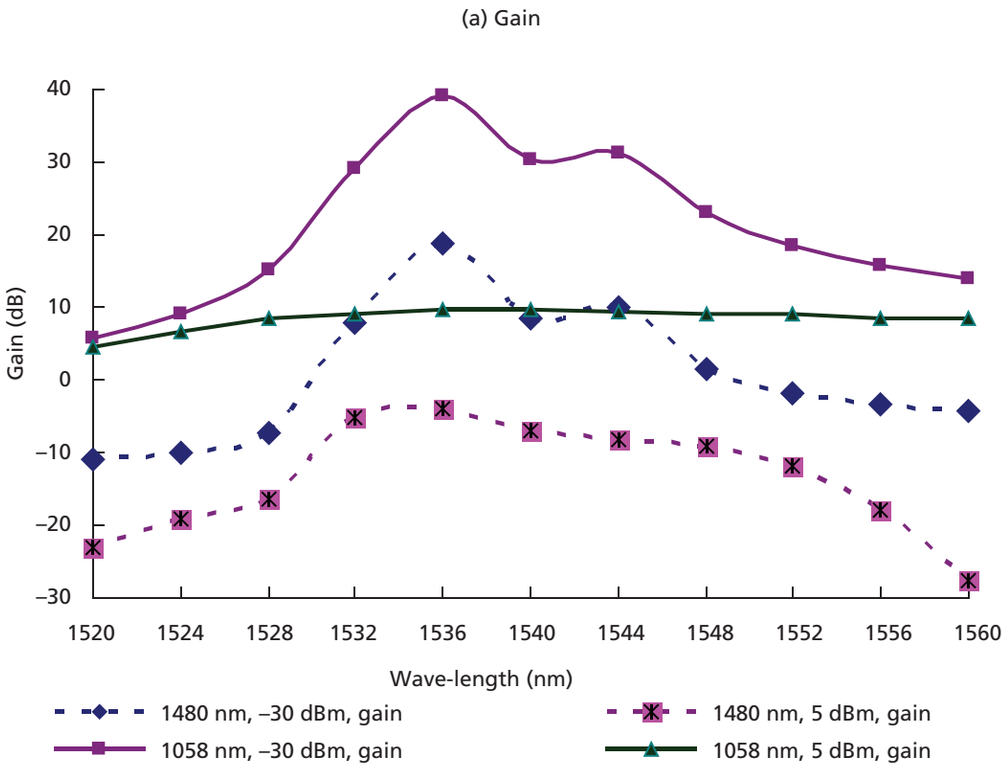


Figure 3. ASE spectra of the EYDFA at different doped fiber length.
Inset shows the peak ASE against EYDF length.



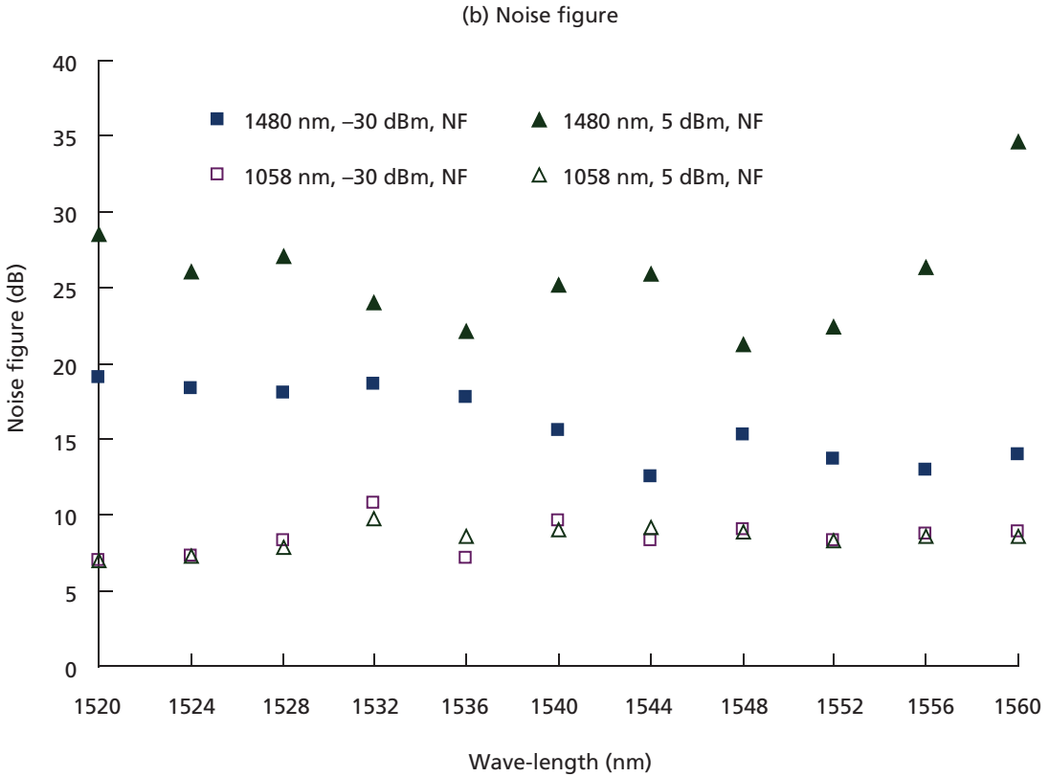


Figure 4. Gain and noise figure spectra of the EYDFA at different pumping wave-lengths: (a) gain; (b) noise figure.

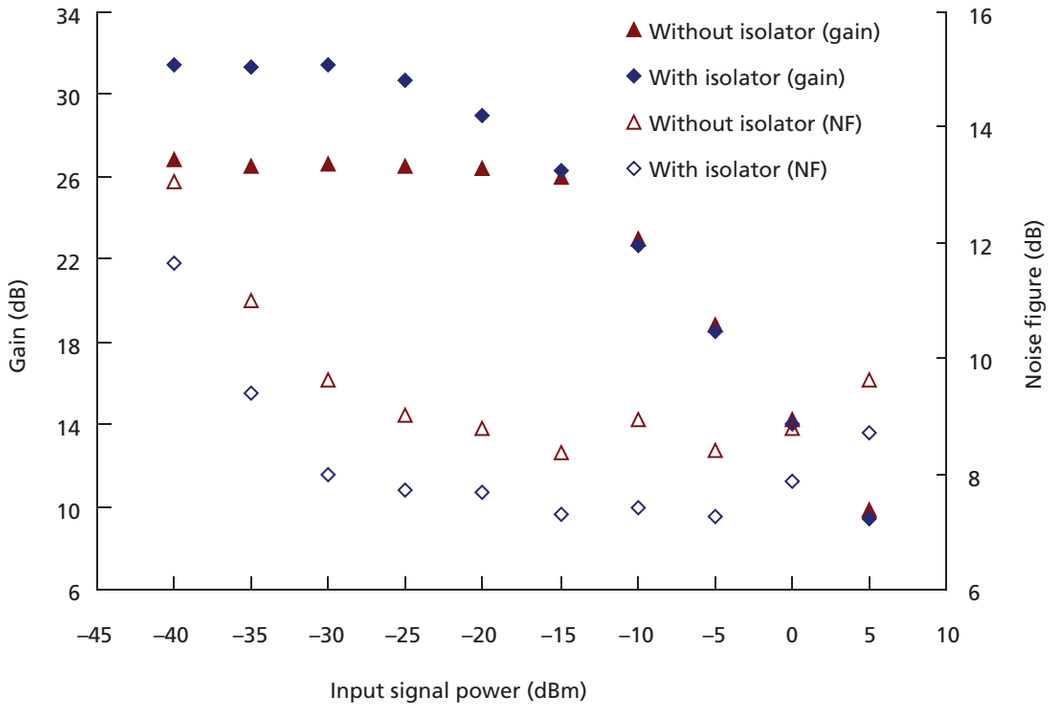


Figure 5. Gain and noise figure as a function of input signal power for the EYDFAs configured with and without optical isolators.

dBm. Without the isolators, the oscillating laser limits the population inversion in the amplifier which in turn increased the noise figure. These results showed that the employment of optical isolators was an important aspect to consider when designing an EYDFA.

CONCLUSION

An EYDFA operating at 1550 nm band and using a 1058 nm pumping wave-length was demonstrated. Amplification was achieved via energy transfer from Yb ion to Er ion, and this increased the limit of erbium doping concentration that was imposed by concentration quenching in EDF. However, the energy transfer could not be utilized with 1480 nm pumping which resulted in severe degrading of the gain and noise figure. The optimum length was obtained at 4 m ~ 6 m for EYDF with Er ion concentration of 1000 p.p.m. The usage of optical isolators prevented the oscillating laser to be created by spurious reflection. Therefore, small signal gain and noise figure was improved by about 4.8 dB and 1.6 dB, respectively compared with the amplifier configured without the isolator.

Date of submission: October 2006
Date of acceptance: January 2008

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Productivity and Efficiency Improvement of a Vehicle Seat Assembly Line Using Computer Simulation Analysis

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All relevant and essential data of an existing vehicle seat assembly line such as the operating time and processes, material handling system, workstation layout, bill of materials, equipment and hand tools, were collected and analyzed. The time standards for each of the vehicle seat assembly elements were established using work study techniques. A simulation approach was used to determine the productivity and efficiency of the existing and proposed lines. Simulation technique was also used to determine and identify bottle-necks in both existing and proposed systems. Comparison of the existing assembly line and the proposed assembly line in terms of their productivity and efficiency are also highlighted.

Key words: Assembly line; productivity; simulation; line balancing; vehicle seat; automotive; efficiency

Assembly is the process by which parts and sub-assemblies of manufactured products are put together to form the finished product (Guetsch 1990). A manual assembly line is a production line that consists of a sequence of workstations where assembly tasks are performed by human workers. Components are assembled as they move along the line. At each workstation, a portion of the total work is performed on each unit. The production rate of an assembly line is determined by its slowest station.

The main objective of this study was to improve the productivity and efficiency of a vehicle seat assembly line in a local automotive vehicle-parts manufacturer. The main problem of the assembly line was that the production department of the factory did not have any standard time for the manufactured products. The assembly line was also not balanced because of the bottle-necks which occured in the assembly line resulting in low productivity and efficiency that was not at its optimum level.

Simulation plays a significant role in the design and operation of a manufacturing production system. While Kosturiak and Gregor (1999) looked at the importance of simulation on the overall production life cycle, this study focused more on a specific section of an assembly production line. The specific code for model generation for a simulation-based shop floor control was also discussed by Son and Wysk (2001). This study employed a dedicated simulation package for personal computer, called ProModel, version 4.2 for simulation analysis.

MATERIALS AND METHODS

The study was performed in the industry by collecting all the data of existing time standard for production lines. Then the proposed standard time for the new layout of the production line was made. There were four researchers involved in this study. The principal researcher spent approximately three months in the industry. The tools deployed during the study include ProModel software and a stop watch. ProModel is a discrete event simulation software used for evaluating, planning or designing manufacturing, warehousing, logistics and other operational and strategic situations.

Existing Assembly Line

The existing assembly line layout consists of two lines of 10 workstations, with each line placed on either side of a conveyor system transporting the product along the production line. The assembly line has manual and automated workstations with an employee deployed at each workstation.

The final product from the line is a vehicle seat Model HS126. One complete set of the seat consists of six pieces of seat portions: 2 front cushions (F/C), 2 front backs (F/B), 1 rear cushion (R/C) and 1 rear back (R/B), as shown in Figure 1. The annual demand is about 29 717 sets.

Since the final vehicle seat assembly line was newly fabricated, no work study has been carried out before.

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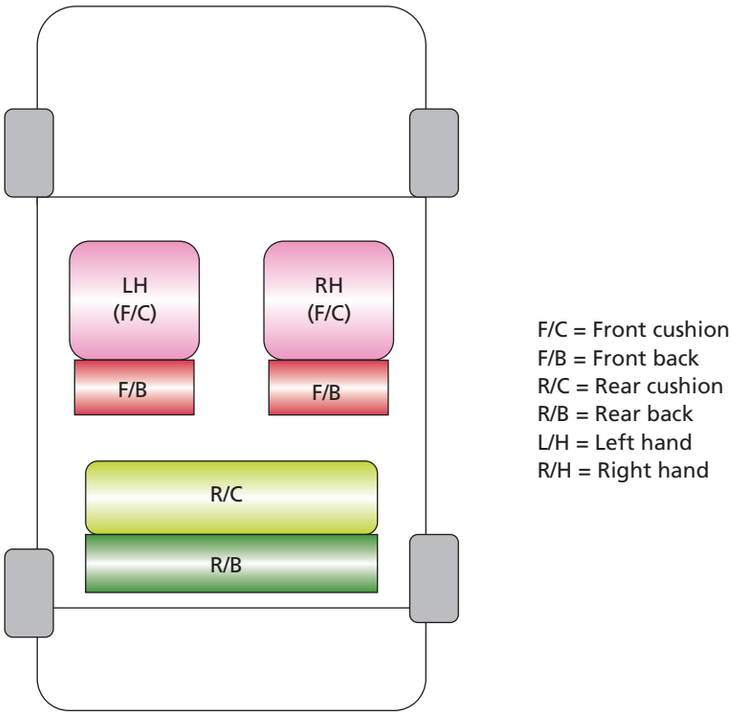

Figure 1. One complete set of vehicle seat.

Therefore, the initial effort was to find out all the relevant and essential data of the existing line such as operating time and processes, material handling system, workstation layout, bill of materials and equipment used based on the work study method outlined by Mundel (1978).

Standard Time and Simulation Approach

The standard time is the time required for a qualified and well-trained person, working at a normal pace, to do a specific task (McDermott 1984). The standard time for a job is the sum of the standard time for all the elements of which it is made up, due regard being paid to the frequencies with which the elements recur, plus the contingency allowance, with its relaxation allowance increment (International Labour Office 1978). In this study, the calculation of the standard time for the element breakdowns is based on the following equations:

$$\text{Standard time (s)} = \text{Allowance time (s)} + \text{Basic time (s)} \quad (1)$$

Where,

$$\text{Total allowance (\%)} = \text{Relaxation allowance (\%)} + \text{Contingency allowance (\%)} \quad (2)$$

$$\text{Allowance time (s)} = \text{Total allowance (\%)} \times \text{Basic time (s)} \times (1/100) \quad (3)$$

The results of the calculation for standard time are shown in Table 1. This standard time was used together with the flow process chart in line balancing and simulation analysis.

ProModel (Promodel 1999) simulation software was used to simulate the existing assembly line system (Model A) and the proposed assembly line (Model B) as shown in Figures 2 and 3, respectively. Simulation was used to obtain the simulated production rate and workstation, and location or manpower utilization. Manpower utilization is one of the important elements of resource utilization. The results were then compared with the existing assembly line. Some assumptions were made as follows:

1. *General assumptions for the workstations*.
   (a) Station Parameter
      (i) The efficiency field described the operating efficiency of the stations which is assumed as 100% efficient and it is a normal practice in manufacturing research to make such an assumption.
      (ii) A normal station performs one operation on a single part or assembly at a time.

Table 1. Standard time for the work elements and their precedence.

Description of work elements	Standard time (minute)	Must be preceded by
Front cushion (f/c)		
1. Panel preparation	0.27	–
2. Trimming	0.76	–
3. Panel and pad assembly	0.46	1, 2
4. Trim cover steaming	0.18	3
5. Trim cover clipping	1.57	4
Front back (f/b)		
6. Recliners installation	1.15	–
7. Frame and spring assembly	2.19	6
8. Torque checking and marking	0.92	7
9. SWB wire installation	0.75	8
10. PU pad installation	0.52	9
11. Trimming	2.28	10
12. Trim cover steaming	0.42	11
13. Trim cover clipping	0.74	12
14. Holder lock checking	0.16	13
15. Fin assembly installation	1.07	14
16. Torque checking and marking	0.28	15
Rear cushion (r/c)		
17. Front side trimming and clipping	2.32	–
18. Back side trimming and clipping	2.41	17
19. Trim cover steaming	0.98	18
20. QC	0.52	19
21. Packing	0.62	20
Rear back (r/b)		
22. Front side trimming and clipping	2.01	–
23. Back side trimming and clipping	1.54	22
24. Bracket installation	0.43	23
25. Trim cover steaming	0.48	24
26. Armrest assembly trimming and clipping	1.07	25
27. Armrest assembly	1.11	26
28. QC	1.98	27
29. Packing	0.75	28
30. F/C and F/B assembly	0.79	5, 16
31. Torque checking and marking	0.64	30
32. Components checking and cleaning	1.82	31
33. Packing	0.63	32
34. Storing	0.23	33, 21, 29
Total, (T_{wc})	34.04	

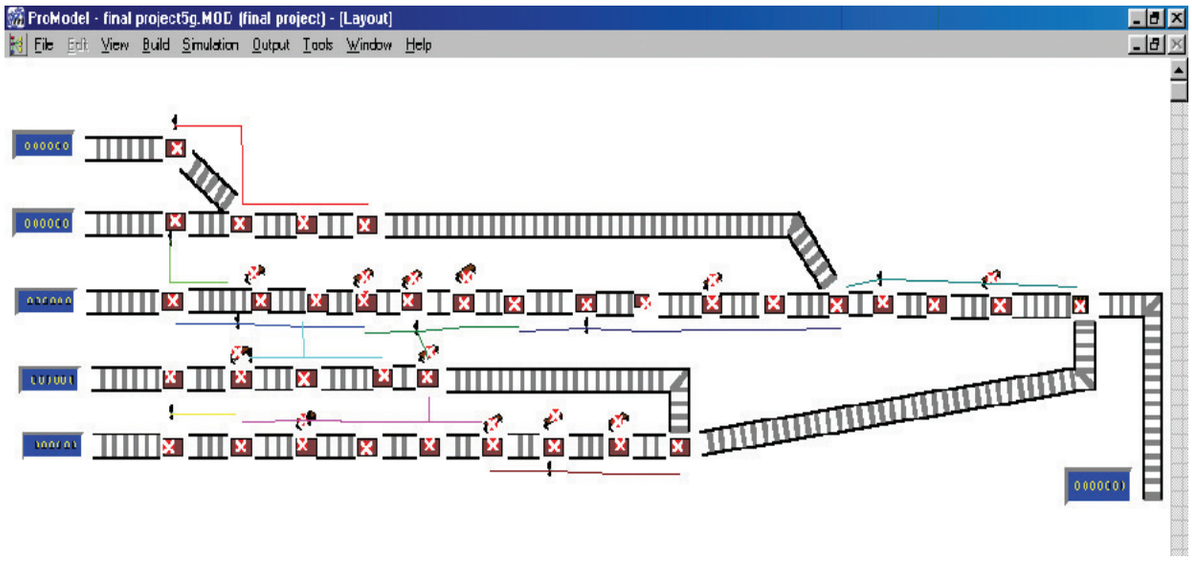

Figure 2. Existing assembly line layout *(Model A)*.

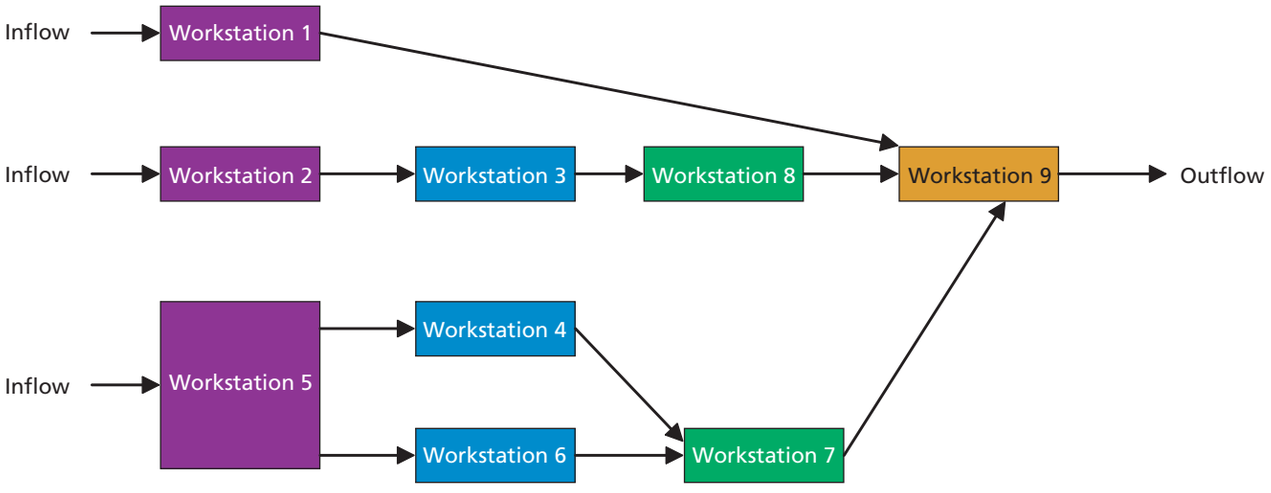

Figure 3. Proposed layout of workstations, after line balancing solution *(Model B)*.

(iii) The station priority field can be set to either low or high. This is used in conjunction with the push and pull rules to control part flow through the model.

(b) Buffer parameter

(i) Buffer priority is used with the push and pull rules to determine part routing.

(ii) The first in first out (FIFO) rule is applied in the buffer and workstation.

2. *Assumptions regarding process menu*.

(a) Part parameters

The priority field can be used to control the order in which parts are stored in a buffer and to affect layout node selection via the push and pull rules. The part priority can range from 1 to infinity.

(b) Arrival parameters

Job arrivals are based on scheduled arrivals that have a single time value, and a quantity to arrive to.

(c) Operation parameters

Processing times for a job at each machine is a random function.

3. *Assumptions regarding setting menu.*

This menu will affect the simulation output.

(a) Model

(i) Warm-up length was set up at 10 min.

The warm-up length is the amount of time to run the simulation prior to gathering statistics. This is used to minimize transient behaviour due to initial condition.

(ii) Clock unit was set to hours.

Sets the basic unit of time which will be used in the model.

4. *Other assumptions.*

(i) The parts are processed in sequence at each workstation.

(ii) 100% of inspected parts are good and are sent to the next station.

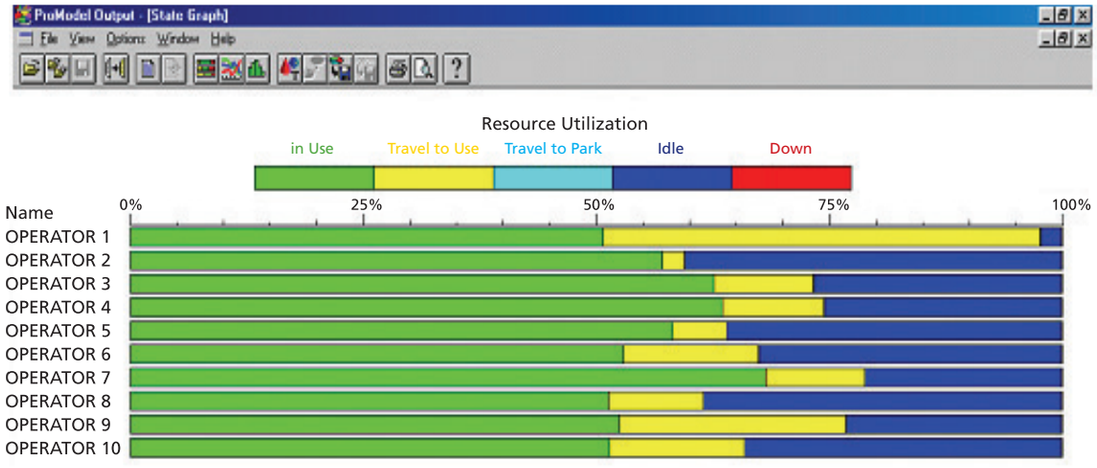

Figure 4(a). Resource state for *Model A*.

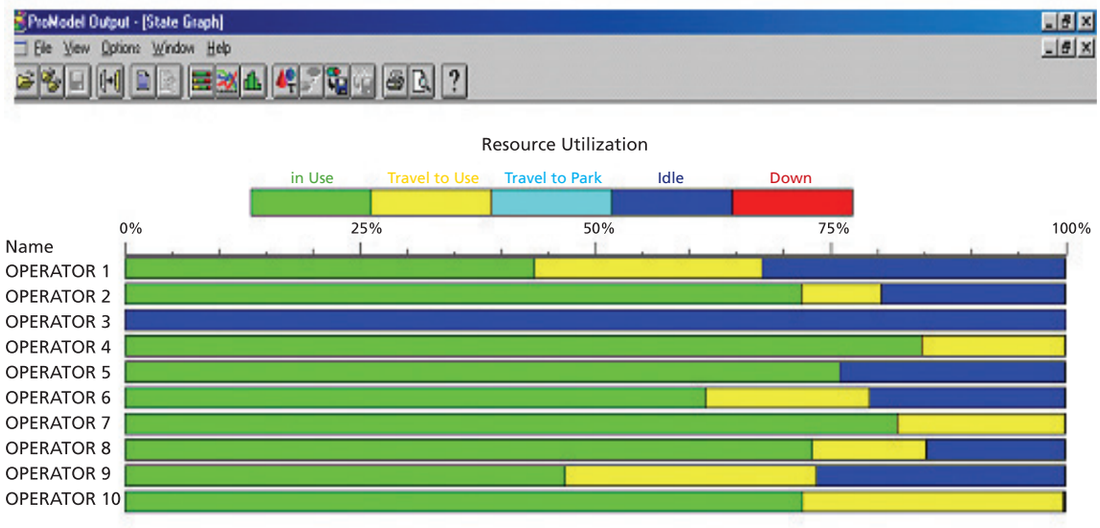

Figure 4(b). Resource state for *Model B*.

RESULTS AND DISCUSSIONS

The existing assembly line is shown in Figure 2. The figure shows work elements, workers and conveyor system. The proposed sequence of station is shown in Figure 3. Resource state reports for both *Model A* and *Model B* are shown in Figures 4(a) and 4(b), while the resource utilization reports are shown in Figures 5(a) and 5(b), respectively.

Resource utilization depends on the number of jobs and also the variables and parameters which will affect the model. The analysis was done on the 'in use' time, 'travel to use' time, 'travel to park' time, 'idle' time and 'downtime'. These will indicate the resource utilization.

As a result, the 'in use', 'travel to use' and 'travel to park' activities for the resource state are the most required because these activities are value-added to the productivity. Meanwhile, 'idle' and 'down' activities are not required in production because these activities are not adding any value.

The results of the different system designs from the simulation output were analyzed. In the existing assembly line, major portions of resource states were 'in use' and 'travel to use', they contributed roughly more than 60% in average at each resource.

The highest resource utilization for the existing assembly line [see Figure 5(a)] was operator 1 (97.82%) and the lowest was operator 2 (59.58%). These exact figures were found from the *General Report: Resources* of the software.

Figure 4(b) shows the major portion of resource states of proposed line where it contributed roughly more than 70% in average at each resource. The resource utilization is shown in Figure 5(b). There are three operators who had almost full resource utilization compared to others. From the *General Report: Resources*, the first three highest resource utilization were operator 4 (99.98%), operator 7 (99.97%) and operator 10 (99.9%). The lowest was operator 1 (67.86%). However, the lowest operator resource utilization was still higher than the lowest resource utilization from existing assembly line. The comparison between the *Model A* and *Model B* is shown in Table 2.

Table 2. Production rate for *Model A* and *Model B*

Parameters	*Model A*	*Model B*
Δ Variation utilization (%)	38.24	32.12
Production rate (sets/h)	8.867	10.513

Even though the proposed *Model B* had only 9 operators compared to 10 operators in the existing line, *Model B* had better resource utilization and production rate. Operator 3 in *Model B* was eliminated to reduce the cost. This was because of the effect of line balancing which had taken place in optimizing all the resource cycle time and operational sequences.

Comparing the percentage of variation utilization parameter, *Model A* has higher variation utilization compared to *Model B* that had been line-balanced. The variation was caused by the unbalanced state of the existing

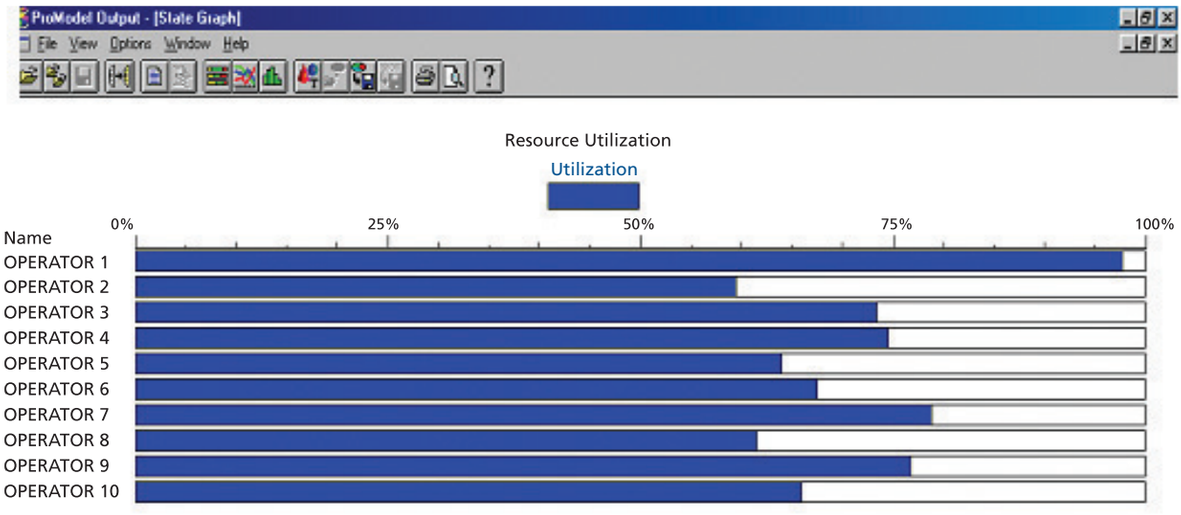

Figure 5(a). Resource utilization for Model A.

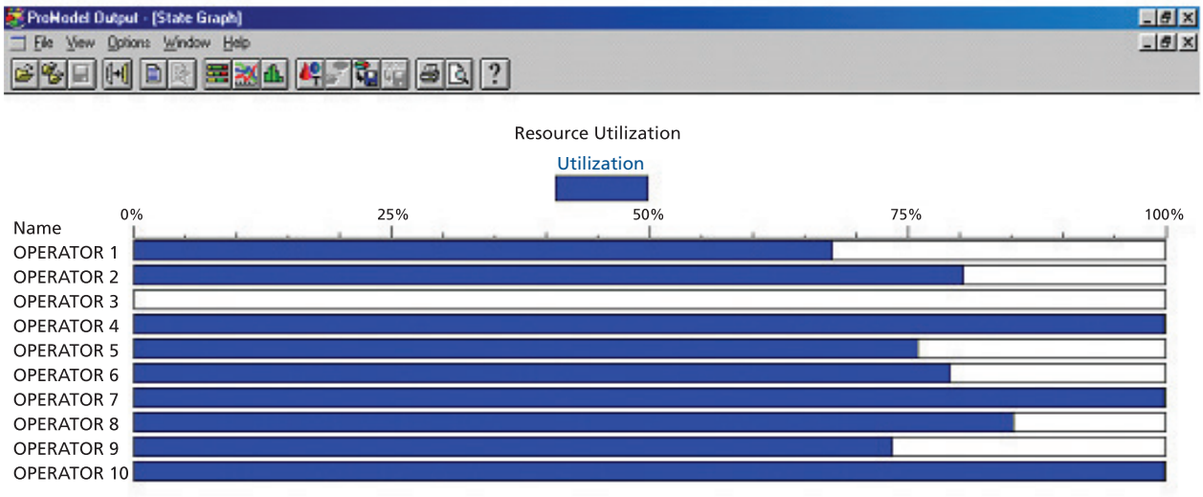

Figure 5(b). Resource utilization for *Model B.*

assembly line in *Model A*. Therefore, it is important for the producer or manufacturer to take the line balancing problem into serious consideration.

Besides, an assembly line with and without line balancing gave a significant effect on the improvement percentage of production rate. *Model A* had 29.44% improvement only if compared to *Model B* that had 53.47%.

CONCLUSION

The results from this study are meaningful for those involved in improving the productivity and efficiency of assembly lines for vehicle seats. The use of a simulation tool in the study helped overcome the tedious line balancing work and reduced the number of steps taken to achieve the optimized condition. It could be concluded that *Model B* was more productive and efficient compared to *Model A*. In a nutshell, simulation could be used to determine effectiveness and efficiency of a production line.

RECOMMENDATIONS FOR FUTURE WORK

It is recommended that a more detailed time study to be carried out on the assembly line process before any simulation is to be done. This will help minimize the errors that will be incorporated into the simulation study. Also, more time should be devoted to understanding the overall flow of the assembly line itself, rather than focusing on the quantitative aspects of the individual process. For example, identification of any bottle-neck operation should be done first and be eliminated from the system before line balancing procedure is applied.

Date of submission: November 2006
Date of acceptance: January 2008

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ASM Sci. J., **1(2)**, 143–154

Prediction of β-carotene Solubility at Supercritical Conditions Using Regular Solutions Theory

K.M. Kassim[1]* and R. Davarnejad[1]

The objective of this paper is to model the extraction of carotenoid with supercritical carbon dioxide as the solvent. Experimental data for the high pressure vapour-liquid phase equilibrium of the binary system carbon dioxide-carotenoid was reviewed for the elevated temperatures of 313.15, 323.15, 333.15 K and pressures up to 500 bar. The experimental data was correlated and modeled using Redlich-Kwong equation of state and regular solution methods. The use of the equation of state as an empirical correlation for collating and predicting liquid-liquid and liquid-dense fluid equilibria is discussed. It was concluded that the estimation of some of the parameters required for these calculations would be difficult if the solute (carotenoid) was a complex substance about which little was known apart from its structural formula.

An alternative procedure is to apply activity coefficient expression of the regular solution theory type to each phase. Calculations along these lines are described and the physical basis for applying these methods under the relevant conditions is discussed. The regular solution theory approach in particular was found to be encouraging for the mutual miscibility calculations for heavy components (such as carotenoid) particularly for substances sensitive to temperature, though the interaction parameters for the prediction activity coefficients must be regarded as pressure dependent.

Key words: supercritical; extraction; solubility; carbon dioxide; regular solution theory; equation of state; interaction parameters; activity coefficient; carotenoid; Quasi-lattice models

Conventional methods based on solvent extraction from natural matrices are time consuming. These methods require multiple extraction steps and large amounts of organic solvent which are often expensive and potentially harmful.

Extraction with carbon dioxide under supercritical conditions constitutes an emerging technology in terms of environmental impact. The advantages of using carbon dioxide are lack of toxicity, chemical inertness, critical temperature and pressure available, low cost and availability (Williams *et al*. 2002, p. 265). Furthermore, the use of carbon dioxide is also beneficial in adding quality to the products obtained since this technique does not give rise to excessive heating which usually has a negative effect on thermolabile compounds (Macánchez-Sánchez *et al*. 2005, p. 246).

Carotenoids are increasingly used in food technology mainly due to consumer pressure and more demanding regulations regarding the use of artificial dyes (Macánchez-Sánchez *et al*. 2005, p. 245). Carotene is a precursor of vitamin A in human and animal metabolism and it is used in the food processing industry for colouring purposes. This large aliphatic molecule has a molecular weight of 536.9 g/mol and one of its isomers, β-carotene, is illustrated in Scheme 1 (Birtigh *et al*. 1995, p. 46).

Supercritical CO_2 has a low solubility for β-carotene, most of which is concentrated in the raffinate. System pressure was found to be more significant rather than temperature for increasing the solubility in supercritical CO_2 (Markom *et al*. 2001, p. 49). The solubilities of pure β-carotene in supercritical CO_2 have been reported by several authors (Birtigh *et al*. 1995, p. 46).

Usually established for pure components, the equation of state can be extended to a solution at equilibrium of a multi-component system by using suitable mixing rules that define the homogenous supercritical mixture characteristics. Numerous equations of state are proposed in the literature, their use is strongly related to the domains of the operating parameters and the nature of the chemical components. The best known equations of state (EOS) for pure components are the cubic equations of state, such as Redlich-Kwong EOS, Redlich-Kwong-Soave EOS and Peng-Robinson EOS (Ksibi 2004, p. 133).

The objective of this study is to predict mutual solubilities for a system involving carbon dioxide and carotene as

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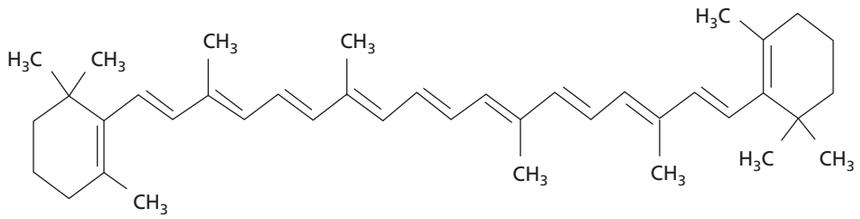


Scheme 1. Structural formula of β-carotene.

heavy component with supercritical carbon dioxide solvent. Theoretical data were calculated from regular solution equations and compared with the experimental data. These equations are described in detail by King *et al*. (1984, pp. 812–820). Calculations using the proposed equations mentioned above are defined and described in this paper, together with the physical basis for applying the proposed methods under the relevant conditions. Some of the interaction parameters that are required for the calculation of activity coefficients can be calculated from the experimental data for some equilibria systems which have been mentioned by Liphard and Schneider (1975, pp. 811–812). The other interaction parameters have been generated by Fredenslund *et al*. (1977, pp. 39–47). The obtained data, activity coefficient, Gibbs function relationships and eventually mutual solubility data are calculated for two equilibria phases by using regular solution equations.

Prediction Phase Equilibrium Solution Using Quasi-lattice Models

The regular solution theory adopted as a model for this system is based on the activity coefficients by applying the following equations:

$$RT\ln\gamma_i = \left[\frac{d\left(nG^{\text{Excess}}_{\text{mixing}}\right)}{dn_i}\right]_{T,P,n_{j\neq i}} = \left[\frac{d\left(nH^{\text{Excess}}_{\text{mixing}}\right)}{dn_i}\right]_{T,P,n_{j\neq i}} - \mathrm{T}\left[\frac{d\left(nS^{\text{Excess}}_{\text{mixing}}\right)}{dn_i}\right]_{T,P,n_{j\neq i}} \quad (1)$$

$$\ln\gamma_i = (\ln\gamma_i)^{\text{Excess}} + (\ln\gamma_i)^{\text{Solute}} \quad (2)$$

$$(\ln\gamma_i)^{\text{Excess}} = \frac{1}{R\times T}\times\left[\frac{d(nH^{\text{Excess}})}{dn_i}\right]_{T,P,n_{j\neq i}} = \left[\frac{\Phi_j^2\times V_{mi}}{R\times T}\right](d_i-\zeta_{ij}d_j)^2 + 2l_{ij}d_i d_j\zeta_{ij} \quad (3)$$

where,

$$\zeta_{ij} = \left[\left(\frac{V_{mj}}{V_{mi}}\right)\left(\frac{q_i}{q_j}\right)\right]^{\frac{1}{2}} \quad (4)$$

$$d_i = \left[\frac{(U^0{}_{mi}-U_{mi})}{V_{mi}}\right]^{\frac{1}{2}} \quad (5)$$

d_i is the well known 'solubility parameter' of component (i). U_{mi} and $U^0{}_{mi}$ are the molar internal energies of the compressed fluid component (i) and the same fluid at the same temperature but a very low pressure. These parameters were calculated by the same equations but for component (j), as well. Equation 3 may be compared with the expression given by the Van der Waals approach (Hildebrand *et al*. 1970, p. 248):

$$(\ln\gamma_i)^{\text{Extract}} = \left(\frac{\Phi_j^{v\,2}\times V_{mi}}{R\times T}\right)\left[(d_i-d_j)^2 + 2l_{ij}d_i d_j\right] \quad (6)$$

It differs from this only in the term ζ (which is usually close to unity) and in the replacement of the area function (Φ_j^v) by the volume function,

$$\Phi_j^v = \frac{(x_j\times V_{mj})}{(x_i\times V_{mi}+x_j\times V_{mj})} \quad (7)$$

where, (V_{mi}) is the molar volume of the pure liquid (i).

For a non-spherical molecule of type (i), quantity (q_i) is defined such that (Zq_i) is the number of interactions made by a molecule of this type with surrounding molecules. A monomer has (Z) interactions with the nearest neighbour molecules (following X-ray diffraction information for simple fluids Z is normally given a value of 10). (q_i) is termed the area function for the molecule. For a linear molecule (Kassim *et al*. 2007),

$$q_i = r_i - \left(\frac{2\times(r_i-1)}{Z}\right) \quad (8)$$

(r) is the number of segments and it is calculated as a function of the number of carbon atoms, for example (n) for alkanes can be determined for the calculation, therefore, $r = 0.90 + 0.283(n-1)$:

Also, there would be an arrangement for Equation 3 as following:

$$\ln\gamma_i^{\text{Extract}} = \sum_{K=1}^{N} \nu_K^{(i)} (\ln \Gamma_K - \ln \Gamma_K^{(i)}) \quad (9)$$

$$\ln \Gamma_K = Q_K \left[1 - \ln \left(\sum_m^N \theta_m \Psi_{mK} \right) - \sum_{m=1}^{N} \frac{\theta_m \Psi_{Km}}{\sum_{n=1}^{N} \theta_n \Psi_{nm}} \right] \quad (10)$$

where,

$$\Psi_{mK} = \text{Exp}\left(-\frac{a_{mn}}{T}\right) \quad (11)$$

Q_K is the area function for group K and θ_m is the area fraction of group m. $\ln \Gamma_k^{(i)}$ is defined similarly except that the group area fractions refer to the pure liquid i and not to the mixture.

$$(\ln \gamma_i)^{\text{Solute}} = \ln\left(\frac{\phi_i}{x_i}\right) + \left(\frac{Zq_i}{2}\right) \times \ln(\theta_m + \phi_i) + l_i - (\phi_i / x_i) \sum_{j=1}^{M} x_j l_j \quad (12)$$

where,

M, θ_i and ϕ_i are the number of components in the solution, the area fraction for component i in the solution and the segment fraction, respectively.

$$l_i = (Z/2)(r_i - q_i) - (r_i - 1)$$

$$\phi_i = \frac{x_i r_i}{\sum_{i=1}^{M} x_i l_i}$$

Also there is another arrangement for Equation 12:

$$(\ln \gamma_i)^{\text{Solute}} = \ln\left(\frac{\phi_i}{x_i}\right) - \left(\frac{Zq_i}{2}\right) \times \ln\left\{1 + (2\phi_j / Zq_i)[(r_i / r_j) - 1]\right\} \quad (13)$$

In the present work activity coefficient was calculated using Equations 2, 9 and 12. In order to present the calculations, details of the mutual solubilities for the system CO_2 (i)/ heavy component (j) it is necessary to define that x_i^E is the mole fraction of component (i) based on the extract phase (carbon dioxide) and x_i^S is the mole fraction of component (i) based on the solute phase. Therefore x_i^E and x_i^S can be calculated from the activity coefficients data γ_i^E and γ_i^S for the phases and from the distribution factors k_i and k_j as:

$$\gamma_i^E x_i^E = \gamma_i^S x_i^S \quad (14)$$

$$k_i = \frac{x_i^E}{x_i^S} \quad (15)$$

The procedure is as follows:

a. Guessing initial k-values for each component given by Equation 15.

b. Use these guessed k-values to obtain the approximate mole fraction of component (i) in each layer.

$$x_i^E = \frac{1 - k_j}{1 - \frac{k_j}{k_i}} \quad (16)$$

$$x_i^S = \frac{x_i^E}{k_i} \quad (17)$$

These values were then inserted at step b, and the cycle was repeated until the mole fractions calculated in step b, showed negligible change from one step to the next.

An alternative approach which was used in the regular solution theory calculations was to establish analytic expressions for a function Q and its derivatives with respect to mole fraction given by:

$$Q_i = -[x_i \ln(x_i\gamma_i) + x_j \ln(x_j\gamma_j)] = -\frac{G_m^{\text{mixing}}}{RT} \quad (18)$$

$$\left(\frac{\partial Q_i}{\partial x_i}\right)^E = \left(\frac{\partial Q_i}{\partial x_i}\right)^S = \frac{(Q_i^E - Q_i^S)}{(x_i^E - x_i^S)} \quad (19)$$

$$\frac{dQ_i}{dx_i} = -\ln\frac{\gamma_i x_i}{\gamma_j x_j} \quad (20)$$

$$\frac{d^2 Q_i}{dx_i^2} = -\frac{d\left(\ln\frac{\gamma_i x_i}{\gamma_j x_j}\right)}{dx_i} \quad (21)$$

(G_m^{mixing}) is the molar Gibbs function of mixing and from standard thermodynamic relationships, it follows that (∂x_i^2) should be negative at all points in a completely miscible system. If the system is partially miscible there will be a region over which ($\partial^2 Q_i / \partial x_i^2$) is positive. In the latter case the points on the Q_i versus x curve corresponding to the equilibrium phase extract (E) and solute (S) have a common tangent, Equation 19 where ($\partial^2 Q_i / \partial x_i^2)^E$ =

gradient , $(\partial^2 Q_i / \partial x_i^2)^E$ taken at the mole fraction (x_i^E) of component (i) in the solvent-rich phase and $(\partial^2 Q_i / \partial x_i^2)^S$ = gradient taken at mole fraction (x_i^S) of component (i) in the solute-rich phase.

If the first assumption is as good (estimations of the) values of $(x_i^E)^0$ and $(x_i^S)^0$ [for the mole fractions (x_i^E) and (x_i^S)] which are already available, the applied procedure was found to be satisfactory for locating (x_i^E) and (x_i^S) using Equation 19.

This procedure was repeated until no further adjustment was required. Equation 19 was then satisfied and the mole fractions (x_i^E) and (x_i^S) specified the required calculated phase compositions

RESULT AND DISCUSSION

The liquid-liquid equilibrium data for the system carbon dioxide-squalane at required pressure and temperature (Figure 1), together with the regular solution derived model (King *et al*. 1984, pp. 812–820; Kassim & Davarnejad 2006) was used in order to calculate effective values for the $a_{CO_2/CH}$ (or $_{CH_2}$ or $_{CH_3}$) and a_{CH/CO_2} interactions as a function of pressure as shown in Table 1. This data were used to predict mutual solubility data in the carbon dioxide-carotenoid system at temperatures 313.15, 323.15, 333.15 K and at pressure up to 500 bar. Parameters other than a_{CO_2/CH_2} and a_{CH_2/CO_2} required in the regular solution model were evaluated using the standard methods described in (Fredenslund *et al*. 1977, pp. 39–47). Furthermore, the derived model based on the regular solution theory used in the present work is given by Kassim and Davarnejad (2006).

In order to examine the behaviour of the system CO_2-carotenoid at various pressures and temperatures, miscible or immiscible, it is necessary to calculate the values of the activity coefficient (γ), Gibbs function (G) and its derivatives (dG/dx) and (d^2G/dx^2), using Equations 2, 9, 12, 18, 20 and 21.

Experimental data (Macánchez-Sánchez *et al*. 2005, p. 248) in Table 2 shows ratio (the yield of extracted carotene per yield of extracted chlorophyll a) at different temperatures and at various pressures. Table 3 shows the yield of extracted carotene (μg carotene/ mg dry weight microalgae (feed) and carotene mole fractions (in extracted phase) related to temperature and pressure.

Interaction parameters were calculated by applying regular solution theory equations related to the experimental data obtained by Liphard and Schneider (1975, p. 811) (which are shown in Figure 1). Therefore interaction parameters obtained at various temperatures and pressures were shown in Table 1.

The CO_2-carotene system was also modeled by applying Redlich-Kwong equation of state. All equations are shown in reference (Kassim & Davarnejad 2007, p. 5). Some necessary parameters such as critical properties and adjustable parameter (as a function of temperature) have been shown in reference (Hartono *et al*. 2001, pp. 6952 and 6956).

All results such as experimental vapour phase data, two phases equilibrium data (based on regular solution theory) and extracted phase data (based on EOS) are tabulated in Tables 4–6 at temperatures 313.15, 323.15, 333.15 K and at various pressures, respectively. However, the relative deviation (RD) data are also shown in the same tables for the two models (which are EOS and regular solution equations):

$$\text{RD} = \frac{\text{Experimental data} - \text{Theoretical data}}{\text{Experimental data}}$$

A statistical analysis was employed for checking the regular solution model accuracy. *Minitab* software was applied for this purpose. Two groups of data involving the experimental data and the data obtained from the regular solution equations were employed. It was observed that confidence interval factor (CI) was at 95% for the range of (–0.003060, 0.002786). T-value was also obtained at –0.10. This analysis showed an acceptable P-value factor (P-value = 0.924>0.05).

Carotene solubility in supercritical carbon dioxide is predicted by applying the regular solution equations, Gibbs function relationships and activity coefficient expression.

Figure 2 shows CO_2 activity coefficient (γ_{CO_2}) calculated from Equations 2, 9 and 12 against CO_2 mole fraction (x_{CO_2}) at constant pressure 200 bar and at temperatures 313.15, 323.15 and 333.15 K. Interaction parameters a_{CH_3/CO_2} and a_{CO_2/CH_3} obtained from Table 1.

Furthermore Figures 3–5 show CO_2 activity coefficient (γ_{CO_2}) at pressures 300, 400 and 500 bar, respectively. Figure 2 showed that CO_2 activity coefficient against CO_2 mole fraction decreased exponentially with increasing CO_2 mole fractions at pressure 200 bar and at various temperatures. However, this trend was observed as an exponential feature at pressure 300 bar and at temperatures 313.15 K and 323.15 K, at pressures 400 bar and temperatures 323.15 K and 333.15 K as well as at pressure 500 bar and at temperatures 323.15 K and 313.15 K. Activity coefficients however linearly decreased with increasing CO_2 mole fractions for the other conditions.

Figure 6 shows the solubility parameter, $d^2Q_{CO_2}/dx^2_{CO_2}$, for CO_2 calculated from Equation 21 against CO_2 mole fraction (x_{CO_2}) at constant pressure 200 bar and at variable

Table 1. Interaction parameters a_{CH_3/CO_2} and a_{CO_2/CH_3} based on the calculations of the experimental data extracted form Figure 2 at temperatures 313.15, 323.15 and 333.15 K

	CO_2/Squalane, T=313.15 K			
P (Bar)	$(X^E_{squalane})^{Exp.} \times 10^3$	$(X^S_{squalane})^{Exp.} \times 10^2$	a_{CH_3/CO_2}	a_{CO_2/CH_3}
200	2.352941	9.7124943	2565.7422	74.0
300	3.5294	2.7810056	1008.8450	95.0
400	4.7059	14.5714285	754.56040	80.0
500	6.670	15.2941179	1915.6307	65.0
	CO_2/Squalane, T=323.15 K			
P (Bar)	$(X^E_{squalane})^{Exp.} \times 10^3$	$(X^S_{squalane})^{Exp.} \times 10^2$	a_{CH_3/CO_2}	a_{CO_2/CH_3}
200	3.5294118	5.57534470	2333.2239	72.0
300	5.2941200	2.78100560	2634.1658	75.0
400	7.0588240	12.9411764	2762.0835	65.2001
500	117.6470580	1.0	961.11400	60.0
	CO_2/Squalane, T=333.15 K			
P (Bar)	$(X^E_{squalane})^{Exp.} \times 10^3$	$(X^S_{squalane})^{Exp.} \times 10^2$	a_{CH_3/CO_2}	a_{CO_2/CH_3}
200	2.5	16.0	2149.3108	80.0
300	5.0	11.666700	799.55430	85.0
400	12.7780	9.2424242	1256.1367	68.0
500	26.6700	6.5151515	719.02610	70.0

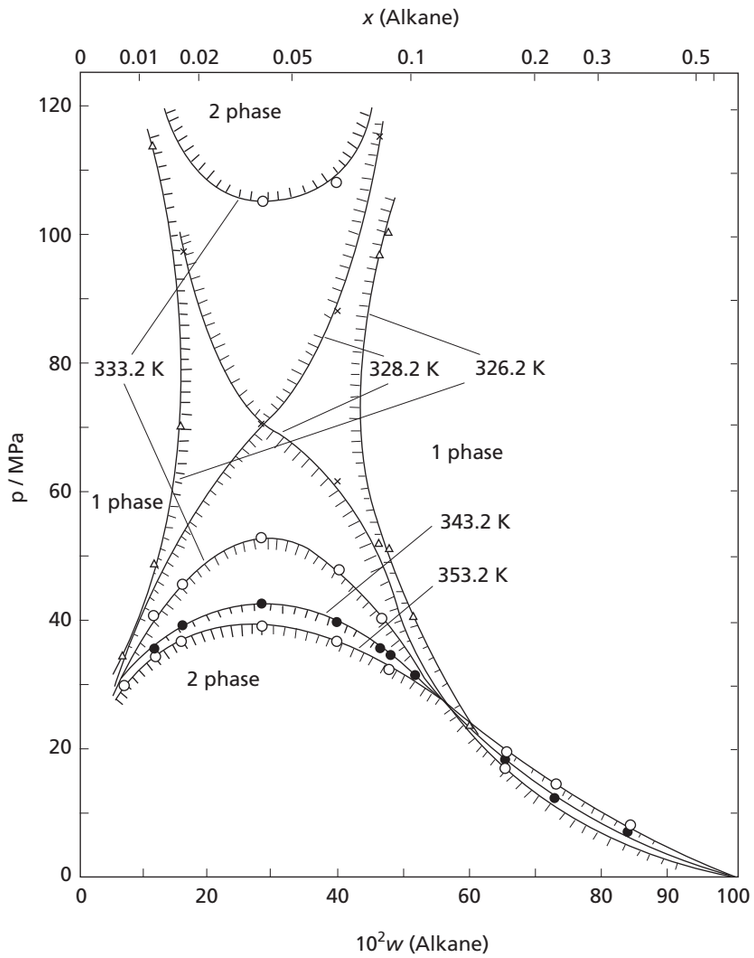
Table 2. Pressure/Ratio of carotenoid at 313.15, 323.15 and 333.15 K[a]

T=313.15 K		T=323.15 K		T=333.15 K	
P (Bar)	Ratio	P (Bar)	Ratio	P (Bar)	Ratio
200	0.524	200	0.410	200	1.389
300	0.258	300	0.230	300	0.179
400	0.115	400	–	400	0.153
500	0.129	500	0.129	500	0.120

[a]Macánchez-Sánchez *et al*. 2005, p. 248.

Table 3. Experimental data extracted from Table 1, Pressure/yield of carotenoid, at temperatures 313.15, 323.15 and 333.15 K.

	CO_2/Carotenoid, T=313.15 K		CO_2/Carotenoid, T=323.15 K		CO_2/Carotenoid, T=333.15 K	
P (Bar)	Yield	$(x_{carotene})^{Exp}$	Yield	$(x_{carotene})^{Exp}$	Yield	$(x_{carotene})^{Exp}$
200	0.152	1.24609×10^{-5}	0.152	1.25×10^{-5}	0.125	1.03×10^{-5}
300	0.208	0.0167680	0.248	2.04×10^{-5}	0.250	2.05×10^{-5}
400	0.125	1.0300×10^{-5}	–	–	0.340	2.79×10^{-5}
500	0.104	8.6000×10^{-6}	0.180	1.48×10^{-5}	0.252	2.07×10^{-5}



w = Weight percentage of squalane; *x* = Mole fraction percentage of squalane; P = Pressure (MPa).

Figure 1. Pressure/composition diagrams for carbon dioxide/squalane system (Liphard & Schneider 1975, p. 811).

Table 4. Comparison of the experimental and theoretical data (based on regular solution theory model and EOS) at temperature 313.15 K and at pressures 200, 300, 400 and 500 bar.

P (bar)	$(X^{E}_{CO_2})^{Exp.}$	$(X^{S}_{CO_2})^{RST}$	$(X^{E}_{CO_2})^{RST}$	$(X^{E}_{CO_2})^{EOS}$	RD% Based on RST	RD% Based on EOS
200	0.999987500	0.005	0.9992	0.99999786	0.0788	1.036×10^{-3}
300	0.983231902	0.3838	0.9996	0.99999929	1.6647	1.705
400	0.999989752	0.6469	0.9989	0.99999957	0.1089	9.818×10^{-4}
500	0.999991473	0.0452	0.9987	0.99999969	0.1291	8.217×10^{-4}

temperatures 313.15, 323.15 and 333.15 K. Interaction parameters a_{CH_3/CO_2} and a_{CO_2/CH_3} were obtained from Table 3. Furthermore Figures 7–9 show the solubility parameter for CO_2 calculated from Equation 21 against CO2 mole fraction (x_{CO_2}) at pressures 300, 400 and 500 bar, respectively. Figure 4 showed that this system was partially miscible at pressure 200 bar and at various temperatures because solubility parameters showed a positive sign in the range for all CO_2 mole fractions. However, this trend (as being partially miscible) was observed at pressures 300 bar, 400 bar and at temperature 323.15 K as well as at pressure 500 bar and at temperature 313.15 K. The others showed point of inflection.

This system (CO_2-carotene) was completely miscible for CO_2 mole fractions less than 0.70, therefore the conditions were at pressure 300 bar and at temperature 313.15 K. The same behaviour was observed for CO_2 mole fractions less than 0.75 at pressure 300 bar and at temperature 323.15 K. Also the same behaviour was observed for CO_2 mole fractions less than 0.80 at pressure 400 bar and at temperature 313.15 K. It was also observed that for CO_2 mole fractions less than 0.65 at pressure 400 bar and at temperature 333.15 K as well as the same behaviour was observed for CO_2 mole fractions less than 0.75 at pressure 500 bar and at temperature 323.15 K and for CO_2 mole fractions less than 0.85 at pressure 500 bar and at temperature 333.15 K.

Regular solution theory data (as a described model) gave the most reliable values for carotene extraction which was carried out at various pressures and at temperatures of 313.15, 323.15 and 333.15 K. It was found that the calculated data based on regular solution theory was in good agreement with the statistical results obtained by Macánchez-Sánchez and co-researchers (2005, p. 250).

CONCLUSION

This study predicted the solubility data of β-carotene at supercritical conditions using the regular solutions theory approach. The theoretical equations and associated parameters used in the modeling were clearly described. The β-carotene experimental data and Redlick-Kwong parameters were obtained from published literature.

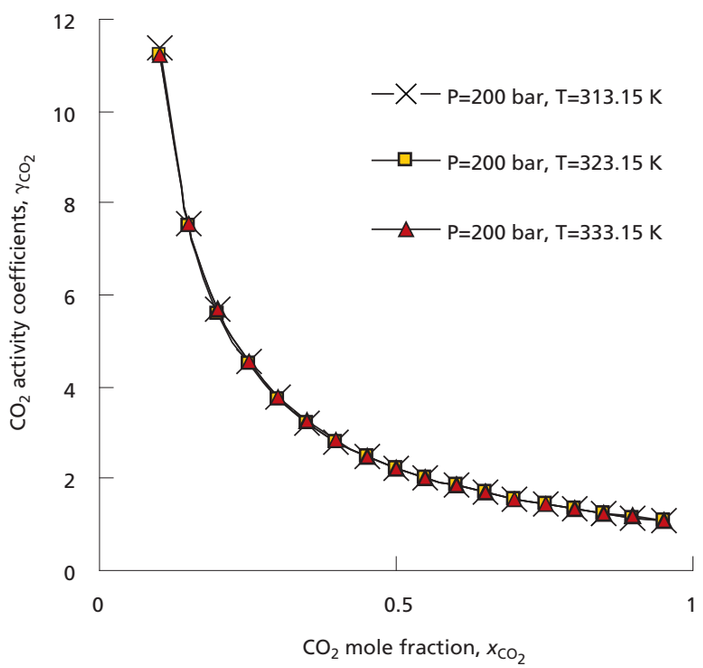


Figure 2. CO_2 activity coefficient (γ_{CO_2}) calculated from Equation 2 against CO_2 mole fraction (x_{CO_2}) at constant pressure 200 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

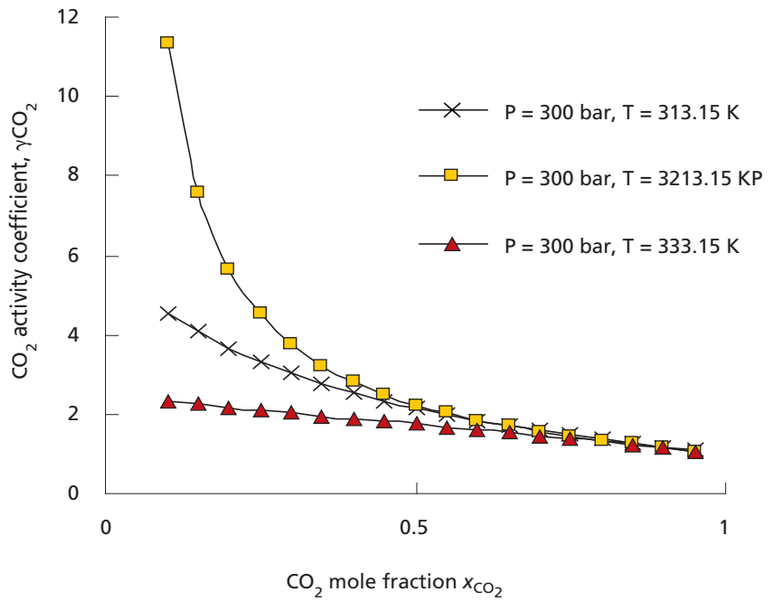


Figure 3. CO_2 activity coefficient (γ_{CO_2}) calculated from Equation 2 against CO_2 mole fraction (x_{CO_2}) at constant pressure 300 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

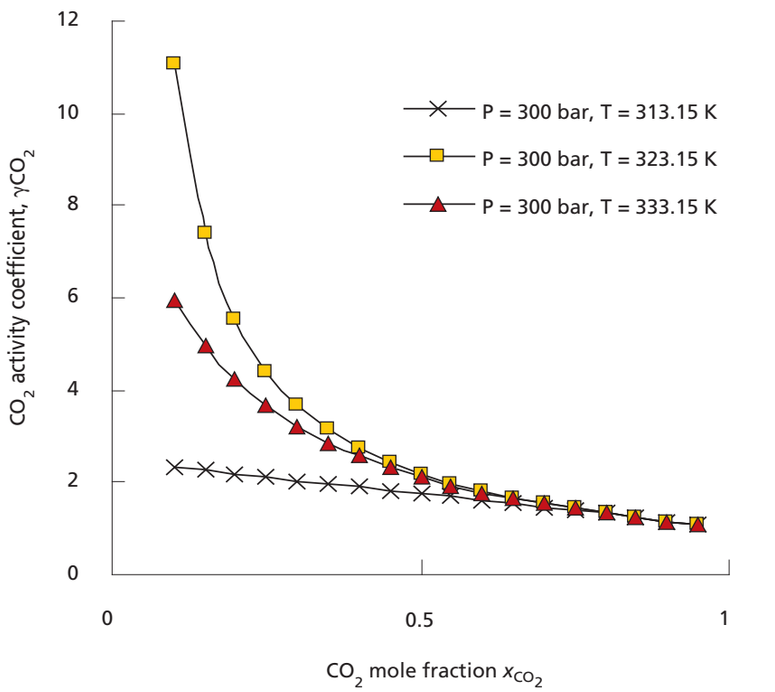


Figure 4. CO_2 activity coefficient (γ_{CO_2}) calculated from Equation 2 against CO_2 mole fraction (x_{CO_2}) at constant pressure 400 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

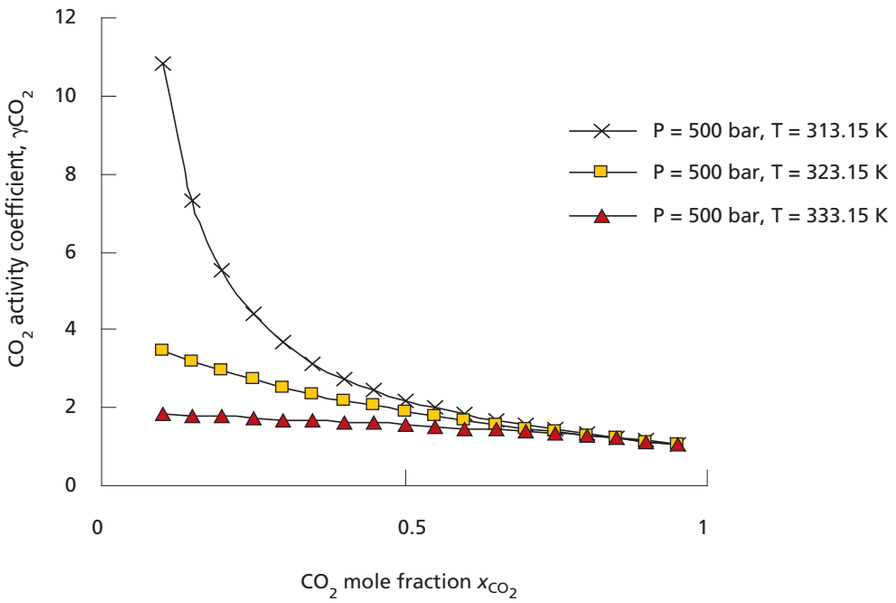


Figure 5. CO_2 activity coefficient (γ_{CO_2}) calculated from Equation 2 against CO_2 mole fraction (x_{CO_2}) at constant pressure 500 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

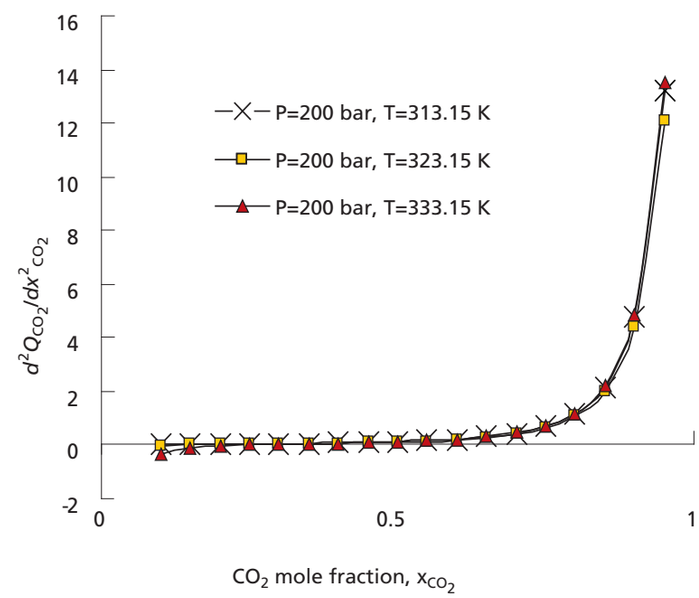


Figure 6. Parameter ($d^2Q_{CO_2}/dx^2_{CO_2}$) calculated from Equation 21 against CO_2 mole fraction (x_{CO_2}) at constant pressure 200 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

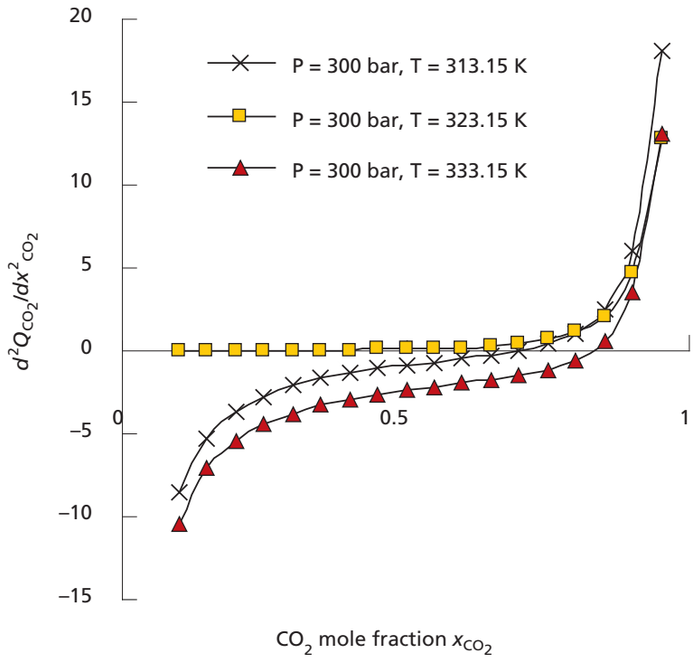


Figure 7. Parameter ($d^2Q_{CO_2}/dx^2_{CO_2}$) calculated from Equation 21 against CO_2 mole fraction (x_{CO_2}) at constant pressure 300 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

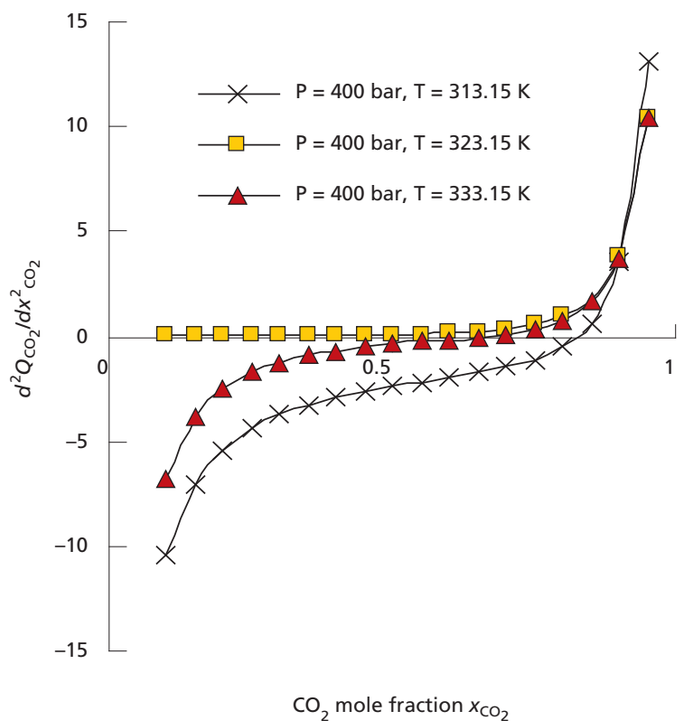


Figure 8. Parameter ($d^2Q_{CO_2}/dx^2_{CO_2}$) calculated from Equation 21 against CO_2 mole fraction (x_{CO_2}) at constant pressure 400 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

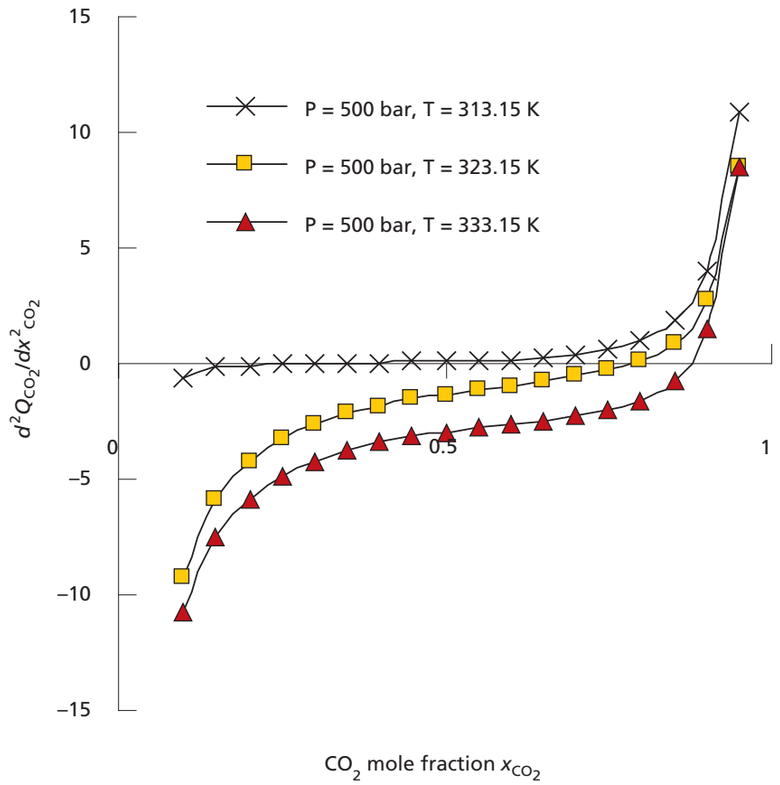


Figure 9. Parameter ($d^2Q_{CO_2}/dx^2_{CO_2}$) calculated from Equation 21 against CO_2 mole fraction (x_{CO_2}) at constant pressure 500 bar and at variable temperatures 313.15, 323.15 and 333.15 K.

Table 5. Comparison of the experimental and theoretical data (based on regular solution theory model and EOS) at temperature 323.15 K and at pressures 200, 300, 400 and 500 bar.

P (Bar)	$(X^E_{CO_2})^{Exp.}$	$(X^S_{CO_2})^{RST}$	$(X^E_{CO_2})^{RST}$	$(X^E_{CO_2})^{EOS}$	RD% Based on RST	RD% Based on EOS
200	0.999987500	0.0144	0.9990	0.99999543	0.0988	7.930×10^{-4}
300	0.999979665	0.0055	0.9992	0.99999508	0.0779	1.542×10^{-3}
400	–	0.0043	0.9986	0.99999839	–	–
500	0.999985242	0.5813	0.9975	0.99999903	0.2485	1.378×10^{-3}

Table 6. Comparison of the experimental and theoretical data (based on regular solution theory model and EOS) at temperature 333.15 K and at pressures 200, 300, 400 and 500 bar.

P (Bar)	$(X^E_{CO_2})^{Exp.}$	$(X^S_{CO_2})^{RST}$	$(X^E_{CO_2})^{RST}$	$(X^E_{CO_2})^{EOS}$	RD% Based on RST	RD% Based on EOS
200	0.999989752	0.0284	0.9992	0.9999678	0.0789	2.1952×10^{-3}
300	0.999979501	0.6498	0.9989	0.99999392	0.1079	1.4419×10^{-3}
400	0.999972120	0.3393	0.9985	0.99999839	0.1472	2.6271×10^{-3}
500	0.999979337	0.7608	0.9974	0.99999906	0.2579	1.9723×10^{-3}

The regular solution theory as a general model can be applied for different systems and at various conditions. The significant difference between the regular solution model and other models (such as equation of states) is that the later required critical constants for phase equilibria data and therefore provides for vapour phase only. For a regular solution model, the data obtained were totally related to group interaction parameters and were independent of temperature. It is possible to predict liquid-liquid and vapour-liquid equilibria from the knowledge of structural formula of the constituent molecular species. The system miscibility also can be obtained by applying the solubility parameter calculated from regular solution equations. In this study the interaction between the individual groups constituting the molecules was considered and group interaction parameters were generated together with parameters that describe the size and shape of the molecules.

Date of submission: June 2007
Date of acceptance: January 2008

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Nomenclature

Symbol	Description
EOS	Equation of state
RST	Regular solution theory
x_i^E	Component *i* mole fraction in extracted phase
x_i^S	Component *i* mole fraction in liquid phase
Ratio	yield of carotene/yield of chlorophyll a
Yield	µg carotene/mg dry weight microalgae (feed)
RD	Relative deviation
γ_i	Component *i* activity coefficient
$\partial^2 Q_i / \partial x_i^2$	Solubility parameter for component *i*

ASM Sci. J., **1(2)**, 155–159

Non-recursive System Architecture for Generation of a Speech Signal via Discrete Cosine Transform

M. Arif

A generic design for non-recursive implementation for the generation of discrete time speech signals by using discrete cosine transform is presented. A procedure was derived for it's generation from a regular structure and the computational procedure was investigated by using discrete cosine transform. An analysis of the speech signal generation with discrete cosine transform was implemented by a simulation and a structure for its non-recursive implementation was drawn. This generic approach could also be applied for the other well known real time signals and is expected to work equally for their implementation. A brief overview is presented in the analysis section to implement an electrocardiogram signal from the same structure by relabeling the various signals in the proposed structure of the discrete time speech signal.

Key words: speech signal; discrete time; impulse response; discrete cosine transform; non-recursive implementation; discrete fourier transform; electrocardiogram

The aim of discrete Fourier transform is to perform the conversion of the discrete time domain real time signal into its discrete frequency domain counterpart and various computationally efficient algorithms exist for its determination. It is also possible to process signals in the frequency domain much faster than in the time domain (Proakis *et al*. 2004).

The discrete cosine transform is a variant of the discrete fourier transform. It is especially useful in coding applications i.e. the coding of waveforms such as speech or pictures for efficient transmission and storage (Orfanidis 1996) and this transform is an orthogonal transform (Parhi 2004). This transform can also be used to compress signal data. It can be used for the transformation of discrete time signal into its frequency domain form. It consists essentially of a real and even function containing only the cosine terms, for example in the case of sampled voltage values, the data used is real and can be made symmetrical, doubling the data, by adding its mirror image (Ifeachor & Jervis 2002).

The discrete cosine transform can also be structured recursively (Kidambi 1998) the same way as it is being implemented non-recursively in this paper. Primarily, the application areas of the discrete time speech signal design are in speech modification, speech coding, speech enhancement, speaker recognition etc. and other important application areas for it include speech recognition, language recognition, and speech recognition from the text (Quatieri 2004). This design is computationally attractive for the implementation of the discrete time speech signal and can be equally applied for any other type of mathematical model that may have the same form as the discrete time speech signal (Arif 2006).

The hardware can be extended to support different sizes of the discrete Fourier transform computation and such type of hardware can be used for bit-serial word-serial or word-serial bit-parallel implementation, and a fast algorithm is mapped into a hardware structure (Jan et al. 2001). As far as two neighbouring discrete cosine transform operators are concerned, the pre- and post-filtering module is placed between them (Tran *et al.* 2003).

Even though fast ways (Britanak & Rao 2002; Chau & Siu 2003; Sherlock & Kakad 2002), all of them can also be used to make a structure to save processing time for the generation of the same discrete time speech signal. Various windows can be directly used in the transform domain for the discrete cosine transform in order to minimize the edge effects caused by implicit symmetries in the transform domain that are not replicated in the real world data (Britanak 2003).

The technique for diagnosing heart disease is based on the electrocardiogram (ECG). The ECG machine permits deduction of many electrical and mechanical defects of the heart by measuring ECGs, which are the potentials measured on the body surface (Tompkins 2006).

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SYSTEM MODEL

The system model can be obtained by connecting various signals together internally in the speech generator circuit i.e. for generation of components of the continuous time speech signal without rejecting any high frequency components. The various components of input signals are required to be taken into account as point sources and all individual impulse responses as basis functions corresponding to each and every component of the input signal, respectively. After that, individual multiplication operations are performed on the various point sources with their basis functions and finally all individual multiplications are passed through an adder circuit to generate a continuous time speech signal. All operations are combined together to be put into one block that is known as the speech generator circuit. This generated signal may contain high frequency components. A low pass filter (Haykin 1995) is added for passing low frequency components and suppressing any high frequency components that are present in the generated signal and it also may prevent aliasing of the generated signal. Finally a sampler switch is connected to get sampled output for generation of the discrete time speech signal by properly adjusting the suitable sampling rate. If reconstruction is required at the receiving end, it may not produce any distortion. The system model in block diagram form is shown in Figure 1.

ANALYSIS

In this section, the analysis of the system model of the discrete time speech signal is presented, this was discussed in the previous section. The segment of a speech signal $y(t)$ is expressed as the sum of several sine waves of different amplitudes $x_i(t)$, frequencies $f_i(t)$, and phases $\theta_i(t)$, for different values of $i = 0,1,\ldots\ldots\ldots\ldots, N-1$, i.e. consists of periodic sounds, in the following manner:

$$y(t) = \sum_{i=0}^{N-1} x_i(t) \sin[2\pi f_i(t)t + \theta_i(t)] \quad (1)$$

For implementation of the speech signal by the discrete cosine transform, it is required that $\theta_i(t) = \pi/2$.

The Equation 1 becomes:

$$y(t) = \sum_{i=0}^{N-1} x_i(t) \cos 2\pi f_i(t)t \quad (2)$$

The discrete Fourier transform $X(k)$ of the discrete time signal $x(n)$ is expressed in the following manner:

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi kn}{N}}, \; k = 0,1\ldots\ldots, N-1 \quad (3)$$

The three important features of any suitable transform are its compression efficiency which relates concentration of the energy at low frequencies, ease of computation, and minimum mean square error. The discrete cosine transform has virtually the same properties and does possess an algorithm.

The discrete cosine transform $X_c(k)$ is the real part of the discrete fourier transform and it is expressed in the following manner:

$$X_c(k) = \mathrm{Re}[X(k)] \quad (4)$$

where Re stands for the real component.

Now, $X_c(k)$ is obtained from $X(k)$ as follows:

$$= \sum_{n=0}^{N-1} x(n) \cos(2\pi kn/N) \quad (5)$$

The causal non-recursive system describes the following discrete time domain form and its output is a function of the input as well as the previous inputs applied to the system:

$$y(n) = F[x(n), x(n-1), \ldots\ldots x(n-M)] \quad (6)$$

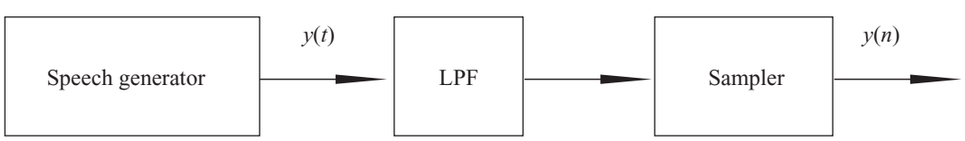

Figure 1. Block diagram of system model for the generation of speech signal in discrete form.

where the various signals are used above as input $x(n)$, previous inputs $x(n)$, $x(n-1)$,.....$x(n-M)$ and the output $y(n)$, respectively.

The discrete time speech signal is expressed corresponding to the above continuous time signal for the phase of 90º as follows:

$$y(n) = \sum_{i=0}^{N-1} x_i(n) \cos 2\pi f_i(n) n \tag{7}$$

The individual impulse response $h_i(n)$ is characterized sinusoidally as below in its role as a basis function in the discrete time speech signal:

$$h_i(n) = cos\ \omega_i n \tag{8}$$

where, angular frequency $\omega_i = 2\pi f_i(n)$.

The individual input applied to the linear system is $x_i(n)$ and the corresponding output $y_i(n)$ is expressed in the following manner:

$$y_i(n) = x_i(n) \times h_i(n) \tag{9}$$

The notation $\times$ indicates the normal multiplication between the two discrete time domain signals.

The discrete time speech signal $y(n)$ is calculated by the principle of superposition and in the time domain as below:

$$y(n) = y_1(n) + y_2(n) + \ldots\ldots\ldots y_{N-1}(n)$$

$$= \sum_{i=0}^{N-1} y_i(n) \tag{10}$$

In frequency domain, the complete response $Y(z)$ is expressed as below.

$$Y(z) = \sum_{i=0}^{N-1} Y_i(z) \tag{11}$$

The mono-polar ECG milli-volt signal (Bera *et al*. 2005) measured at any electrode located on a normal human body surface is a periodic signal and hence it can be represented by the Fourier harmonic components given by Equation 12.

$$e(t) = C_0 + \sum_{n=0}^{N-1} (a_n \cos n\omega_0 t + b_n \sin n\omega_0 t) \tag{12}$$

Equation 12 may be written as:

$$e(t) = C_0 + \sum_{n=1}^{N} C_n \sin (n\omega_0 t + \theta_n) \tag{13}$$

Put $C_0 = 0$ in Equation 13 and the resultant equation will become as below:

$$e(t) = \sum_{n=1}^{N} C_n \sin (n\omega_0 t + \theta_n) \tag{14}$$

IMPLEMENTATION

The structure to implement the discrete time speech signal of Equation 10 is shown in Figure 2. In this implementation, two types of functional blocks i.e. adder and multipliers were used and all the signals which are expressed in Figure 2, are functions of discrete time in nature.

The form of the ECG signal Equation 14 is identical to the speech signal Equation 1 in the analog domain. The continuous time ECG signal Equation 14 can also be derived in discrete time in a similar manner as the speech signal of Equation 10 has been obtained from Equation 1. Its hardware will also require exactly the same structure for its implementation as presented in Figure 2 for the discrete time speech signal.

SIMULATION RESULT

The MATLAB simulated result is shown in Figure 3 by taking four different values of amplitude, frequency and keeping phase $\pi/2$ of the different components of a discrete time speech signal. The observed characteristics from a simulated MATLAB program clearly satisfy that of the discrete time speech signal and these characteristics could also be obtained from the structure proposed in this realization that could be seen if an output display device was connected at the output.

CONCLUSION

In this paper, a non-recursive structure for the implementation of discrete cosine transform for discrete time speech signal is presented. This transform could also be applied for the implementation of other digital processing signals i.e. sound signal, video signal, other communication signals, and most commonly signals for biomedical applications like EEG and EMG. This approach would work equally for all the standard test signals of real time applications for their implementation of generation as per their mathematical representations. This approach is a generic one and emphasizes the generation of the discrete

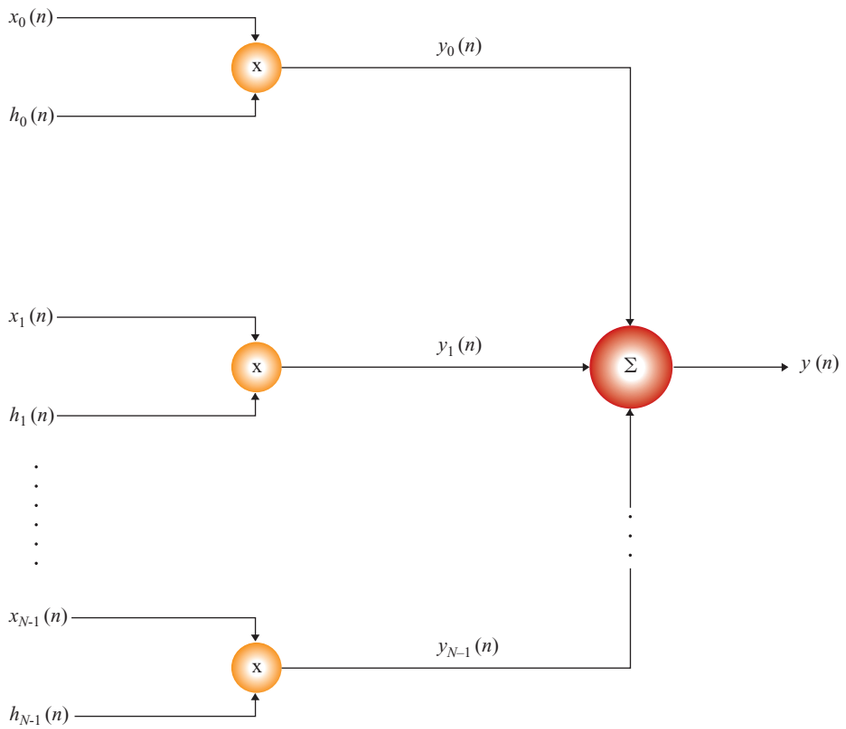

Figure 2. Implementation of discrete time speech signal by discrete cosine transform.

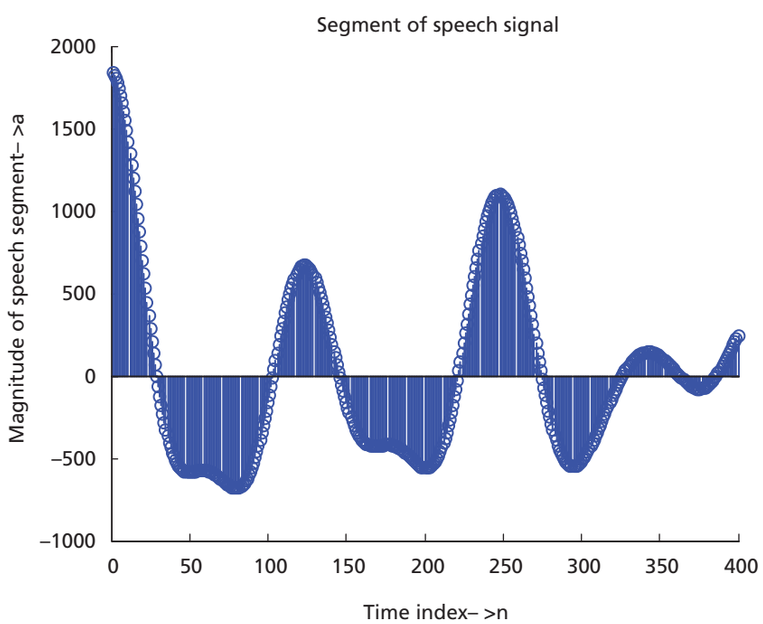

Figure 3. Generation of discrete time speech signal by MATLAB.

time speech signal without taking into consideration the processing time. In addition, a procedure to implement an ECG signal from the same structure for a heart patient in biomedical application was shown. The processing time for its generation could be reduced by applying various fast algorithms for its generation as well as efficient multiplier units in the hardware structure. The MATLAB simulation result for the generation of the discrete time speech signal could also be verified by this proposed structure; this structure would give the same result as presented by a MATLAB.

Date of submission: November 2007
Date of acceptance: January 2008

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Future Direction of Asian Agriculture: Sustaining Productivity without Ecological Degradation

P.C. Kesavan[1]* and M.S. Swaminathan[1]

From Hunting and Gathering to Farming

The transition about 10 000 years ago, from hunting and gathering food to cultivating crops and domesticating animals for meat, milk and draught purposes brought about two major events in the socio-cultural evolution of *Homo sapiens* and ecological degradation on planet Earth. One is that of a settled life with food security, setting in motion the unfolding of human creativity in arts, science, sculpture, philosophy, spiritualism, music etc. The invention of the steam engine in 1780 by James Watt heralded the beginning of the great industrial revolution. With a more settled life, the human population started increasing in numbers. On the other side, expansion of agricultural areas correspondingly reduced forest land and the associated rich biodiversity of fauna and flora especially in the regions within 22º north and south of the equator. Yet, agriculture until about the 1950s, particularly in the developing Asian countries, was largely eco-friendly in the sense that the application of chemical fertilizers and chemical pesticides was negligible. Farm operations such as ploughing, weeding, irrigation and harvesting were all carried out manually with the help of farm animals. The invention of nitrogen-containing chemical compounds for enriching nitrogen content of the soil to promote luxious growth of crop plants by Justus von Liebig in Germany in the middle of the 19th century and the discovery of the insecticidal properties of a compound, dichlorodiphenyltrichloroethane (DDT) by Muller (1939) led to impressive gains in yield and prevention of losses due to pest infestations, respectively. Then came the book *Silent Spring* (Carson 1962) vividly describing the deleterious effects of DDT and other chemical pesticides on wildlife and humans. It became evident that the use of chemical agents should be stopped. The dramatic breakthrough in yield improvements of wheat and rice had came through the pathway of the green revolution which involved genetically altered plant forms (i.e. dwarf and semi-dwarf plant types without reduction in the panicle length) and application of high doses of chemical fertilizers and copious irrigation. Since their luxuriant growth attracts a variety of pests, application of high doses of chemical pesticides is also an integral part of the green revolution farming. The negative ecological dimensions of the green revolution have been pointed out (Swaminathan 1968) even before the term 'green revolution' was coined. He drew attention to the long-term harmful consequences of the excessive applications of chemical fertilizers, pesticides and irrigation using ground water without adequate drainage on soil structure and health. His plea for strict adherence to the scientific principles of soil and plant health management in order to sustain the benefits of enhanced productivity over long periods was largely neglected. Consequently, the damage to ecological foundations essential for sustainable advances in crop productivity led to the onset of a fatigue in the green revolution. The lessons drawn from the green revolution were that steps taken towards productivity enhancement should concurrently address the conservation and improvement of soil, water, biodiversity, atmosphere, renewable energy sources etc. The fatigue of the green revolution recapitulates the words of Roman farmer Varro (first century BC) "Agriculture is a science which teaches us what crops should be planted in each kind of soil, and what operations are to be carried out, in order that the land may produce the highest yields in perpetuity".

Things have, however, changed a great deal since the time of Varro. The human population on our planet Earth has soared from about 300 million around 1000 BC to over six billion around the year 2000. The human population was about 950 million in 1798 when Malthus wrote his essay on the principle of population. The lifestyle of the people in the highly industrialized countries as well as of the rich in poor countries have become unsustainable. The life support systems of land, water, flora, fauna and the atmosphere are being depleted at a rapid pace. The global warming caused by increased concentration of greenhouse gases in the atmosphere has led to climate change characterized by erratic monsoons, and extreme hydro-meteorological disasters. Hence, future endeavours in agriculture should not only produce more food from less arable land but also in an eco-friendly manner. Today's high productivity levels should not compromise tomorrow's yields because of progressive degradation of soil, water and biodiversity.

In a nutshell, both the productivity in perpetuity and sustainable livelihood should be concurrently addressed in an eco-friendly manner. The concepts developed

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over the years and put successfully into working models (Swaminathan 1972; 1996a,b; 2000; 2002; 2003; 2004a,b,c; 2005a,b) in the nature of evergreen revolution integrating biovillage paradigm and village knowledge centres are briefly reviewed in the paper.

Agricultural Productivity and Rural Livelihoods at Crossroads — Way Forward

Quite a disturbing trend in the current scenario of the developing Asian countries is the rush towards rapid economic development without establishing a strong premise to defend the gains made from the green revolution and making concerted efforts towards breaking the vicious mutually-reinforcing spiral among poverty, environmental degradation and global warming. For most of the developing Asian countries, the likely runaway population growth and global warming are the most serious limiting factors for achieving food security at the individual household levels. The trade-related Agreement in Agriculture is yet another cause for concern to predominantly agrarian countries. Kesavan and Swaminathan (2007, in press) have discussed these in great detail. In India, subsistence farming has always been less productive and even catastrophic at times. Millions of marginal farmers with small farms are now susceptible not only to the vagaries of climate change and uncertain market fluctuations for agricultural commodities but also to spurious seed, chemical pesticides and fertilizers. The economic hardship and social disintegration caused by the vicious feedback linkages among ecological degradation, global warming, free but not fair globalized market and climate change resulting from global warming need to be taken into consideration before making prescriptions for the future direction of Asian agriculture.

These are briefly analyzed below:

The Malthusian view that population increase beyond Earth's carrying capacity would cause environmental degradation and outrun the growth of food production still seems valid. As observed by Trewavas (2002), advances in science and technology have so far been thwarting the realization of Malthusian predictions made in 1798 in his *Essay on the Principle of Population*. The human population of the planet then was less than one billion. India's green revolution of the 1960s is a good example of Mendelian genetics having thwarted the Malthusian predictions. Since then, population explosion on one hand, degradation of ecological foundations and global warming-induced climate change and fatigue in the productivity of the green revolution on the other, are lending credence to Malthusian predictions. It is also evident that the very scientific and technological methods so far employed to stall Malthusian predictions have caused extinction of several landraces, traditional varieties, as also a few unrelated plant and animal species due to monoculture and encroachment of farming into virgin forestland. That has been the concern of several ecologists elegantly epitomized by Wilson (2002). The point is that the Earth's natural resources, both renewable and non-renewable, are finite and therefore, the consumers (humans and other living beings) cannot multiply exponentially to be infinite. The developing Asian countries often refer to the unsustainable lifestyle and wasteful consumption levels of a few industrialized countries. The fact is that both over population and unsustainable lifestyles are unacceptable because they exert pressure beyond the carrying capacity of the Earth and result in 'ecological overshoot' (Wackernagel *et al.* 1999; Clarke 2006). Brown and Kane (1994) have discussed in detail the population carrying capacity of the croplands of the largest food-producing nations (United States, China, former Soviet Union, and India) as these account for well over half the world's food production and about half its population. Next to India and China, four other populous Asian countries with concern over the carrying capacity of croplands are Pakistan, Bangladesh, Indonesia and Iran. Brown (1996) has provided statistics to argue that by 2030, China would need to import 216 million tons (~45%) of the total requirement of 479 million tonnes for a population projected to be around 1.624 billion. India's situation is that it would have to import about 45 million tons of grain in 2030 to meet the needs of a population expected to be around 1.443 billion assuming that India could stabilize its grain harvest at about 222 million tons by that year.

Food production and making food available is only the first step towards ensuring food security at the individual household level. Swaminathan (2002; 2004a,b,c) has emphasized the need for integrated attention to the three basic components of food security. These are (i) Availability of food — a function of production, (ii) Access to food — a function of purchasing power/access to sustainable livelihoods, and (iii) Absorption of food in the body — determined by access to safe drinking water and non-food factors like environmental hygiene, primary health care and primary education. These analyses by the MSSRF in collaboration with World Food Programme (WFP), New Delhi confirmed what had already been emphasized about 35 years ago by Swaminathan (1972) in the Princess Leelavathi Memorial Lecture delivered by him at the University of Mysore. The title of his talk, 'Agricultural Production, Productive Employment and Rural Prosperity' set forth a blueprint for an approach combining eco-agriculture and sustainable livelihood based on sustainable management of natural resources. Yet, major policies and implementation has continued to be focussed only on the enhancement of productivity through the pathway of green revolution, and consequently, the paradox of 'mountains of grains on one hand and millions of hungry on the other' has set in. The other concern is about sustainable productivity and conservation of agro-biodiversity. The ceaseless endeavour of crop improvement, search for new genes together with conservation and their sustainable use must go on forever. Hence, emphasis on genetic conservation of

all organisms from microbes to man (Swaminathan 1984) is of special interest and a great responsibility of developing Asian countries. Productivity in perpetuity and creation of on-farm and off-farm livelihoods through sustainable management of locally available natural resources should receive concurrent attention. Hence, the M.S. Swaminathan Research Foundation (MSSRF) was established in 1988 to operationalise eco-agriculture integrated with ecolivelihoods on the principles of economics, ecology, ethics and equity in social and gender aspects. This blueprint was christened as 'evergreen revolution' (Swaminathan, 1972; 1996a). It was especially designed to transform the economically and ecologically unsustainable 'subsistence farming' in the smallholdings of millions of marginal farmers in India and other populous developing Asian countries into vibrant small farm production units. Keeping in view, a more holistic definition of food security, 'biovillages' (bios=living), and village knowledge centres were set up. The biovillages are the sites of sustainable management of local resources with ecotechnological empowerment of the rural poor for adopting on-farm and off-farm livelihoods for their income generation. Along side, the modern ICT-based village knowledge centres are also established for knowledge empowerment of the largely illiterate, unskilled, resource-poor farming and landless rural communities. With these in place, an appropriate re-definition of 'food security' (Swaminathan 1996b) is as follows, '*Sustainable food security involves strengthening the livelihood security of all members within a household by ensuring both physical and economic access to balanced diet, including the needed micronutrients, safe drinking water, environmental sanitation, basic health care and primary education*'.

The action plan of the evergreen revolution involving concurrent attention to eco-agriculture, ecotechnologies and knowledge empowerment of the rural women and men through biovillages and village knowledge centres provides an effective means to break the mutually-reinforcing vicious spiral between poverty and environmental degradation.

Transforming Green Revolution into an Evergreen Revolution

Should the goal of farm productivity be the 'food for all', then the pathways chosen should comprehensively cover economic, ecological and social factors determining sustainability (Swaminathan, 1996a; 2000; 2002; 2004a,b,c). Particularly in the populous developing countries, agriculture including crop and animal husbandry, fisheries, forestry and agro-processing, constitute the backbone of the livelihood and ecological security systems. On an average, over 70% of the population depend on farm enterprises for their income. Household food security is best defined in terms of person years of jobs or livelihoods, rather than in terms of tons of food grains. A famine of jobs or of purchasing power leads to famine of food at the level of consumption. Hence, sustainable eco-agriculture is the foundation for sustainable food security for about 70% of the population living in the rural areas. The green revolution that significantly enhanced the productivity, food security at the national level, and saved nearly 80 million hectares of forest land (Kesavan and Swaminathan 2006) and changed the image of India from a 'begging bowl' to 'bread basket', however, failed to ensure food security at the individual household level as it caused ecological degradation and failed to promote livelihood based on on-farm, and off-farm eco-enterprises. These considerations led Swaminathan (1996a; 2000) to design the evergreen revolution. He put forward the concept of evergreen revolution as follows, '*what nations with small farms and resource poor farmers need is the enhancement of productivity in perpetuity, without associated ecological or social harm. The green revolution should become an evergreen revolution rooted in the principles of ecology, economics, social and gender equity*'. The paradigm shift was illustrated as follows (Swaminathan 1996a; 2005a) in Figure 1.

Wilson (2002) has acknowledged that the evergreen revolution conceptualized by Swaminathan (1996a; 2000)

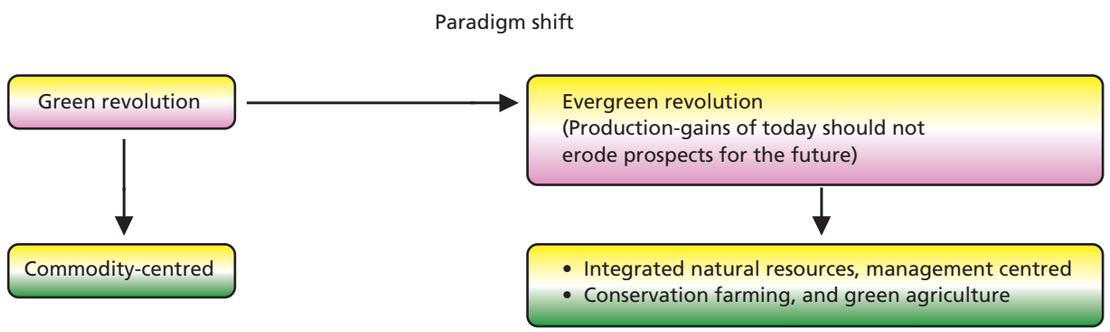

Figure 1. Transforming green revolution into evergreen revolution.

is the best option available today to feed billions of new mouths over the next several decades and save the rest of life at the same time without being trapped in a Faustian bargain that threatens freedom and security.

In practice, the evergreen revolution involves a comprehensive farming systems approach covering land, water, biodiversity and integrated natural resources management. The farm animals (cows, milk buffaloes, bullocks) provide dung and urine to enrich the soil, while crop residues and fodder form bulk of the feed for these animals. Instead of just one or two rain-fed crops for subsistence, the suggestion (Swaminathan 1996a,b) is to develop community-centric water banks with rainwater harvesting and its judicious management in order to facilitate rotation of cereals (rice during monsoon, if good enough), millets, pulses (help in soil nitrogen fixation) and oil seeds, besides fodder and fruit crops. It is also recognized that the small farm holders with severe resource constraints require urgent solutions for day-to-day problems regarding crop and animal husbandry, soil and water management, conservation of traditional varieties and landraces, post-harvest processing and marketing their crop and animal produces with reasonable profit. Modern satellite and computer based information and communication technology has emerged as the most relevant technology in support of the evergreen revolution.

In developing the concept of evergreen revolution, Swaminathan (1999) has kept in view that the global agriculture is at a crossroads, because it is depleting biodiversity, causing degradation of the soil and freshwater sources, and also promoting economic, social, and gender inequities. At this rate, hunger on our planet would only increase and intensify, and not become a 'thing of the past'.

Evergreen Revolution-beyond Eco-agriculture

Of late, there is growing emphasis on application of less/no chemical input and more biological input in crop husbandry. Kesavan and Swaminathan (2006) have concisely reviewed the various terminologies and practices ranging from strict organic farming [as defined by the International Federation of Organic Agriculture Movement (IFOAM)], to varying levels of combinations of traditional and modern scientific methods to transform the green into an evergreen revolution. This paper of Kesavan and Swaminathan (2006) deals with just one dimension of the 'evergreen revolution', namely the eco-agriculture alone. However, in the context of elaborating the future direction of agriculture in the highly populous, predominantly agrarian developing Asian countries, the definition and practices of evergreen revolution ideally includes eco-agriculture, ecotechnology and sustainable natural resource-based biovillage paradigm and knowledge empowerment through modern ICT-based village knowledge centres together with forward market linkages. Thus, the integration of these also necessitates appropriate post-harvest technology, and adherence to 'Codex Alimentarius' when farm produce or the aquatic food source cultured or captured are processed for extending their shelf-life and value addition. Thus, the evergreen revolution that would ensure food and nutrition security to millions of subsistence farmers, landless communities and marginal fishers necessarily involves concurrent attention to eco-agriculture, sustainable livelihoods through technological and knowledge empowerment of the rural producers-cum-consumers and ethics and equities across social, economic and gender divides (Swaminathan 1996b; 2002; 2004a,b,c; 2005a). Based on these, a holistic model of the evergreen revolution is presented (Figure 2):

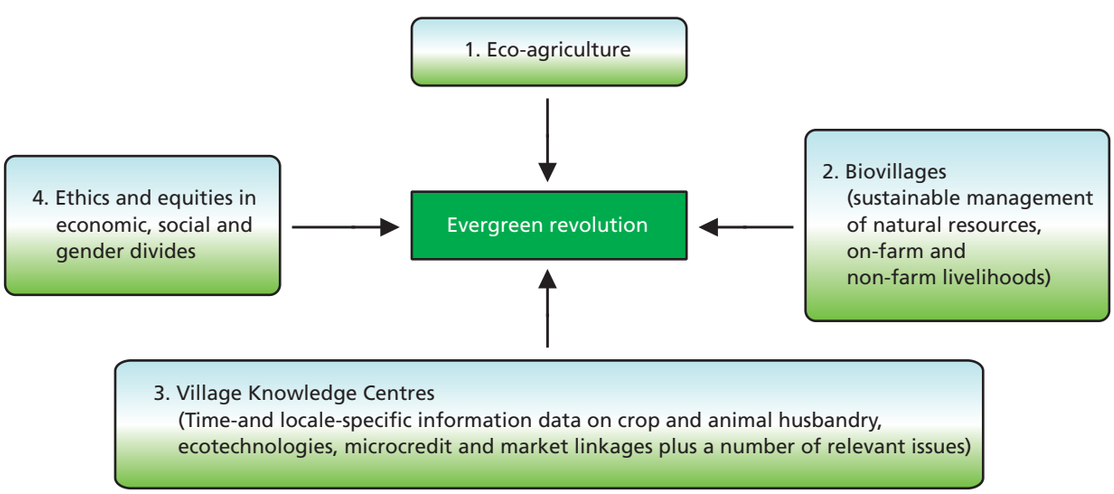

Figure 2. Components of evergreen revolution.

Each of these components of the evergreen revolution is briefly presented below:

Eco-agriculture. The precise description of the objective, namely 'productivity in perpetuity' implies that the farming practices must be such that these do not cause degradation of soil, freshwater, biodiversity, renewable energy through over-exploitation, chemical pollution etc. Indiscriminate use of inorganic chemical fertilizers, chemical pesticides, monoculture of crops, and over-irrigation with ground water must be strictly avoided. Instead, 'mixed dynamic' farming with farm animals for milk, meat and draught purposes, multiple cropping system with legumes, millets, oilseeds and cereals in rotation should be adopted. Fresh water is indeed everyone's business, and the community-centred water banks (Swaminathan 2001; 2003) serve the purpose of rainwater harvesting and its judicious use by the entire rural community for farming and other related activities. Use of a wide range of bio-fertilizers (Azolla, blue green nodulating algae and *Trichoderma viridae*) vermicompost and stem nodulating legumes like *Sesbania rostrata*, is highly recommended. Increase in humus and organic content not only increases moisture retentivity but also the activity of beneficial soil organisms. The distinction between green agriculture and organic farming is important. Green agriculture permits the use of Integrated Nutrient Supply (INS), and other procedures which involve the use of minimum essential mineral fertilizers and chemical pesticides. Green agriculture also permits the use of varieties resulting from recombinant DNA technology. Organic agriculture, on the other hand precludes the use of GMOs, mineral fertilizers and chemical pesticides. For a majority of small farmers, who do not possess livestock, organic farming will be difficult. Green agriculture on the other hand can help to increase productivity in perpetuity without ecological harm. The National Commission on Farmers, India has recommended that there should be certification procedures, both for products of organic farming, and green agriculture. Integrated Pest Management (IPM) is the integration of cultural, physical, mechanical, biological and chemical measures to manage crop pests below the 'Economic Injury Level' (EIL) (<http: www.pestinfo.ca/main/session/lang/EN/ns/22/doc/32>). IPM is effective for controlling pests such as suckers, borers, internal feeders etc. The cultural and mechanical methods consist of cultivating insect resistant/tolerant crops and using trap crops that are highly preferred/susceptible so that the main crop is spared. Light traps and pheromone traps which are chemical substances secreted by adult insects (mostly female) for attracting numbers of opposite sex of its own species are used to lure and trap the males. With the reduction in number of males, there is less mating and egg laying. The multiplication of crop pests is greatly reduced. The biological methods involve the utilization of living agents (insects, micro-organisms) to manage the harmful crop pests. The parasitoids are parasite-like but almost the same size as their host and kill the host during development. The INM and IPM require close interaction between scientists with their modern scientific input and the traditional farmers with their ecological prudence and practical knowledge of farm and pest management. Hence, these entail a 'bottom-up' or participatory approach.

Kesavan and Swaminathan (2006) note that pathways to productivity in perpetuity without associated ecological harm which are described in literature vary in terminologies and relative emphasis on one or more of the key external input. The International Federation of Organic Agriculture Movement (IFOAM) has defined organic agriculture as 'all agricultural systems that promote the environmentally, socially and economically sound production of food and fishes' (www.ifoam.org.). Chemical fertilizers and pesticides are strictly banned. Only organic biopesticides and biofertilizers are permitted. Genetically modified (GM) crops are totally excluded from organic agriculture. The organic certification process is a rigorous one and consequently, even a very slight deviation from or compromise with the stipulations in the production of organic foods result in their outright rejection. The commercial use of the word organic, outside of the certification framework is illegal. Alternatively, a less rigorous and more practical way forward for eco-agriculture with emphasis on soil fertility management is the green agriculture. This involves a system of cultivation with the help of integrated pest management, integrated nutrient supply and integrated natural resources management systems. This is widely practiced in China. The other systems of ecofriendly agriculture described by Kesavan and Swaminathan (2007) are the eco-agriculture (Mc Neely & Scherr 2003), 'Effective micro-organisms-based agriculture' (Higa 1994), white agriculture (Stevenson 2004), and 'One straw revolution' (Fukuoka 1978). After analysis of the merits of the above mentioned systems of agriculture, Kesavan and Swaminathan (2006) recommend that each farm should develop a system of eco-agriculture based on an appropriate mix of the different approaches which can ensure both ecological and economic sustainability.

Biovillages for sustainable management of natural resources and overcoming famine of livelihoods. Swaminathan (1996a,b) has emphasized that lack of purchasing power deprives a person from access to food even though food is available. Despite a stock of over 30 million tons of wheat and rice in the government storehouses, poverty-induced hunger affects over 200 million people in India. Such a situation is endemic in south Asia. To tackle the famine of livelihood in the rural areas, Swaminathan (1996a,b; 2001; 2005a) has described the biovillage model first set up in 1992 by the MSSRF. This model facilitates imparting a pro-poor, pro-nature and pro-woman orientation to technology development and dissemination in the rural areas. The biovillage concept involves the technological upgradation of eco-agriculture and local resources-based on-farm and off-farm enterprises through ecotechnologies developed by blending frontier technologies (bio-, nuclear,

space, information and communication, nano renewable energy technologies) with traditional knowledge and ecological prudence. The demystification of technologies that are relevant to the sustainable management of local resources and enabling the largely illiterate, unskilled rural women and men to become skilled through 'techniracy' (Swaminathan 1972) which is the pedagogic method of learning by doing are the initial steps. Self-help groups of women, men or a combination of both sexes are formed and they discuss and decide in a participatory (bottom-up) manner as to which ecotechnologies would be taken up for eco-enterprises. Wherever necessary, micro-credit facilities are arranged. These eco-enterprises have market linkages. One of the several eco-enterprises promoted by the MSSRF, that has won international recognition and reward to the self-help group is the production of *Trichogramma chilonis* egg parasitoid cards by landless women. The other dynamic, income-generating eco-enterprises are mushroom production on rice straw substrate and conversion of banana waste into paper and file boards. Several other enterprises include making vermicompost, biofertilizers, culturing ornamental fish, fish pickle etc. Ideally, a cluster of biovillages is linked with a 'biocentre' (a technical resource centre) in a hub and spokes model.

Village knowledge centres. In the 21st century, knowledge is power and various approaches towards evergreen revolution involve knowledge empowerment of the farming and fishing communities. The success of the eco-enterprises is greatly dependent on time- and locale-specific information on weather, particularly monsoon, microcredit facilities, getting instant and appropriate information/guidance for treatment of diseases of crops and farm animals, market trends and prices for agricultural produces, healthcare and such other day to day requirements. Hence, the MSSRF has taken advantage of modern information and communication technology and provided internet connectivity. A wired-wireless hybrid technology is used wherever telephone connection is not available. Solar power is effectively used even when rural electrification is appreciable. The success of the village knowledge centres has led to the government of India's Mission 2007 which is aimed at transforming most of the 600 000 plus villages of India into knowledge centers.

The point is that sustainable eco-agriculture involves enlisting several technologies, and participatory approaches of the farmers, fishermen, agricultural scientists, planners, environmentalists, policy makers, politicians, non-governmental organizations, media and so on.

Ethics and equities in economic, social and gender divides. The evergreen revolution as has been conceived and implemented (Swaminathan 2005a) requires elimination of social, gender and economic inequities besides strengthening the foundations of eco-agriculture and avenues for income generation through eco-enterprises. It is well known that poverty and deprivation affect women the most. The women are seldom recognized and much less rewarded for the major role which they are playing in conserving and enhancing biodiversity, particularly agro-biodiversity, and food security of families. On the other hand, the sufferings of farm women has been steadily increasing through a phenomenon referred to as 'feminization poverty' in India and possibly several other developing countries. This is an offshoot of yet another phenomenon called the 'environmental refugees' discussed in detail by Myers (2002). These are the resource-poor farming and landless rural families who leave their native villages because of extensive degradation of their livelihood resource base. In search of livelihood, they migrate to the urban areas where they are also blamed for mushrooming slums. Wherever only young men migrate to the urban areas abandoning young women in their native villages to tend to meagre subsistence farming, a debt burden falls on the shoulders of these young women. This is because 'subsistence farming' without adequate input of fresh water for irrigation, exogenous application of soil nutrients, IPM, INM, etc., results in very poor yield, leaving no surplus to market. These women without income and any financial support, subject themselves, their children and their old and infirm dependents to food and nutrition insecurity. The social disintegration arising from hunger and deprivation is considerable but is beyond the scope of the present review.

The best option to eradicate gender-based inequities is to empower rural women with 'doable' technologies and time- and locale-specific data/information which is also best created and disseminated by them. There are already several case studies and examples of technological and knowledge empowerment in the rural villages covered by MSSRF. One is the production of biopesticide, *T. chilonis* egg parasitoid by a women self-help group consisting of landless women living 'below the poverty line' (BPL). These women located in a small village in Tamil Nadu, India have mastered the art of culturing the egg parasitoid (*T. chilonis*) and making the '*T. chilonis* cards' which are about the size of a post-card to which tens of thousands of the eggs of the parasitoid are gently stuck and sold to the farmers. Two of the women leaders of this eco-enterprise were invited to Alexandria, Egypt by Youth Employment Summit (YES), New York. They won an Award for developing an eco-enterprise that is pro-nature, pro-poor, pro-women and pro-livelihood oriented. These women have now become trainers. Women self-help groups making fish pickle, breeding ornamental fish, production of oyster mushroom on paddy chaff, production of vermicompost are some of the other rural eco-enterprises which enhance the social and economic empowerment of the rural women. The MSSRF's village knowledge centres impart computer literacy to young women who have passed 7th or 8th class in vernacular; these women become well-versed in the use of internet, powerpoint, video-conferencing, developing and

disseminating time- and locale-specific information, and providing these services for a nominal payment to those who need them. In a few villages the women self-help groups maintain and operate battery operated mini vans to provide local transport. All these enterprises elevate the women who had been oppressed for centuries to dominant positions in society. Yet, in another case, over 75 million women contribute to making an ocean of milk (~90 million tons per year) and placing India as the number one country in the world in milk production. Alongside, education and healthcare to girl children further exhalt their status as decision-makers. There is progressive realization of the fact that economic and social empowerment of women leads to higher food security at the household level, better education to children and more effective family planning. In as much as the focus is on sustainable agriculture and development, planning human population growth should be accorded the highest priority. Addressing social, gender inequities effectively results in tangible as well as several intangible benefits and creation of a holistic foundation for an evergreen revolution that is the future agriculture for the populous, biodiversity rich, resource-poor developing Asian countries in the 21st century.

Shaping the Economic Destiny of the Farmers

The recent report entitled *Serving Farmers and Saving Farming* by the National Commission on Farmers in India (Chaired by Prof M.S. Swaminathan) observes, among other things, that rural poverty and under-nutrition are higher than urban poverty and hunger and there is increasing feminization of agriculture. The other finding of equally serious nature is that the ecological foundations essential for sustainable agriculture like land, water, forests and biodiversity are in varying degrees of decay and adverse changes in climate appear a distinct possibility as a result of global warming.

As against the situation in the developing countries, the farmers in the industrialized countries constitute just 2% to 4% of the population. The per capita income of these farmers is high both because of the size of the farm operated and the extensive support extended by the government. They are technology, capital and subsidy rich. Public policies in these countries concurrently promote conservation, cultivation, consumption and commerce. The commission points out that the collapse of the Doha Round of Negotiations in Agriculture is an indication that farming cannot survive in industrialized countries without substantial support from public funds to ensure its economic viability.

The National Commission on Farmers, India, refers to the opportunities opened up by new technologies. It points out that new agriculture technologies like genomics and information technology together with improved agronomic management should form the cornerstone of increasing agricultural productivity and profitability of small farms, both in irrigated and rainfed areas as well as in problem soils and coastal areas.

The Commission has taken into account possible serious setbacks to sustainable agriculture caused by increasing coastal salinization and drought brought about by climate change. In this context, reference is made to the recombinant DNA technology that has already resulted in the breeding of crop varieties possessing tolerance to salinity and drought as well as to serious biotic stresses caused by the triple alliance of pests, pathogens and weeds. The sea level rise on account of global warming is already causing salinization of the coastal soil and aquifers. Several agricultural crops, particularly the cultivation of paddy, the staple diet of millions of people, would be seriously affected. Hence, anticipatory research to develop transgenic rice with a 'genetic shield for salinity tolerance' was undertaken by MSSRF. The salt tolerance genes isolated from a mangrove species, *Avicennia marina* have been genetically engineered into the genome of the cultivated rice. Today, these transgenic paddy with a capacity of tolerance to 150 mM of salinity are undergoing field trials in an isolated field (Mehta *et al*. 2005; Prashant & Parida 2005). The MSSRF is currently engaged in developing drought tolerant rice incorporating the genes for drought-tolerance from *Prosopis juliflora*. While genetic modification of staple crops has become necessary to sustain agriculture in the face of abiotic stresses induced by sea level rise and prolonged droughts, the commission has prescribed a bottom line for crops bred by molecular methods. The report emphasizes, '*The bottom line for any biotechnology regulatory policy should be safety of the environment, the well-being of farming families, the ecological and economic sustainability of farming systems, the health and nutrition security of consumers, safeguarding of home and external trade, and the biosecurity of the nation*'.

The commission notes that in addition to biotechnology, information and communication technology and ecotechnology, there are opportunities in space application, nuclear techniques and GIS and GPS-based precision farming.

Thus, the future direction of Asian agriculture is in organic and/or green agriculture (eco-agriculture) integrated with ecotechnological and knowledge empowerment of the farming communities. The term 'farming' is expanded to include farm animals for milk, meat and draught purposes. For achieving the goal of enhancing productivity per unit of land and per drop of water, the frontier technologies (modern biotechnology, information and communication technology, space technology and remote sensing etc.) should be harnessed. Particular attention should be given to soil health, and community-centric rainwater harvesting and its sustainable management. In designing agricultural production systems for sustainable food security, the following statement made by Confucius (551 BC–479 BC)

over 2500 years ago should be kept in view: 'Despite many accomplishments of mankind, we owe our existence to a six-inch layer of top soil and the fact that it rains'.

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Value Creation in the Knowledge Economy: A Malaysian Experience in Diagnostics

A. Ismail

As we move towards the knowledge (K) era, the challenge in R&D is to focus on the development of original K-based products that can compete in the global market. The development of commercially viable, patented K-based products within a university environment require an innovation system and innovation policies in place and a change in the paradigm towards the approach to research. A crucial agent towards the success of the innovation system is development and training of the human capital that would be the future drivers of the K-industry. Awareness of intellectual property rights, the need for original research, entrepreneurship as well as the development and strengthening of self-confidence and leadership are among the factors needed towards the training of K-workers facing the new economy.

For K-based products to fare well in developing countries, it is imperative that development and design of these products take into consideration the clients' needs. Enhancement of the value chain can be achieved with the existence of innovation policies and venture capitalists willing to invest in indigenous R&D products. Malaysian experience in the commercialization of indigenous diagnostics towards wealth creation and improvement in the quality of life, is also discussed.

Research is an integral component and one of the core activities of the university. It is intimately connected to teaching and services, and it is through excellent research that students get to be taught the latest developments and applications in the field. The question most often posed by academicians is why research can not be done for the simple enjoyment of finding new discoveries (and publishing it) without having to patent and bother about commercialization and entrepreneurship? This, to most academicians, has become a disturbing movement required by universities around the world. Resistance among academicians can be felt with most torn between performing fundamental or basic research for scientific advancement (without worries of product development) and performing applied research to convert scientific discoveries into a product. Einstein had once said, 'Knowledge that cannot be used is not good knowledge'. Essentially, making sure science is made to good use becomes the global agenda in the new economy. This requirement drives and strengthens the need for developing and underdeveloped countries to move into the knowledge (k)-based economy. When K-based industries become the ticket to ensure survival in the new economy, the government needs to ensure that research performed in local universities and research institutes are relevant, can contribute to nation building and create wealth for the country. The global agenda and the need for K-economy in the 21st century (Oliver 1998) are perhaps best explained in Figure 1.

In the K-based economy, a developing country needs to effectively compete and survive in the global market. For survival, R&D in the country must now move towards the requirements needed to succeed in the new economy which include:

- Having its own scientific discoveries
- Having its own technology platforms
- Sufficient scientists with expertise and capability to manipulate technology and set new trends in technology; and
- Policies that support innovation and entrepreneurship.

With the advent of K-economy, there is a need for R&D-based innovations to contribute towards wealth creation and improvement in the quality of life. This would mean that excellence in research (either fundamental or applied) should benefit and contribute (either short- term or long-term) to the community, industry and towards nation building. To be successful in K-economy, factors required by the country include:

- Sufficient numbers of relevant human capital (Knowledge-workers)
- Change in the R&D approach; and
- Creation of policies that support innovation and entrepreneurship.

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Development of Relevant Human Capital

Studies have shown that competitiveness of a country is a result of intangible assets — creativity and innovation of its K-workers. Hence to be successful in the new economy, we need to:

- Train sufficient knowledge workers to be creative, innovative and relevant to the needs of the country, to support the existing industries or set up new industries in the country
- Perform fundamental research to produce original discoveries with the generation of intellectual properties
- Perform fundamental research to create new advances in technology
- Transform new knowledge/scientific discoveries into innovations; and
- Have correct mind and mindset towards translational research.

Among the strategies used by Malaysia to enhance the number of K-workers and K-products (Malaysia) is the setting up of four Research (intensive) Universities (RUs) (Ministry of Education Malaysia 2004). The research universities will NOT be new universities but would expand on the existing philosophies and good practices in the current public universities. The RUs will place a heavy emphasis on research but their objectives would also include teaching and training of undergraduates, just like the well known universities such as Harvard, Stanford and MIT. In essence, RUs will focus on producing highly skilled post-graduates capable of generating intellectual capital, new knowledge and innovative technology. An attractive advantage of becoming a RU is to attain a change in governance in matters pertaining to research. Public universities that satisfy the criteria of a RU will be provided allocations above their operational yearly budget to 'jump start' the university in terms of training, and improve its learning environment and facilities to enable it to compete globally. It is hoped that among others, RUs will attract the best brains for teaching and research and attract quality graduate students.

Change in the R&D Approach

Researchers should realize that for a country to survive in the K-based economy, it is essential that the research performed would result in original discoveries or at the least value-added discoveries. Original research will inevitably add on to the country's own intellectual properties in the form of:

- Own scientific discoveries
- Indigenous technology platforms; and
- Indigenous innovations of global impact.

In the K-based society, original discoveries are needed to enhance the competitiveness of the country. It provides the

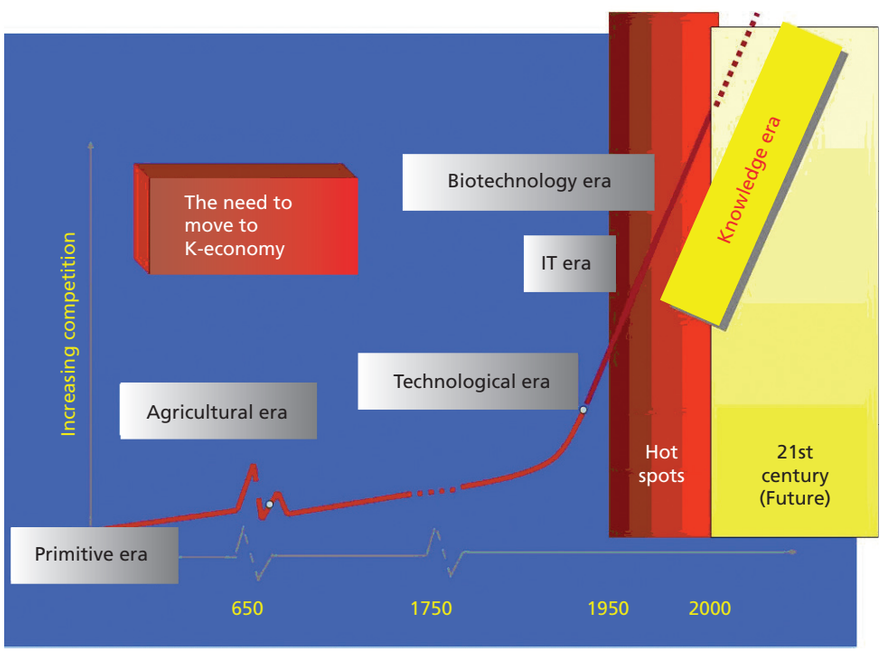

Figure 1. The global agenda.

leading edge for the country. The question then is whether the country in question has sufficient original discoveries?

Based on Table 1, it shows that a country like Malaysia or Thailand lacks a sufficient number of original discoveries (Fadzilah 2003). The reasons for this observation are multi-factorial. The assumptions that the local scientists are unable to deliver original scientific discoveries can only be confirmed after examining all angles. It is also possible that the observations showing a lack of patents filed by most developing and underdeveloped countries may just be an 'iceberg phenomenon'. What was revealed on the surface may not reflect the real situation in the country with respect to patent filing. The reasons for the low number of patents filed could be due to:

a. There is a lack of patent awareness among research scientists. Most scientists are more concerned about publications which are attached to the promotional exercise at the universities and research institutes. In essence, patent filing has not become a priority. Once published, the discovery is made public and the number of countries willing to consider the discovery for patent granting now becomes limited. What must be emphasized is that publication should be a question of when (timing) and not a question of unable to do so if we choose to patent. Awareness of intellectual property rights (IPR) and the patent culture should be made a priority among academics and researchers if the country is to succeed in the new economy.
b. What is more important is that administrators and decision makers should not view patent filing as a number game. When we patent we should use the patent to design and develop new innovations. For maximum benefit to the country concerned, patents when filed, must be used to generate income. It must be used to generate K-based industries for the country like what has been observed for Nokia in Finland and Samsung in South Korea.
c. There must also be awareness among those involved in the decision making, the outcomes and consequences of NOT filing. When we file a patent, we prevent anyone from copying, manufacturing and selling the product in the country filed and in all the countries that the patent had been filed in. Patents protect those who made the discoveries. It provides protection to the country. Patents when viewed in the bigger picture, provide for exclusive revenue and benefits, especially to the country of origin.
d. The lack of funding available for patent filing is probably the main reason for the low numbers of patent, especially among the undeveloped and developing countries. The policies on IPRs for the country must also be taken into account when analyzing its IPR data. In Malaysia, government policy has encouraged and provided funds for the purposes of patent filing and maintenance to all universities and research institutes in the country.

There must be a change in the mindset, attitude and approach towards research design and methodology in the journey towards value creation, especially of R&D products from local universities and research institutes. R&D in the new economy demands priority-driven research instead of investigator-driven research (Ismail 1997) to satisfy the vacuum in the country. In priority driven research, there is a need for commercialization of R&D outcomes. Such research is client-driven and creates wealth for the country. In short, there is a need to perform innovation-driven or translational research. Performing translational research requires a paradigm shift in research approach. It requires the researchers to be good in both fundamental and applied research and to be able to combine the findings to create innovations. It also requires closer contact with the needs of the industry. This public-private relationship requires time, tolerance and patience to nurture among both parties in developing and underdeveloped countries. The reasons include:

- The private sector does not support research from the beginning.
- The private sector would want to be involved only at the latter part of research when the product,

Table 1. Patent situation in various countries.

Country	% GDP (USD)	Patents per 100 000 population	Efficiency [USD(m)]/patent
Malaysia	0.5 (440 m)	1.7	259
Thailand	0.2 (306 m)	2.6	118
South Korea	2.9 (12 bn)	456	26
Japan	2.9 (142 bn)	820	175

device, services or process have been developed at prototype level. At this stage, the private sector would want to undergo technology licensing or direct selling of the know-how; and

- Investors such as venture capitalists (VCs), even those created by the government, are not adventurous in their efforts to commercialise local R&D products. They are also not willing to take risks on 'deep pocket investments' such as in the areas of vaccine and drug development. Hence the setting up of spin-off companies are slow and trickling.

The above are among the factors why underdeveloped or developing countries are slow to catch up with the demands of the K-based economy. Decision makers must ensure or provide incentives to encourage universities and the private sector to meet half-way and collaborate. This move is imperative if the country wants to be a global player in the K-based economy.

The move towards commercialization of R&D requires that researchers undergo a paradigm shift in their approach towards R&D (see Figure 2). Researchers need to have the client in mind and work from Z (the final milestone) to A (the beginning). It is important to decide what product needs to be developed as the final aim of the research programme and the criteria that the product must have in order to be useful or commercially viable in the local and global market. Market foresight and demands must match with the technology platforms chosen to create marketable innovation. Working backwards, the researchers will then strive to perform strategic fundamental research to create new discoveries and applied research to enhance existing or create new technology platforms. In the new economy, both fundamental (basic) research and applied research are equally important. One cannot move and create new discoveries or create new trends in technology without the strength and knowledge in fundamental and applied research. The research findings however, should not stop with publications and seminars. The advancements created in new knowledge must be combined with technology platforms to create innovations. Successful performance of enabling or translational research will generate original indigenous products for the country that must be patented to provide protection to both researchers and the country. The innovation can then be used to create spin-off companies that can consolidate existing industries or generate new industries for the country. The aim for wealth creation should also be balanced with enhancement of the quality of life.

For the smooth transition of the innovation from the laboratory to the industry, there is a need for several factors to be in play which include:

- Provisions of grants to set up and maintain research incubators
- Providing motivation and incentives for scientists to pursue translational research
- Providing incentives for industries to commercialise local R&D products
- Training of local patent lawyers to be proficient in the advanced sciences e.g. molecular biology so as to provide good guides for patent claims.

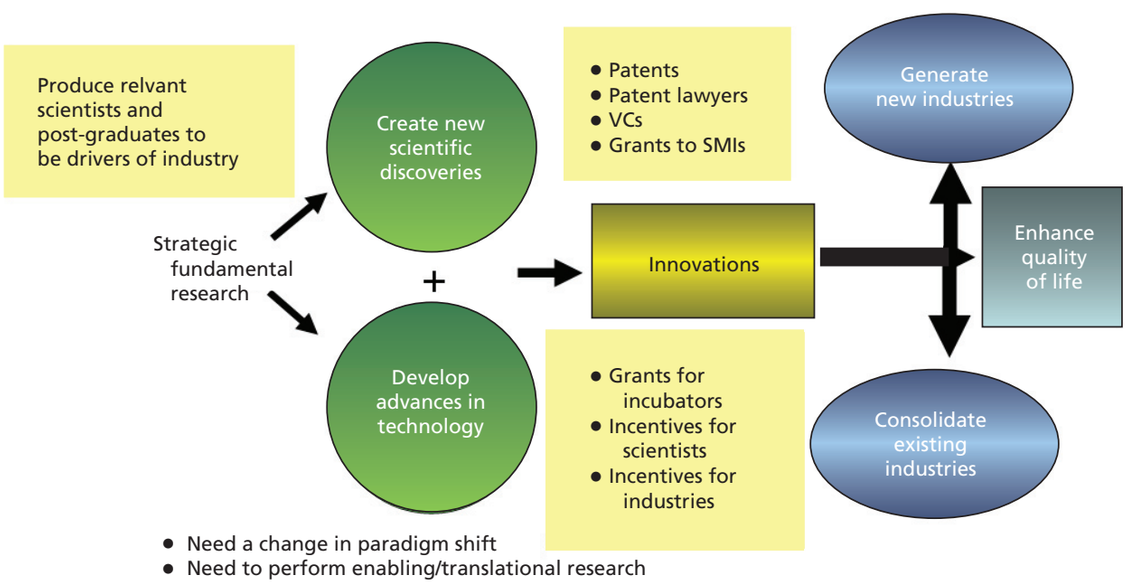

Figure 2. Moving R&D towards commercialization.

- Venture capitalists willing to believe and take risks with local R&D discoveries; and
- Provide grants to small- and medium-industries to manufacture and market the products.

In the new economy, a discovery has no enhancement in the value chain until it can benefit the public. Discoveries and products cannot reach the public until it has been commercialized. Hence to commercialize, research performed must be client-based rather than researcher based. It must be priority driven rather than investigator driven and the experimental design strategy must be from Z to A rather than A to Z. New research practices in the new economy include:

- Performing R&D that has impact by combining fundamental and applied research
- Working in a cluster/team of multi-disciplinary experts to provide solutions to problems
- Learning concepts of entrepreneurship so that product designed is commercially viable
- Choosing the technology platform well. Researchers must have the technology foresight to predict the trend of technology; and
- Preparing years in advance so that the products we produce will remain technologically competitive in the global market.

K-workers have the responsibility to prepare the country today for tomorrow for in the new economy, the country is very much dependent on its K-workers to deliver. Among the impacts of such a research approach include providing jobs for the country as shown in Figure 3.

Policies that Support Innovation and Entrepreneurship

To drive the K-economy of the country, political will must be there to ensure that:

- Grants be given to perform research, development and commercialization
- All universities/research institutes be encouraged to undergo R&D towards commercialization
- Incentives provided to industries that commercialize R&D products of local universities/research institutes; and
- Incentives provided to researchers who undergo commercialization.

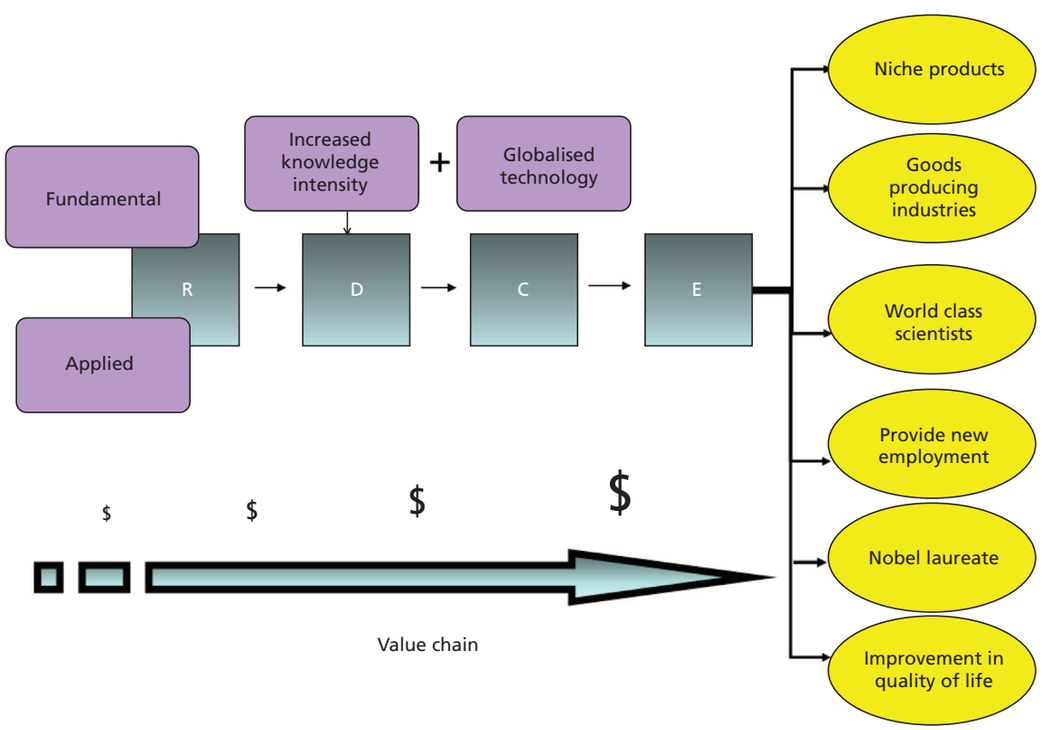

Figure 3. Impact of enabling research.

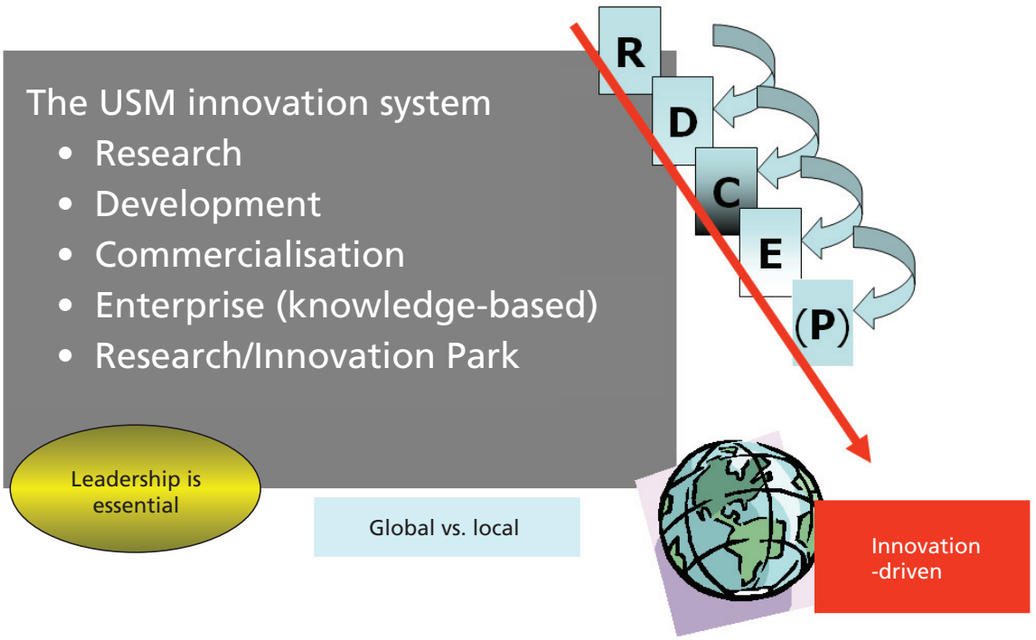

Figure 4. Integrating new R&D challenges in a university/research institution.

When all the above are in place then the country will be in a position to generate intellectual properties and establish new industries for the country.

Integrating New R&D Challenges in a University/ Research Institution: The Malaysian Experience

The Prime Minister of Malaysia, Abdullah Badawi, has set the tone for the country by saying 'Being a global player is unavoidable for a country that wants to develop' (New Straits Times, 17 August 2005). The Deputy Prime Minister, Najib Abdul Razak, has advised that to support the vision, universities must globalize (New Straits Times, 3 October 2005). The question then is how do universities manage their research and human resource such that they would reflect excellence in scientific research, contribute towards K-economy and at the same time train their K-workers to imbibe the spirit of entrepreneurship and improve the quality of life of society?

At Universiti Sains Malaysia (USM), both vision and advice are translated by its Vice-Chancellor, Dzulkifli A. Razak, into an innovation system that forms the policy and backbone of the research, development, commercialization and setting up of knowledge-based enterprises (start-ups) in the USM Research Park (Figure 4).

As proof of the concept of the innovation system, the Rapid Diagnostic research team at USM took up the challenge of performing translational research working from Z to A. The diagnostics were created based on market foresight and client requirements. The development and design of the diagnostics were based on the set criteria of being:

- Rapid
- Specific
- Sensitive
- Easy to perform
- Cost effective; and
- Could be transported without cold chain.

In terms of strategy, the design and development of the diagnostics were focused on diseases that were relevant to S.E. Asia where more than half of the world's population is located. The West has not shown much interest in such diseases. The diagnostics were made for both DNA and protein-based tests for:

- Typhoid
- Cholera
- Campylobacteriosis
- Filariasis
- Tuberculosis
- Dysentery
- Paratyphoid
- Nosocomial infections; and
- Drug response to TB.

Biological markers that were original discoveries were patented and these were then combined with innovative

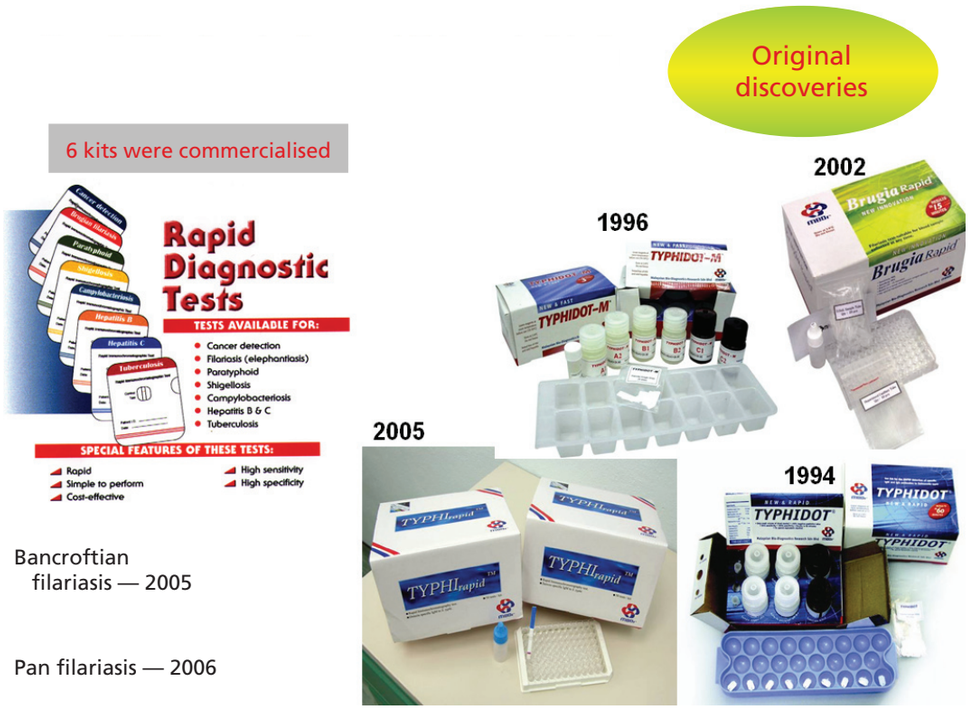

Figure 5. USM commercialization track record (Antibody-based Biotech kits).

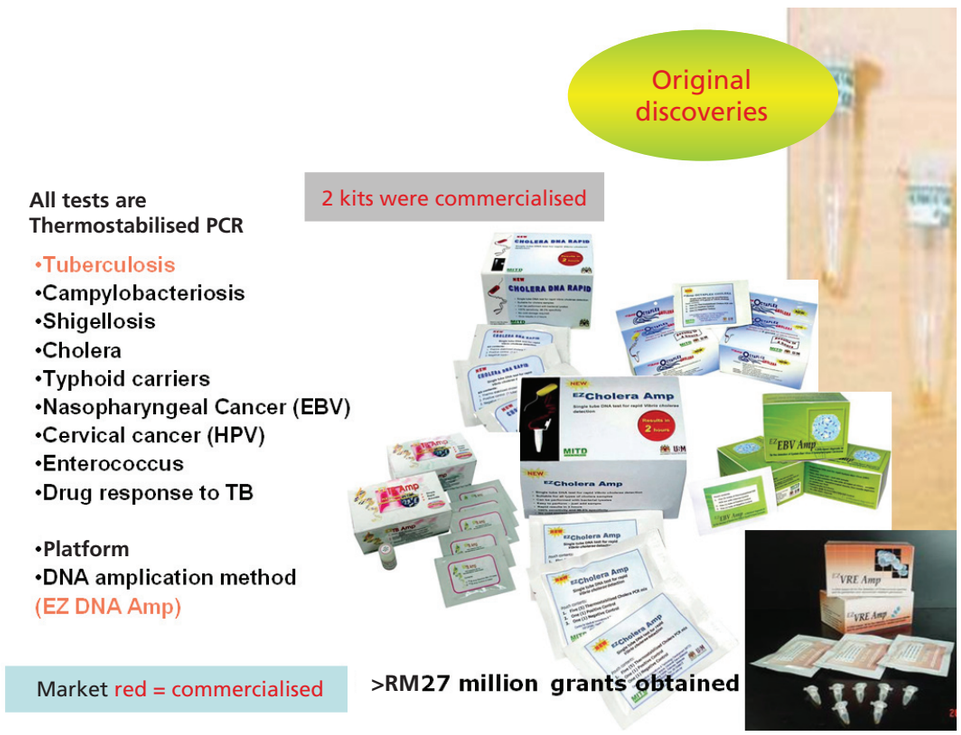

Figure 6. Commercialization track record (DNA-based Biotech kits).

technology platforms, also patented, to create Malaysian innovations for the global market. The technology platforms used were switched to newer platforms according to market demands and hence kept the commercialised Malaysian diagnostics in the global market technologically competitive. Since every product has its life cycle and faces fierce competition in the global market, it is essential that technology advancements are continuously created and combined with the scientific discoveries to allow the products to be in the market long enough to create the Malaysian branding for diagnostics. Such breakthroughs were made with the Typhoid rapid diagnostic kit called *TYPHIDOT*™ that was sold since 1994 and still remains as the flagship product for the company that commercialised it. The kit produced results in 3 h when it was first commercialised in 1994 while it takes 15 min since 2006. Currently the test is created for use at point of care without need of cold chain for transportation and storage. Typhoid diagnostics kits are sold in 18 countries and was used by more that 2 million people world-wide. Patents for it were applied for in 23 countries and seven have been attained till today. To date, at least 18 different kits have been developed at USM and eight kits have been successfully commercialised world-wide (Figures 5 and 6).

CONCLUSION

Value creation for research innovation is a result of research done with a purpose. It is done to enhance wealth creation for the country and improve the quality of life of the people. Research and development when performed with the client in mind, have well thought out criteria to satisfy market demand. Focused criteria will determine the direction of scientific discovery and technology platforms created and used. This in turn will determine the kind of skills and expertise needed and generated among the knowledge workers. When R&D is done within the priority areas of the country, it will determine the nature of the R&D products placed on the K-economy shelf of the country. Products placed on the shelf will generate growth of the knowledge-based industries for the country. Examples round the world can be observed, such as India for its Information Technology industry and South Korea for its electronics and automobile industry. A change in the mindset of researchers is necessary to focus on translational research that are priority driven rather than focussing on investigator driven research. Successful translational research outcome demands a change in the paradigm shift of design and development of the research idea by working from Z to A. Speed, direction and directives are essential to push commercialization of R&D to happen faster. Combined with the innovation policies of the country, R&D can be done with respect and profit and not seen as an economic drain.These factors are essential if the country is serious about having sustained innovations.

ACKNOWLEDGEMENTS

The work described was performed by the USM Rapid Diagnostics research team and supported by the Intensification of Research in Priority Areas grant and National Biotechnology Development grant from the Ministry of Science, Technology and Innovation, Malaysia.

Date of submission: January 2007
Date of acceptance: January 2008

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Education Programme on Science of Microgravity in Commemoration of the First Malaysian Astronaut in Space

M.S. Khalijah[1]* and M.H.M. Helmy[2]

The Ministry of Science Technology and Innovation (MOSTI) *Angkasawan* (Astronaut) Programme achieved its mission to send the first Malaysian astronaut Sheikh Muszaphar Shukur by Soyuz TM11 to the International Space Ship (ISS) on 10 October 2007. He returned to earth, landing safely on 21 October 2007. Such a momentous event has carved out yet another milestone in the country's history and development of a civilisation based on science and technology for its people. This mission has provided the educational sector with an opportunity to initiate a curriculum innovation. Together with the Ministry of Education (MOE), the initiative was undertaken to improve techniques of teaching and learning (TL) and to broaden its scope to include space science and technology.

To implement the education programme, a co-ordinating committee for the education of the science of microgravity was formed. Its members comprised those from the National Space Agency (ANGKASA), MOE and Universiti Kebangsaan Malaysia (UKM). The committee was assigned to conduct nationwide secondary school level activities to expose students to space science, in particular physics in a microgravity environment. This constituted the National Astronaut Educational Programme.

The National Space Agency (NSA) acted as the secretariat, MOE managed matters related to teachers and schools, while UKM provided the expertise in the microgravity discipline and in education. Representatives from these three agencies carried out several activities in preparing the live telecast between the astronaut and the school children on the science of microgravity education programme. Right from the beginning till the end of the programme, the activities were carried out in three phases: study tour; development of the science of microgravity education module; and the direct live telecast.

This paper reports the activities carried out by the committee for microgravity science education programme from the beginning right till the live telecast of the education program on ISS with Sheikh Muszaphar Shukur on 19 October 2007.

Educational Visit

Commencing 11 February through 18 February 2006, NSA under the leadership of the Director General, Mazlan Othman, sent a group of scientists and educators to the Laboratory for Atmospheric and Space Physics (LASP); University Columbia, Colorado, USA and the Canadian Space Agency, Montreal, Canada to learn about science research and science education activities in ISS. The visit was also to prepare members of the entourage to undertake the responsibility of conducting research and educational programmes on returning to Malaysia.

The visit was fruitful in allowing the members to know and understand (i) space research activities that have been carried out by those institutions visited, (ii) related educational acitivities both formal and outreach among undergraduates that could be conducted, (iii) engineering capabilities, and (iv) all matters regarding mission operation including planning, scheduling, data system, the astronaut training and earth monitoring of ISS.

After the overseas study tour, a committee for the science of microgravity education was established. It was chaired by Khalijah Mohd Salleh (UKM) and the members were Zainuddin Abbas (MOE), and Mohd Helmy Hashim (NSA) with Mazlan Othman as the advisor. The committee was responsible for the planning and implementation of the education programme.

Preparation of the Educational Module on Science of Microgravity

The preparation of the module took place at three stages. These were: (i) Exploring possible types of experiments that could be carried out in the ISS; (ii) testing of experiments and documenting the plan of the lesson, and (iii) completing and refining the educational module in the ISS.

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Exploring possible types of experiments. A Science of Microgravity Education Workshop was held on 27–30 July 2006 which was attended by 15 participants, majority of whom were secondary school teachers. There were also representatives from MOE, UKM, and Universiti Teknologi Malaysia. NSA provided the secretariat for the workshop. As this was the first workshop, it was aimed at exposing the basic concepts of microgravity, research methodology in space, and exploration of possible experiments that could be conducted in ISS. Zulkeffeli Mat Jusoh, who was then NSA Mission Flight Surgeon was invited to give a briefing on the national Astronaut Programme. Participants were also shown on video experiments that had been done in the ISS. They also had a discussion on the environment in the ISS.

Following this the participants were able to form groups to suggest and discuss the different science experiments (in physics, chemistry and biology) that could be carried out in the ISS. Teachers were then asked to present their experiments and in turn the experts made their comments. The workshop was fortunate to have a space expert from Bioserve University of Colorado, USA to guide participants on matters related to the conducting of proposed experiments in the ISS. After refining the proposed experiments, the proposals were handed in to the Secretariat to be further assessed by NSA.

A total of 13 scientific experiments under micro-gravity were proposed: five on physics, three on biology and five on chemistry. The physics experiments included those on three dimensional magnetic fields, fluid mixing while flowing (including *teh tarik*[a] (cooling of hot tea), condensation, boiling and evaporation), and a study on surface phenomena which included hydrostatic pressure. The physics group further proposed an experiment on mechanics (involving a simple pendulum) and also on observing the sun and moon from the ISS.

Three biology experiments were proposed. These were on the rate of water uptake by a cut shoot, the movement of water through partially permeable membrane by osmosis, the regeneration process of *gamat* (sea-cucumber) and the effect of auxin distribution in growth of seedlings. Finally the five chemistry experiments proposed were on the growth of copper (II) sulphate crystals, the effectiveness of plant methanol extracts to inhibit the growth of calcium oxalate crystals (kidney stones) the effect of a microgravity environment on the shape of the ice produced during water freezing and finally the glowing of wooden splinters by the oxygen gas.

The proposed experiments were then sent to NSA for assessment and selection. The committee was later informed that the Russians would allow only selected physics experiments. Chemistry and biology experiments would not be conducted in ISS for safety reasons. Furthermore, these latter experiments involved the use of organic materials and chemicals.

Writing on Edcuation Module. The second workshop on Science of Microgravity Education was successfully carried out starting 16 through 19 April 2007 at a hotel here. During the workshop, the participants were informed that Russia had agreed with the proposal for a video session with the Malaysian astronaut. The time alloted was eight minutes while the ISS was orbiting Malaysian space.

The objectives of the second workshop were: (i) to identify the need to prepare the content for the Science of Microgravity Education programme, (ii) to design a lesson plan to demonstrate physics principles on earth for teachers who will conduct the lesson in school and for the astronaut to conduct the lesson in the ISS; and (iii) to train teachers as members of the core group who understand the concepts on microgravity. This workshop was facilitated by education specialists T. Subhan Meerah and Lilia Halim (from the Faculty of Education), Baharudin Yatim and Geri Gopir, as specialists on space science (from the School of Applied Physics/Institute of Space Science UKM), Chia Song Choy (Principal, Technical Secondary School, Kuala Klawang) and Lau Chen Chen (Planetarium, NSA). The participants of the workshop were 21 specialist physics teachers from schools within Kuala Lumpur, Selangor, Negeri Sembilan, Melaka and Perak.

Participants were initially given a physics test. This was done for the purpose of group formation. They were then briefed on prediction, observation and experimentation (POE) as a teaching method, the technique to prepare a lesson plan and the script for the astronaut when demonstrating the three experiments that NSA had selected. These experiments were the Twisted Orbital Platform principle which is basically a spinning top, fluid properties and stones to demonstrate Newton's laws of motion. The topics chosen represent basic concepts in physics of motion. There was a special reason to choose the top[b]. It is symbolic of Malaysian culture.

[a] The crude and simple process of cooling hot tea (by hawkers) by pouring it repeatedly from a container held from an elevated position to a container held lower, and varying the distance between the two containers while pouring.

[b] A top was specially designed by Prof Anuar Sirat and assisted by Mohammad Azroll Ahmad and Sharifuddin Marsibin (Faculty of Fine Arts and Design, Universiti Teknologi Mara, Shah Alam). However the copyright of the top belongs to NSA. The top is approximately t ~ 90 gm made from alluminium, a metal that is light weight and not inflammable.

At the end of the workshop, participants were asked to demonstate their experiments as well as present their lesson plans and the scripts that they had written. Facilitators then gave their comments so that refinement could be made to lesson plans and the scripts. The workshop took the opportunity to make the presentations as a competition. This was just to inject excitement and motivation among the participants. The product of the workshop was comprehensive. It included the various aspects of content for the module. These were the work sheets, scripts of lesson plans and demonstration experiments for the astronaut and the teachers. Once again the products developed were submitted to NSA for further scrutinisation and final decision.

Finalising the module on Science of Microgravity. The final discussion on the module was held on 16 October through 19 October 2007. The objectives of the discussion were: (i) to prepare and update the reading materials on microgravity, spinning phenomenon, and surface tension; (ii) to complete the POE work sheets for the test before and after the live telecast demonstrations, and (iii) to refine the live telecast procedures.

Video Session of the Live Telecast on Education on Science of Microgravity

This was the peak of the programme on education of science on microgravity. A live telecast video session with the astronaut in the ISS was scheduled on 19 October 2007. It was decided that the location for the live telecast session was the National Science Centre (NSA), and the direct telecast was to be managed by ASTRO (a local satellite station).

The objective of the live telecast video program was to primarily expose to secondary school students, the target group, physics concepts in microgravity and also, to enhance public awareness and understanding of the science of microgravity, besides promoting interest in space science and technology.

Live telecast preparation. The ISS live telecast video session to earth was set for eight minutes, starting at 8.40 p.m. to 8.48 p.m. on 19 October 2007. The agenda for the evening programme started at 6.00 p.m. through to 10.00 p.m. The live telecast was scheduled from 8.40 p.m. till 9.00 p.m. local time.

Two dry-runs were carried out on the afternoon of 18 October and morning of 19 October 2007. A total of 307 students from 12 schools from the Federal Territory of Kuala Lumpur, and states of Negeri Selangor, and Perak participated in this live telecast programme. They started to arrive at PSN at 6.00 p.m. There was no participation from other states due to festive holidays. However, there appeared to be primary school children from private institutions. This live telecast was facilited by eight specialist physics teachers and staff from NSA.

After registration, students were given souvenirs consisting of posters, notebook, reading materials and worksheets. These souvenirs were contributed by MOSTI, NSA dan NSC. The highlight of the telecast was a demonstration of experiments by the astronaut, Q&A session with guest of honour and a press conference.

While waiting for the ISS live telecast by ASTRO, the students were entertained with a quiz. Five questions on the astronaut mission were given to the students. NSA gave away token gifts to those who answered the questions. At 8.40 p.m. astronaut Sheikh Muszaphar appeared on the screen and there was a round of applause by the students and guests. He immediately set to his tasks. He could only demonstrate two experiments that were submitted to him. These were the spinning top and the fluid experiment. He however also demonstrated to the students the yoyo game, and motion of three balls of different sizes, made from different materials. The live telecast session ended with the Deputy Minister of MOSTI asking Sheikh Muszaphar the challenges that he faced while in the ISS. Sheikh replied that in microgravity an object if set free would just wander anywhere compared to when it was under the influence of gravity. He narrated an incident that once on waking up he found himself away from where he had initially slept.

After the live telecast, a press conference was held. The Deputy Minister of Education, H.E. Noh Omar announced that the Ministry would include space science as a topic in the school curriculum. The objective was towards developing human resources that the country would need to be involved in the space science programme.

Audience Reaction

Random feedback from the public was solicited after the live telecast. There were two groups of people: those who supported the programme and those who did not. Even among the scientists there were those who questioned the justification for taking air time to demonstrate the spinning top in the ISS. Why waste money just to show the effect of microgravity on a spinning top? It would have been better if the astronaut demonstrated, say the phenomena of superconductivity. However response from those without science background was more encouraging. They were excited to see a spinning top floating on air. They wanted to know why. This showed that there are events that could arouse people's curiosity and this was precisely one of the objectives of having an educational session in the ISS.

This educational programme was carried out partly for the public. At a time when the general public is not inclined towards science and technology (reflected through declining enrolment for science at school level), such a

programme was a necessity. This was a strategy to enhance public interest especially among the younger generation and to inculcate interest in science. The top-spinning demonstration was easy and quick. People could easily identify with it and hence easily realise the difference in the spinning behaviour in microgravity.

However, an impact study of the program was needed if we were to exactly know the effect of the Astronaut Programme particularly for the younger generation. Furthermore, space science programmes could stimulate spin offs. In fact this was demonstrated by the making of tops, specially designed by local craftmen. The top with the copyright of NSA had commercial value and could be sold as souvenirs in commemoration of Malaysia's success in sending her own astronaut. The top can still be used as a toy or a teaching /learning aid.

The Space Science Programme opens up space in the nation's capacity building in a variety of areas. Space science activities generate social research. Impact studies can reveal how Malaysian society responds to new development programmes that the country would like to embark upon. It can identify factors that affect peoples' response. Such findings would be useful for identification of strategies needed to gain public support toward new development projects or programmes that need to be carried out by the country. These research activities could be carried out by postgraduate students working for their advanced degrees at masters or PhD levels. Such programmes also promote linkages, networking and collaboration between research institutions like UKM and UiTM, government agencies, (MOE, MOSTI dan NSA), and the media like ASTRO dan CELCOM (local telecomunication company). This was a one short show which had a gigantic national vision that could become a reality when the significant players play their cards well in space science.

CONCLUSION

The education session on space science opens up a new dimension and potentional in the nation's education curriculum. Such a programme could reach the whole of the Malaysian student population and can therefore nullify the negative support that has been given to the program. It is hoped that the session with Mushapar was able to help the public see for themselves and understand better the effect of microgravity. It was a once in a life time event. The Space Science Programme should not be looked at as exclusively for the scientists. The public need to be given the opportunity to observe microgravity phenomena, and the importance of space science research to the security, growth and development of the country. It also promotes other opportunities in creative arts, innovation and economy. Malaysia's involvement in the Space Science Programme will allow her to position herself better against other developed countries. This is important in the light of Malaysia's aim to become a developed country by the year 2020.

ACKNOWLEDGEMENTS

The Committee for Science of Microgravity Education would like to express their gratitude to MOSTI, NSA, MOE, UKM, UiTM, National Science Centre, ASTRO, CELCOM, schools, teachers, students, the media and all who have contributed to make the education programme a success.

A section of the audience during the live telecast on 19 October 2007.

Comet 17P/Holmes

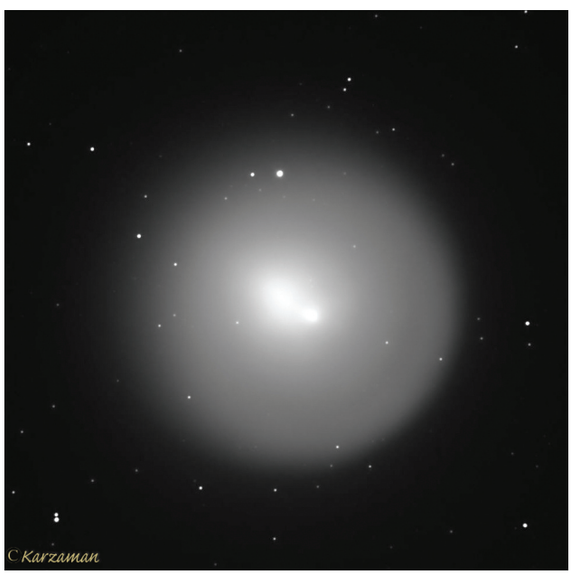
M. Othman[1]* and K. Ahmad[2]

Comet 17P/Holmes was discovered by Edwin Holmes on 6 November 1892 while he was conducting regular observations of the Andromeda Galaxy (M31). Calculations using observation of its orbits established the perihelion date as 13 June and the orbital period as 6.9 years. The 1899 and 1906 appearances were observed, but the comet was only seen again in 1964. The comet has since been observed on every subsequent return.

Between 23 and 24 October 2007, comet Holmes grew almost a million times brighter. During the comet's outburst, Earth observers were looking nearly straight down along the tail, making the comet appear as a bright sphere. Based on orbital computations and luminosity before the 2007 outburst, the comet's nucleus was estimated at 3.4 km. In late October 2007, the coma of the comet was about half the diameter that the moon subtends in the sky, equivalent to a true diameter of over 1 million km, or about 70% of the diameter of the sun.

By 9 November 2007, the coma had dispersed to a volume larger than the sun, briefly giving it the largest extended atmosphere in the solar system. The cause of the outburst has not been ascertained. The coma might have been a huge cloud of gas and dust that materialized as a result of either a collision with a meteoroid or a build-up of gas from inside.

The images and technical details of comet Holmes are shown below. The optical instrument used, the camera and the location are (1) Telescope 20 inch f/8.1 Ritchey-Chrétien; (2) SBIG STL1001E camera; and (3) Location—Langkawi National Observatory (Malaysia), respectively. All the images were the creation of Karzaman Ahmad.



Holmes 1

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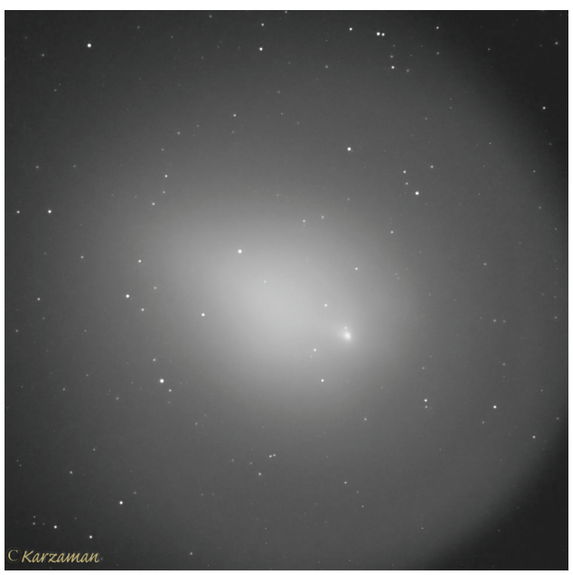
Date — 2 Nov 2007
Exposure — 5 minutes



Holmes 2

Filter — SBIG Standard Luminance
Date — 10 Nov 2007
Exposure — 5 minutes

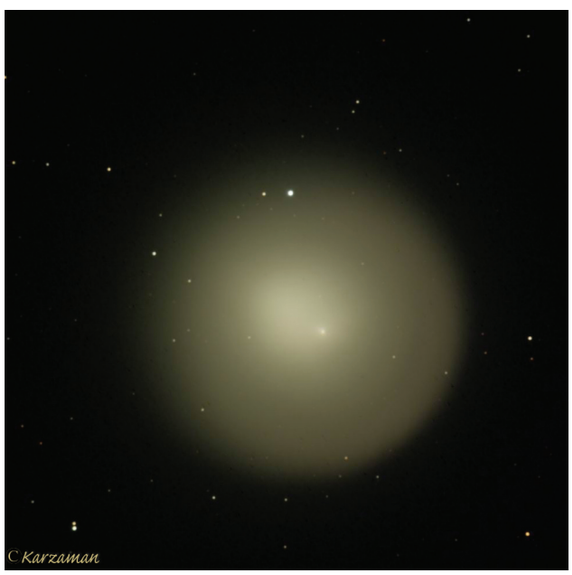
[1]United Nations Office for Outer Space Affairs, Vienna International Centre, P.O. Box 500, A-1400 Vienna, Austria
[2]National Space Agency, 5th Floor, Complex PJH, Block 2, Precinct 2, 62100 Putrajaya, Malaysia
* Corresponding author (e-mail: Mazlan.OTHMAN@unoosa.org)

Holmes 3

Filter — SBIG Standard Luminance
Date — 10 Nov 2007
Exposure — 3 minutes

Holmes 4

Filter — SBIG Standard Luminance
Date — 3 Dec 2007
Exposure — 5 minutes



Holmes 5

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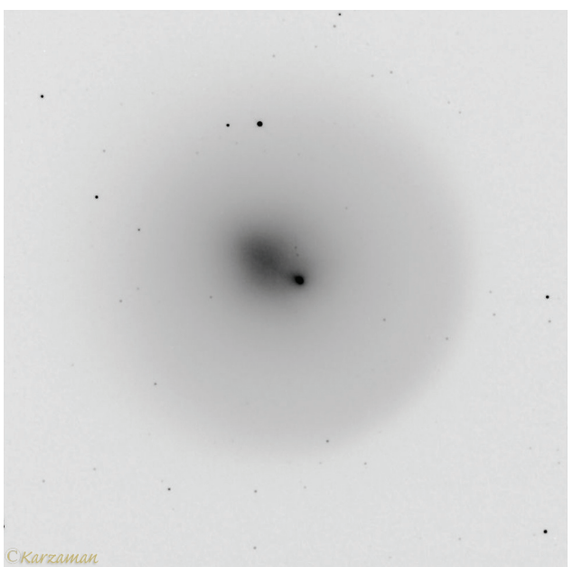
Exposure — L=6, R=4 G=4 B=4 minutes



Holmes 6

Filter — SBIG Standard Luminance (Inverted)
Date — 4 Nov 2007
Exposure — 5 minutes

Recipient of Mahathir Science Award 2006
Faculty of Medicine, University of Malaya

The Faculty of Medicine, University of Malaya is the oldest and the largest Faculty offering medical education in Malaysia. Established in 1964, it currently provides many professional and research programs in health sciences including medicine, nursing, public health, allied health sciences and pharmacy. Its academic staff also serve at its teaching hospital, the University Malaya Medical Centre (UMMC), where medical science is put into practice in providing healthcare to the community.

Between September 1998 and June 1999, there was an outbreak of viral encephalitis in the pig-farming communities in Perak, Negeri Sembilan and Selangor, that affected more than 265 individuals. The outbreak caused 105 deaths before it was contained. A total of 91 patients from the outbreak were admitted to the UMMC, Kuala Lumpur.

Originally, the Japanese encephalitis virus was erroneously thought to be the cause. Based initially on epidemiology and subsequently with the isolation of the Nipah virus from a patient by Dr K.B. Chua at the Department of Medical Microbiology, Faculty of Medicine, University of Malaya, the outbreak was confirmed to be caused by a novel virus previously unknown to science (Figure 1). Together with the Hendra virus, it is now recognised as a new genus, Henipavirus (Hendra + Nipah), in the Paramyxoviridae family. The discovery of a highly infectious virus capable of high human fatality, brought Malaysia into sharp focus in the scientific world. From this discovery, numerous other studies throughout the world, many in collaboration with Malaysian scientists, were initiated and are on-going.

At the Faculty of Medicine-Hospital Complex, the effort to save lives and the race to contain the outbreak was a multi-disciplinary team effort involving all levels of healthcare and scientific personnel. Indeed it was a harrowing time that challenged each member to examine how true they were to their professional calling. The fact that this was an 'unknown' virus, made each realise that they and their families were at risk. The neurology team, headed by Prof C.T. Tan, who were in constant direct contact with the patients, exemplified the professional vigour and commitment required. This was no less true for those who worked behind the scenes such as in the laboratories and imaging rooms.

True to their scientific calling, the multi-disciplinary Nipah virus team helped to determine that close contact with pigs was the main mode of transmission to humans. This formed the basis for pig-culling that eventually stopped the outbreak that would otherwise have devastated a billion dollar industry. Demonstration of viral infectivity in human secretions initiated a rigorous barrier nursing protocol that was instituted throughout Malaysia to prevent human-to-human transmission. In subsequent Nipah outbreaks in Bangladesh and India, human-to-human transmission caused much mortality among healthcare workers and family members. The barrier nursing protocol probably helped prevent similar tragedies in the Malaysian outbreak.

The vigorous scientific work of the Team was largely responsible for characterizing the clinical, radiological and neurophysiological manifestations, and the pathology and pathogenesis of this new human disease. This led to the discovery and better understanding of the acute, subclinical, relapsed and late-onset forms of the disease enabling improved diagnosis of future patients. Nipah encephalitis is unique among viral encephalitides to have relapsed and late-onset forms (Figure 2). The other unique feature in the acute form is that tissue damage arose from two mechanisms namely, vasculitis-induced thrombosis and neuronal infection.

The Team also formulated the general management, and instituted and confirmed Ribavirin in improving the outcome of acute encephalitis. The golden hamster was later discovered to be a good infectious model, paving the way for successful experimental trials for various therapeutic agents.

Investigations by the Team confirmed the Pteropus bats as the reservoir hosts, determined human infection risk from bats, and identified the anthropogenic and environmental factors that may have led to its emergence. This knowledge could help prevent future outbreaks. The widespread prevalence of the Nipah virus in bats in Bangladesh, Thailand and Cambodia, and the recent Nipah outbreaks in Bangladesh and India makes it likely that there will be more future outbreaks in Asia. The Team's contribution in expanding the frontiers of knowledge on Nipah infection would be of great importance and relevant to viral encephalitis in general, and to future outbreaks in particular.

Their research of the virus has resulted in 33 original publications and 10 invited reviews in more than 25 journals, including high impact journals as *Science, New England Journal of Medicine, Lancet, Annals of Neurology, American Journal of Pathology and Journal of Virology*. Their work have won many accolades from the global scientific community, such as the Nikkei Asia Prize for Technological Innovation (2002), James H. Nakano

Citation Award from the Centers of Disease Control, USA (2003) and the Richardson Lecture (2004). Team members also served as World Health Organisation consultants to investigations of the Nipah encephalitis outbreak in Bangladesh in 2004.

The Academy of Sciences Malaysia, confered the Mahathir Science Award 2006 to the Faculty of Medicine, University of Malaya, for the exemplary way the team handled the outbreak and their outstanding scientific work which has greatly enhanced the image of the Nation.

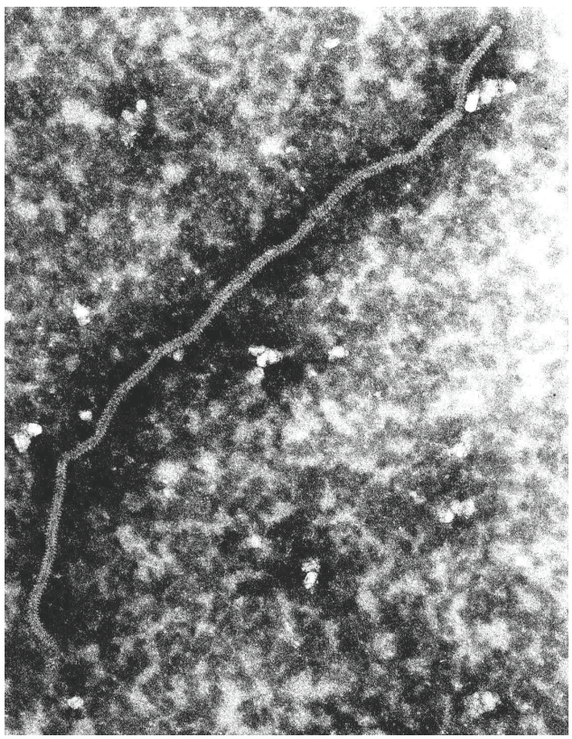


Figure 1. Electron micrograph of the Nipah virus.

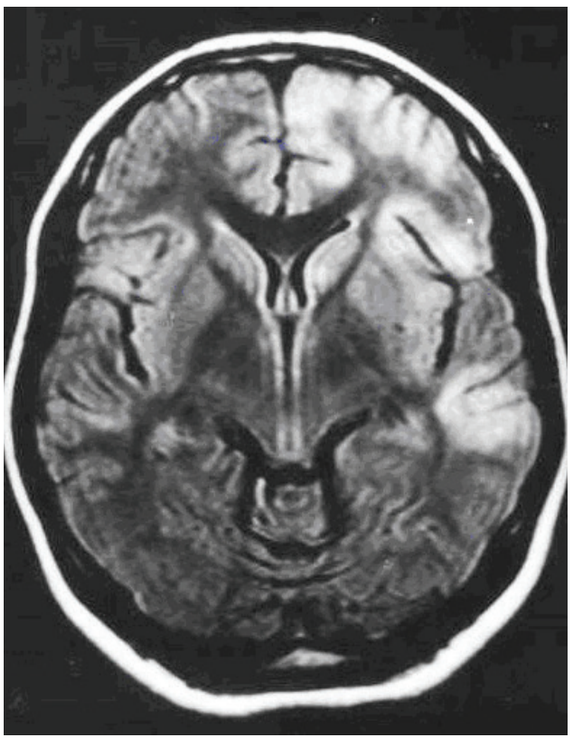
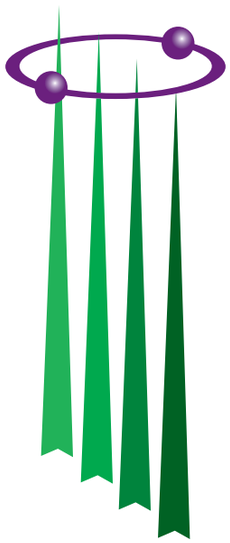


Figure 2. MRI of patient with late-onset Nipah encephalitis. Dense white areas indicate involvement of the left frontal lobe, left temporal lobe and caudate nucleus.



MAHATHIR SCIENCE AWARD 2009

Invitation for Nominations

The Academy of Sciences Malaysia (ASM) is a body set up with a mission that encompasses pursuit, encouragement and enhancement of excellence in the fields of science, engineering and technology for the development of the nation and the benefit of mankind. The Academy has instituted the Mahathir Science Award (Formerly Known as ASM Award For Scientific Excellence in Honour of Tun Dr Mahathir Mohamad) in recognition of scientists/institutions who have contributed to cutting-edge tropical research that have had an impact on society.

This Award is Malaysia's most prestigious Science Award for tropical research launched in honour of Tun Dr Mahathir Mohamad who promoted and pursued with great spirit and determination his convictions in science and scientific research in advancing the progress of mankind and nations. Tun Dr Mahathir was the major force and the man who put into place much of the enabling mechanisms for a scientific milieu in our country.

This Award will be given to researchers who have made internationally recognised breakthroughs in pioneering tropical research in the fields of Tropical Medicine, Tropical Agriculture, Tropical Architecture and Engineering, and Tropical Natural Resources.

One Award will be conferred in 2009 covering any of the above four fields. The Award carries a cash prize of RM100 000, a gold medal and a certificate.

NOMINATION CRITERIA

- Awards will be given to researchers who have made internationally recognised breakthroughs in pioneering tropical research that have brought greater positive impacts on the well-being of society.
- Nominations can be made by individuals or institutions.
- A recipient could be an individual or an institution.

Nomination forms may be downloaded from the Academy's website:
www.akademisains.gov.my

Closing date: 31 March 2009

For more information, please contact:
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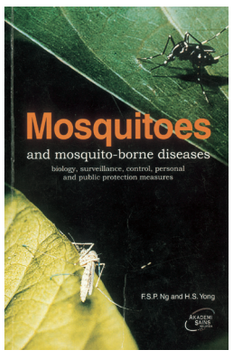

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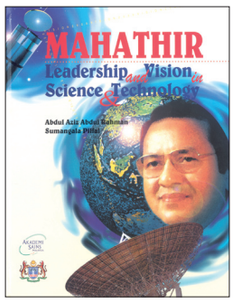

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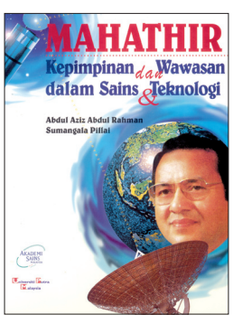

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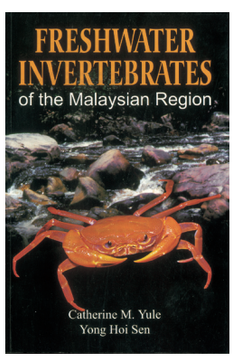

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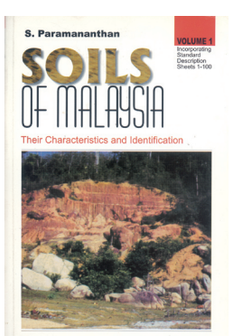

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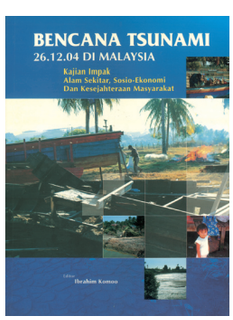

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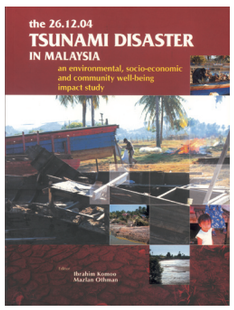

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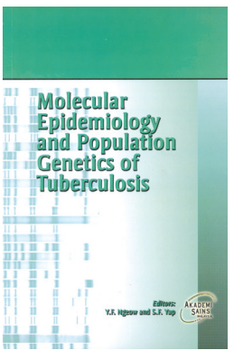

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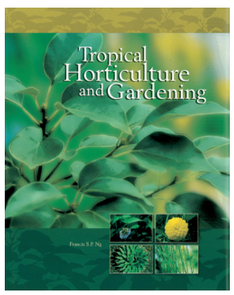

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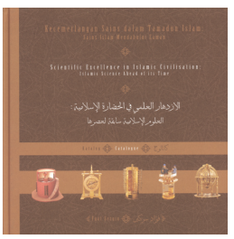

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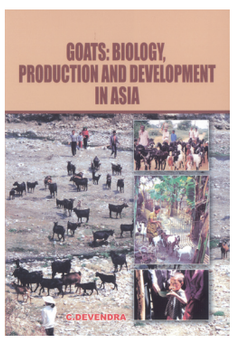

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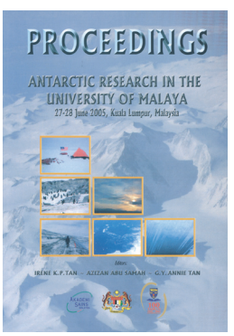

Proceedings: Seminar on Antarctic Research, 27–28 June 2005, University of Malaya, Kuala Lumpur, Malaysia

Irene K.P. Tan et al. *(Editors)*
(2006)

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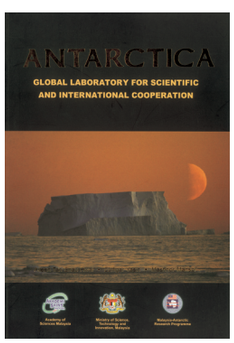

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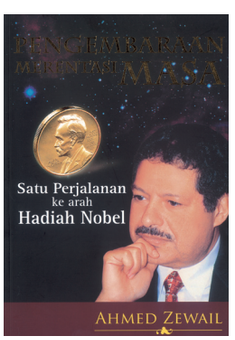

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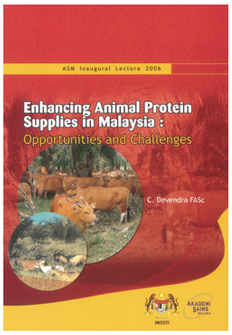

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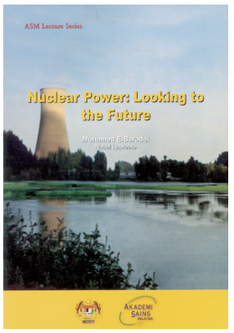

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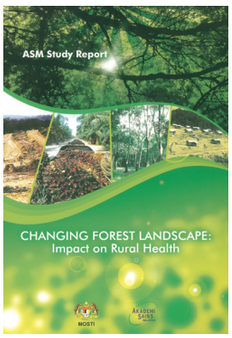

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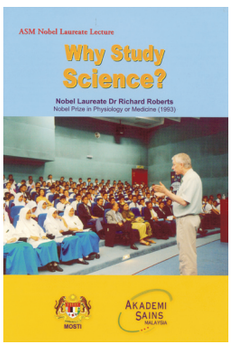

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Monograph

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Chapter in a monograph

Biale, JB 1975, 'Synthetic and degradative processes in fruit ripening', eds NF Hard & DK Salunkhe, in *Postharvest biology and handling of fruits and vegetables*, AVI, Westport, CT, pp. 5–18.

Conference proceedings

Common, M 2001, 'The role of economics in natural heritage decision making', in *Heritage economics: challenges for heritage conservation and sustainable development in the 21st century: Proceedings of the International Society for Ecological Economics Conference, Canberra, 4th July 2000*, Australian Heritage Commission, Canberra.

Report

McColloch, LP, Cook, HT & Wright, WR 1968, *Market diseases of tomatoes, peppers and egg-plants*, Agriculture Handbook no. 28, United States Department of Agriculture, Washington, DC.

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ASM Sc. J.
Volume 1(2), 2007

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ISSN 1823-6782

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