CHAPTER 6: TECHNICAL REPORT WRITING

Writing a Formal Report

A formal report describes the results of a scientific investigation. Thousands of papers are written each year by scientists at universities and research institutions all over the world. These reports are published in scientific journals, many of which you can find in the University library. You will probably have difficulty understanding much of the material, however, *American Journal of Physics* and *The Physics Teacher* often contain articles of a more general nature, as well as other popular magazines such as *Scientific American*.

Your formal report will describe the results of an experiment that you have performed in the laboratory. It is not the same as the report you write in your regular lab notebook. The goal of the formal report is not to prove that you got the right answers; the goal of a formal report is to document your findings and communicate the knowledge you have acquired from a laboratory experiment.

It must be written with the same care and attention that a professional scientist might use. Thus it must follow an accepted international format, with emphasis on good English, spelling and grammar. Upon reading the report, the reader should be able to understand

- what you have done,
- why you have done it, and
- what you have concluded.

Specialized fields such as physics have their own technical terminology. While appropriate in some situations, the use of jargon should be avoided if it causes confusion. Do not include irrelevant details. You will have to use your judgment in determining what to include and what to exclude.

Be prepared to make several revisions before submitting the final draft. NEVER SUBMIT A FIRST DRAFT. Let somebody else read you report before you submit.

The report is divided into distinct sections, with its own characteristic heading: *Abstract, Introduction, Apparatus and Experimental Procedure (or Method), Results, Discussion* and *Conclusions*. Each of these will now be described. There is no Table of Contents.

Abstract

The abstract is a miniature version of the whole report. Everything in the abstract is repeated in the paper, but with more elaboration. An abstract is different from synopsis or summary of a report. Your abstract should emphasize the objective, procedure, results and significance. Use this section to demonstrate how all the information holds together. Often, many people will not read beyond the abstract, so it is important that you are precise and specific. The Abstract should be no more than a paragraph in length. In other words, the abstract should be brief, written in one paragraph and not exceed 300 words.

Since the abstract is a summary of the report, you cannot write it until after you have completed the report.

Example:

Process variation is unavoidable and affects quality in manufacturing, and addressing it has become more challenging due to more stringent demands on manufacturing processes. It is becoming necessary to very rapidly identify sources of unnatural variation for diagnostic and intervention purposes. As such, it is crucial that process variability patterns be recognised in a timely manner, as waiting for process deterioration to develop fully could be too late for preventive purposes or may even be catastrophic. The purpose of this study was to develop a scheme for enabling on-line recognition of such patterns on Shewhart charts even as they are developing. Extensive simulations were performed and a scheme that can address the requirements is proposed. Evaluation was based on recognition accuracy, average run length, type I error, type II error, and a new measure, average recognition attempts. It was found that a scheme developed using a minimal set of statistical features for input representation, compact structure of artificial neural network pattern recognisers, synergy of specialised and generalised recognisers, and joint monitoring by runs rules and CUSUM resulted in the best scheme among the alternative designs developed. This scheme showed significant improvement in overall performance and, among others, timely and accurate on-line recognition, ignoring unnecessary recognition of stable processes and capability to recover from false alarms. The findings suggest that the recognition of developing control chart patterns should be addressed from an interlinking monitoring and recognition perspective and by implementing a "recognise only when necessary" philosophy. The framework used to develop the scheme is general enough for further investigation by either evaluating other designs of its components or by extending its application to other problems.

Introduction

This section sets the scene. It brings the reader up to date so that the report can be understood in context. The background to the work needs to be clearly described. Some experiments have historical significance, e.g., Millikan Oil Drop, and this would be described also.

The Introduction will also include some theory. Derivations of standard formulae are not necessary, but if you develop an equation into some other form to fit your analysis, you should include the derivation. Mathematical expressions should be written in sentences, for example, "*The magnetic field at the centre of a plane circular coil is given by*

$$B = \frac{\mu_o n I}{2r},$$

while the field along the x axis is given by

$$B = \frac{\mu_o n I}{2(x^2 + r^2)^{3/2}},$$

where n is the number of turns in the coil.

Note that equations are written on separate lines and numbered consecutively, but otherwise fit smoothly within the sentence. Equations are also followed by appropriate punctuation marks. Ensure that you typeset subscripts and superscripts correctly.

End the Introduction by stating the objectives of the work. How will the basic information will be applied to your experiment? The best way is to start with a sentence like, "*The objectives of this work are to . . .*" or might end with the phrase like, " *. . . and it is the purpose of this experiment to determine a value for the coefficient of viscosity of water*."

The textbook is the most obvious sources of reference, but you should not restrict yourself to it. Cite each reference you use, either by number, [1], [2], etc., or by author and year, e.g. Smith and Jones (1994), Smith (1998). A list of references should be included in a bibliography at the end of the report. The laboratory instruction sheet is not an acceptable reference source since it is only a guide to the experiment; it is not intended to be complete and must be supplemented by outside reading.

At this point the reader should have gained a clear understanding of the current state of knowledge as it applies to your experiment, and is now ready to read about how you actually did the experiment.

Apparatus and Experimental Procedure

This section should contain sufficient detail so that another researcher in your field could use your description to replicate the experiment. Be complete, accurate and precise. Do not copy the instructions given in the lab notes. Use your own wording to say what you really did and what actually happened. Do not waste time by stating the obvious: the reader does not wish to know that the power supply was switched on or that you connected a wire from point A to point B. Standard laboratory equipment does not need to be described, but if you used a special piece of apparatus to measure something, it is important to tell the reader.

A clear, labeled diagram of the apparatus can save a lot of written description which would be difficult to read if it were part of the text, for example, "*Using the apparatus shown in Figure 1, the time required for a ball bearing to fall was measured over the range of heights 20 cm to 150 cm*." Neatness and clarity are important and good, legible labeling assists enormously in understanding the experiment.

Results

This section describes how you arrived at a final answer. Raw data and rough calculations are not included in the report and should stay in your laboratory notebook. Nor is the reader interested in going through the details of how you multiplied, divided, etc. Introduce each block of information so that the reader knows what is coming up next. Usually a graph is the best way of presenting results because it shows what the data looks like. A graph in a formal report is not the same as a graph in a regular lab report. The main purpose of the graph in your lab notebook is to aid calculation; in the formal report, graphs serve mainly as illustrations, which must be clear, neat and uncluttered so that readers do not have to work too hard to get the message. Do not fill up empty spaces on the graph with calculations of slopes and the like. In the professional literature, graphs do not usually have titles, but will have a descriptive figure caption. The axes will be labeled

and additional information should either be placed in the main body of the report, or in the figure caption.

All tables must be numbered using Arabic numeric. A caption should be positioned at the top of the table. If the caption is written in a single line, it should be centered. If the caption is written more than one line, it should be align to the left. Tables must be numbered with respect to the chapter. For example, Table 4.3 is the third table that appears in chapter 4. The example is as follows:

Table 4.3 : Comparison of exprimental and computer simulation results

Distance Ratio	Experiment (mean value)	Computer Simulation (mean value)
0.125	0.25	0.137
0.250	0.46	0.560
0.375	0.63	0.738
0.500	0.75	0.861
0.625	0.83	0.939
0.750	0.88	0.981
0.875	0.93	0.997
1.000	1.00	1.000

A table should be positioned after it is being cited for the first time in the text. All tables in the chapter can also be grouped together and positioned at an appropriate location.

Illustrations such as maps, charts, graphs, drawings, diagrams, and photographs are referred as *figures*. Introduce each figure by pointing out its most important feature, for example, "*We see from Figure 2 that the temperature becomes constant after approximately half an hour*." Similarly, each figure should have a caption so that the reader can understand its content, for example, "*Figure 2. Variation of temperature with time, using the specific heat apparatus*."

All figures must be clear and of high quality. Figures must be numbered using Arabic numeric. A caption should be located at the bottom of the figure. If the caption is written in a single line, it should be centered. If the caption is written in more than one line, it should be align to the left. Figures are numbered with respect to the chapter. For example, Figure 4.3 is the third figure that appears in chapter 4.

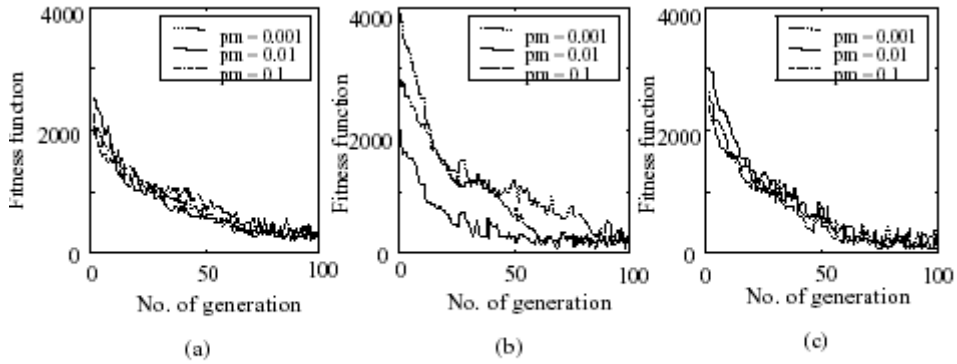

Figure 4.3 Simulation results for model 1 on effect of varied crossover and mutation a) $p_c = 0.05$, varied p_m, b) $p_c = 0.6$, varied p_m c) $p_c = 0.95$, varied p_m

A figure should be positioned after it has being cited for the first time in the text. All figures in the chapter can also be grouped together and positioned at an appropriate location.

Then just say what you did to obtain the result. For example, "*The value for the coefficient of viscosity was obtained from the slope of the graph of Q versus P.*" or "*The experimental value for the speed of sound in air was calculated using Equation (6).*" and state the final result. Include the uncertainty where appropriate, but keep the arithmetic details in your lab notebook.

You can save graphs in various formats (e.g., jpeg or pdf), which can be imported, into your document. In the final document, the graph will be placed in the body of the report, with text above and below it, as you might see in any textbook. You can, if you wish, print the graph on a separate page and attach it to the back of the report, making sure that it has a clear figure caption. Do not use brand names such as *Mathematica*, in your report. You should say something more generic, like "*a mathematical software package*".

If an experiment consists of several parts, you should describe the procedure and results for each part separately, rather than list everything together.

It is essential that you present your results carefully. Merely supplying the equations or diagrams and expecting the reader to interpret them without guidance from you is not sufficient. Only then can you effectively discuss your results and present your conclusions.

Discussion

The Discussion is the most difficult part of the report to write, but it is also the most important because it describes the relation between your results and the theory. The reader needs to know the outcome of such a comparison. You must provide evidence that you have thought carefully about the meaning of the results.

Try starting with the words, "*The results show that . . .*" and then say what happened. For example, "*The results show that the data can be modeled by a straight line fit, exactly as predicted by theory. From this, we can conclude that our hypothesis is correct.*"

State your conclusions as clearly as possible and summarize your evidence for each conclusion. Excessive length is not a virtue. If you have performed an experiment to determine the acceleration due to gravity and you find that your value for g agrees with an accepted value for your location, there is probably little else to say besides that. On the other hand, if the result shows something unexpected, you might write something like, "*We note that the straight line does not pass through the origin, as expected. This may be due to . . .,* and carry on from there, telling the reader what you consider to be important.

The Discussion is not the place to list "*sources of error*", or to include a verbose description of why things might have gone wrong. While appropriate (and necessary) in your lab notebook, to say that certain conditions of the experiment "*may have caused error*" communicates no useful information unless you cite some specific evidence or a plausible mechanism pointing to that fact. As an experimentalist, you should have already taken care to minimize uncertainties.

Focus your attention on questions like these:

- What results were expected? What results were obtained? Is some other physical phenomenon showing itself that had not been predicted by theory?
- Do any of your results have particular technical or theoretical interest?
- How do your results relate to your experimental objective?
- How do your results compare to those obtained in similar investigations? Have you discovered anything new or unexpected?
- What are the strengths and weaknesses of your experimental design?

The reader should come away from the discussion with a clear message about what you have done and what you have discovered. What do you want the reader to remember about your work?

Discussion that been made usually been prepared with help from some references. For each references that been made, we need to cite it. Citation is a means of formally recognizing within the text, the resources from which the information or idea were obtained. The purpose is to acknowledge the work of others, to demonstrate the body of knowledge in which the work is based on and to lead others for further information. Citation in the texts must be written according to any one of the styles described as in following:

Citing in the Text

The references cited in the text should be indicated using the name of the author and the date of publication. Examples are as follow:

- If the name of an author is written as part of a sentence, the year published should be written in parentheses.

"Works by Yao (1993) have shown that in order to maintain the behavioural link between the offsprings and their parents, the use of crossover operator should be avoided."

- If the name of an author is not written as part of a sentence, both the name and year published should be written in parentheses.

  "ANN offers useful properties and capabilities such as non-linearity, input and output mapping, adaptability and fault tolerance among others (Haykin, 1999)."

- If there are two authors for a cited reference, both names should be written.

  "In designing the model for non-linear system, the parsimonious principle (Soderstrom and Stoica, 1989) is critical because a non-linear model involves an excessive number of parameters."

  "Syu and Chang (1999) successfully used neural networks to adaptively control *Penicillin acylase* fermentation."

- If there are more than three authors for a cited reference, use *et al*. after the name of the first author.

  "The algorithm can be calculated by applying Gram-Schmidt procedures as described by Korenberg *et al*. (1988)."

- If more than one reference materials by the same author in a same year are cited, use small letter alphabets (a, b, c, and so on) to distinguish them.

  "Some of the basic principles widely used by many researchers are Lagrange-Euler (LE) equations (Uicker, 1965; Bejczy and Paul,1981), Newton-Euler (NE) equations (Luh *et al*., 1980a) and d'Alembert (G-D) equations (Lee *et al*., 1983)."

  "Luh *et al*. (1980b) presented an example of an acceleration control of robot arm/manipulator."

- Cross referencing in not allowed. Only primary sources should be used.

Conclusions

Take an overview of the experiment. Draw conclusions from the results and discussion that answer the question, "So What?" Avoid phrases like, "*The results agreed with theory within the limits of experimental error*." In this section you may also criticize the lab experiment and make recommendations for improvement. However, such criticisms should focus on the lab as a learning experience; mere complaints about faulty equipment or the amount of time spent are not appropriate.

Note: The Results, Discussion, and Conclusions sections can be combined in various ways. Use whatever combination is most appropriate for your situation.

Bibliography

References are detailed description of items from which information were obtained in preparing the report. All references must be listed at the end of the text. Each reference that you cite should be listed at the end of the report. It should be as complete as possible so that the reader should have no trouble locating it. References to a book should look like this:

Baird, D. C., *Experimentation: An Introduction to Measurement Theory and Experiment Design*. 3rd Ed., (Prentice-Hall, Englewood Cliffs, 1995), pp. 157–170.

A reference to the melting point of sodium chlorate might be given as

CRC Handbook of Chemistry and Physics. 71st Ed., 4-103, edited by David R. Lide, CRC Press (1990).

Journal articles are referenced like this:

Deacon, C. G., *Error analysis in the introductory physics laboratory*, The Physics Teacher, 30, 368–370 (1992)

Documents retrieved from the World Wide Web should be cited as follows:

Jacobson, J. W., Mulick, J. A., & Schwartz, A. A. (1995). *A history of facilitated communication: Science, pseudoscience, and antiscience: Science working group on facilitated communication*. American Psychologist, 50, 750–765. Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/journals/jacobson.html

It is important to use "Retrieved from" and the date because documents on the Web may change in content, move or be removed from a site altogether.

Further information about reference styles can be read out in following section.

Writing Style for Authors' Names in the List of References

Generally authors' names are listed using surname followed by their initials. The followings are examples of writing style according to the name of the author:

(i) Single and multiple authors

> *Example (single author):*
> Veres, S. M. (1990). *Structure Selection of Stochastic Dynamic Systems*. New York: Gordon and Breach Science Publishers.

Example (two or more authors):
Soderstrom, T., and Stoica, P. (1989). *System Identification*. United Kingdom: Prentice Hall International Ltd.

Luh, J. Y. S., Walker, M. W., and Paul, R. P. (1980b). Resolved-Acceleration Control of Mechanical Manipulators. *IEEE Trans. Automatic Control*. 25(3): 468-474.

(ii) Editor

Example:
Martin, A. M. ed. (1991). *Peat as an Agent in Biological Degradation of Waste*. London: Elsevier

Lees, R. H. and Thomas T. R. eds. (1974). *Chemical Nomenclature Usage*. Chichester: Ellis Horwood.

(iii) Corporate author/editor

Example:
Engineers Joint Council (1969). *Thesaurus of Engineering and Scientific Terms*. New York: Engineers Joint Council.

Writing Style for Various Types of Publication Materials in the List of References

Frequently, different types of publication materials are cited in a thesis. The style of writing details on cited publication in the List of References should be as follows:

(i) Book

Author (Year). *Title*. Edition (if not the first). Placed published: Publisher.

Example:
Theusen, G. J. and Fabrycky, W. J. (1984). *Engineering Economy*. 6th ed. Englewood Cliffs, N. J.: Prentice-Hall.

(ii) Article in a book

Author of the article (Year). Title of the article. In: Author of the book. *Title of the book*. Place published: Publisher. page.

Example:
Hussein, S. B., Jamaluddin, H., Mailah, M. and Zalzala, A. M. S. (2000). An Evolutionary Neural Network Controller for Intelligent Active Force Control. In: Parmee, I. C. ed. *Evolutionary Design and Manufacturing*. London: Springer-Verlag. 351 –362.

(iii) Journal articles

Author (Year). Title of the article. *Title of the Journal*. Volume (Number): page.

Example:
Billings. S. A. (1980). Identification of Nonlinear Systems: A survey. *Proc. IEE, Part D*. 127(6): 272-284.

(iv) Conference articles

Author (Year). Title of the article. *Name of the conference*. Date of the conference. Place published: Publisher, page.

Example:
Sheta, A. F. and De Jong, K. (1996). Parameter Estimation of Nonlinear Systems in Noisy Environments Using Genetic Algorithms. *Proceedings of the 1996 IEEE International Symposium on Intelligent Control*. September 15-18. Dearborn, Michigan: IEEE, 360 - 365.

(v) Thesis

Author (Year). *Title of the thesis*. Institution: Thesis award.

Example:
Adnan bin Hassan (2002). *On-line Recognition of Developing Control Chart Patterns*. Universiti Teknologi Malaysia: Ph.D. Thesis.

(vi) Legislations

Name of the country (year). *Title of the legislation*. Legislation number.

Example:
Malaysia (1983). *Perintah Monumen Lama dan Tapak Tanah Bersejarah*. P.U.(A)41 1983.

(vii) Standards

Name of the institution (Year). *Title of the standard*. Place published, standard number.

Example:
British Standards Institution (1987). *Tongued and Grooved Software Flooring*. London, BS 1297.

(viii) Patent

Owner's name (Year). *Title of the patent*. (patent number).

Example:
Lindgren, E. A. (1960). *Screen Room Air Inlet and Wave Guard*. (U.S. Patent 2, 925, 457).

(ix) Commercial catalogue

Name of distributor (Year). *Title*. Place published: Note.

Example:
Howick Partitioning Ltd. (1984). *Howick: Partitioning in Business*. Redhill (U.K.): Trade Brochure.

(x) Measured drawings

Name (Year). *Title*. Place published: Note.

Example:
Zairul Azidin Badri (1980). *Rumah Kutai Haji Sahak, Kampung Tanjung, Kampung Gajah, Perak*. UTM: Lukisan Terukur.

Salim Man (1989). *Pengisi Sekam ke Dalam Kontena Penyimpan: Pandangan Isometrik*. UTM: Lukisan Teknik.

(xi) Unpublished materials

Name (Year). *Title*. Place/Institution. unpublished.

"unpublished" should be written at the end.

Example:

<u>Sample of a reference list using author and year system</u>

Ahmad Zaki Abu Bakar (1989). *Pemprosesan Teks Bahasa Melayu UntukPemahaman Komputer*. Universiti Teknologi Malaysia: Tesis Doktor Falsafah.

American Chemical Society ed. (1978). *Handbook for Authors of American Chemical Society Publications*. Washington, D. C.: American Chemical Society.

Billings. S. A. (1980). Identification of Nonlinear Systems: A survey. *Proc. Instn Electr. Engrs, Part D*. 127(6): 272-284.

Engineers Joint Council (1969). *Thesaurus of Engineering and Scientific Terms* . New York: Engineers Joint Council.

Martin, A. M. ed. (1991). *Peat as an Agent in Biological Degradation of Waste*. London: Elsevier. 314–362.

Puget, J. F. and Albert, P. (1994a). *SOLVER: Constraints – Objects Descriptions*. Technical Report. ILOG S. A.

Puget, J. F. and Albert, P. (1994b). *A C++ Implementation of CLP*. Technical Report. ILOG S. A.

Sheta, A. F. and De Jong, K.(1996). Parameter Estimation of Nonlinear Systems in Noisy Environments Using Genetic Algorithms. *Proceedings of the 1966 IEEE International Symposium on Intelligent Control*. September 15-18. Dearborn, Michigan: IEEE, 360-365.

Sukiman Sarmani (1987). Pencemaran Radioaktif. Dlm. Ahmad Badri Mohamad. *Perspektif Persekitaran*. Petaling Jaya: Fajar Bakti. 71-87.

Theusen, G. J. and Fabrycky, W. J. (1984). *Engineering Economy*. 6th edition. Englewood Cliffs, N. J.: Prentice-Hall.

Veres, S. M. (1990). *Structure Selection of Stochastic Dynamic Systems*. New York: Gordon and Breach Science Publishers.

Note: Arranged alphabetically according to author's name.

Appendix

Appendices are supplementary materials to the text. These include tables, charts, computer program listings, and others. An appendix is not necessary, but may be used to put additional information about the experiment, where it will not interrupt the flow of the main text. The derivation of a complicated equation might go here, for example. You would refer to it in the body of the report with a sentence like "*A full derivation of Equation (7) is given in Appendix 1*". This way, the reader should be able to follow what you have done without reading the appendix (but the details are there if the reader chooses to look at it). Raw data is not normally put in an appendix, unless you believe that the reader should see it. You always have your lab notebook as evidence of your original measurements. Do not put final graphs in the appendix. If you choose to include an appendix, it must be readable as a separate document.

The following should be noted:

- Appendix is not a must in a thesis. If necessary, data used for analysis, example of questionnaires, maps, photographs and other materials which are lengthy to be included in the text or materials that are not required implicitly to clarify matters discussed can be accompanied as appendix.
- Appendix can be named as Appendix A, Appendix B, and so on, depends on types and quantity to be included. Specific titles can also be given.