ISSUE 8 • SPRING 1999

Counting on IT

INFORMATION SYSTEM ENGINEERING

A Good First Year for the SS*f*M Programme and Club

Networking at the 2nd SS*f*M Club Meeting

The Software Support for Metrology (SS*f*M) Programme has had a good first year. Many of the results will be evident from this newsletter. A particular success has been the establishment of the SS*f*M Club.

The SS*f*M Club enables users and suppliers of metrology software to benefit from the programme, to meet one another, and to influence the future direction of government-funded work in this area. Members receive regular notification of events covering topics such as integrity of spreadsheet data and reliability of instrumentation and equipment, and are able to meet and discuss current problems central to metrology and metrological based services.

The club has now been running for a year, and has a broad base of membership including people from about 90 different organisations. Two meetings have been held so far, the club launch in September 1998 and the Spring 1999 meeting which took place during March.

The introductory meeting was attended by nearly 40 people from a broad range of metrology and software related organisations and disciplines. Its main themes were:

- introduction to the programme and the related INTErSECT partnership
- spreadsheet quality - how to work with spreadsheets to ensure the integrity of your data
- the reliability of instrumentation and equipment used for measurement purposes
- data fusion
- measurement system validation

The Spring 1999 meeting was attended by around 50 delegates and again there was an opportunity for them to meet other Club members and to talk to people with concerns and solutions to problems in the area of metrology software. The meeting provided delegates with information on a number of new projects within the SS*f*M Programme and presented the findings from the Status Reports on the use of software and mathematics in all areas of metrology.

Other topics covered included:

- an introduction to the National Measurement Partnership
- the impact of legacy software issues including the millennium bug in metrology
- a software best practice proposition
- designing and using mathematical models in measurement and testing
- model validation
- visual modelling
- human factors in measurement

Analysis of feedback forms showed that both meetings were perceived to be useful and successful, with over 80% of responses to both meetings in 'good' or 'excellent' categories, confirming their value to Club members.

Contents

NPL National Physical Laboratory

Club Administrator, Wendy Johnson; Programme Manager, Dave Rayner; and Club Secretary, Cathy Thomas

If you join the SS*f*M Club from April 1999, you will be entitled to two free Club meetings per year. In addition, you will receive:

- a discount on related meetings
- access to draft documents and other important documents as they are released
- access to the private section of the website and bulletin board
- priority for free consultancy service through the NPL helpline
- e-mail notification of news and events
- opportunity to feed into the programme

Membership from April 1999 to March 2000 costs £110, or £95 for existing members. Membership is for a named person within an organisation, with benefits fully transferable on a permanent or temporary basis within the organisation.

With the overall aim of promoting the UK's economic competitiveness by helping to support needs in metrology, the SS*f*M Programme should have a significant influence on the development of metrology software in the future. It is therefore vital to obtain feedback from metrologists and metrology software developers, and the Club is the main avenue for this.

For further information contact the Club Administrator:
extension 6106 or 7100
e-mail: ssfm@npl.co.uk or visit the SS*f*M website:
http://www.npl.co.uk/ssfm/

SS*f*M Status Reports

Two NPL Reports have been published as a result of research into the current status of software and mathematics activities in the context of metrology programmes. These are:

- Initial Status Report on Software Activity Worldwide, by B Butler - NPL Report CISE 17/98, December 1998
- Initial Report on Status of Software and Mathematics in Each Metrology Area, by D Rayner - NPL Report CISE 18/99, February 1999

The latter report gives a synthesis of findings on surveying the status in each metrology area covered by a UK National Measurement System programme (excluding Legal Metrology). It is structured according to the themes and projects of the SS*f*M Programme.

In the Modelling Techniques area, it reveals that discrete models (those using algebraic equations) are used in all areas of metrology, whereas continuous models (those using differential equations) are currently only used in flow, thermal and electrical metrology, although their use is increasing. Hybrid models (using both algebraic and differential equations) are currently only used in length metrology.

"discrete models are used in all areas of metrology"

In the Uncertainties area, most metrologists use the ISO Guide to the expression of Uncertainty in Measurement (GUM). However, deficiencies in using the GUM have been identified in 13 different situations, where the assumptions of the GUM do not hold. The UKAS training course on uncertainties is adequate for most metrologists, but a significant minority need training in techniques which fall outside the GUM (e.g. robust statistics, non-parametric methods, techniques to handle correlations and non-Gaussian distributions). These findings have validated the focus of the SS*f*M Uncertainties project on those techniques which fall outside the GUM.

The most widely used packages for processing measurement data are found to be:

- Excel - in 10 areas
- MathCad - in 8 areas
- MatLab - in 7 areas
- LabView - in 6 areas
- Mathematica - in 6 areas

Metrologists perform relatively little testing and validation on such packages, but it is clear that not all mathematical functions in such packages are sufficiently accurate or stable for use in precision measurement applications.

The most widely used programming languages are found to be:

- Visual Basic - in 9 areas
- HT Basic - in 9 areas
- FORTRAN - in 9 areas
- Pascal - in 8 areas
- HP Basic - in 7 areas

Possible case studies have been identified in all but one of the SS*f*M project areas. The exception is the project on Guidance on Development of Metrology Software. The areas in which we are spoiled for choice of case studies are Uncertainties, Visual Modelling and Data Visualisation, and Automation of Measurement and Calibration Processes.

In surveying the status of software activities worldwide, we received input from Australia, Austria, Brazil, Denmark, Germany, Greece, Indonesia, Ireland, Italy, Japan, Singapore, South Africa, Taiwan, USA and BIPM. Only one similarly broad SS*f*M-type programme was identified, in CSIRO in Australia. Some countries have programmes addressing particular topics in particular metrology fields. A few have purely internal programmes and a few have programmes to support Quality System Certification. Nevertheless, many wish to collaborate with SS*f*M.

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Guidance on Developing Software for Metrology (GDSM)

Introduction

The SS*f*M GDSM project started around Christmas 1998 and runs through to September 2000. It will produce a best practice guide to help with the construction of software for metrology applications combined with awareness articles and events.

Members of the project team are keenly aware that the guide must be easy for people in the target audience to use. Past experience suggests that if the guide is to be adopted widely it must cater to the special needs of the metrology community: they must feel it is their guide. The guide will therefore be structured to be consistent with the needs of the automated metrology community and establish best practice and capture views expressed by the sources interviewed in the data gathering phase.

Background

Over the years there have been many initiatives to improve software development practice. In the UK the most recent was the DTI TickIT programme. For the first time, the TickIT Guide presented a detailed picture of how the software industry functioned. It defined the necessary roles of the purchaser, supplier and auditors and recognised software as a project based activity. Similarly we expect the first issue of the guide to development of software in metrology to show the particular importance of a sound project based method.

A major strength of the GDSM project requirement is its insistence that the guide must contain a flexible, scaleable methodology for the construction of metrology software. Our intention is to provide a development method that closely fits the requirements of the metrology sector, to the extent that its benefits will be self evident. We will therefore identify critical processes necessary to the successful creation of metrology applications. Predefined processes are easier to apply to small projects than to large ones, so particular attention will be paid to how important an appropriate choice of project scope is to achieving successful metrology software projects.

To many, the success of TickIT might suggest that there is sufficient in the TickIT Guide to render a separate guide for the development of software for metrology unnecessary. Certainly the GDSM project is a much smaller and more focused undertaking as a result of the existence of TickIT. But in the same way that TickIT exposed the lack of guidance for software development under the umbrella of ISO 9000, GDSM seeks to serve those who need more detailed guidance for the particular problems of software in metrology.

David Brinkley at the 2nd SS*f*M Club Meeting

Issues

Existing best practice on software system development is principally concerned with developing a system according to an agreed specification without much regard to hardware issues, e.g:

- hardware control is performed implicitly by the host system
- data recovery and processing is performed by the host system according to user domain instructions, e.g. instructions written in a 4GL for business applications, or in Ada for scientific applications

Such advice is useful as far as it goes, but usually neglects the methods required for verification of measurement channels containing combinations of unverified hardware controlled by unverified software.

To make the Guide as easy as possible to apply, for systems of all sizes, the guidance will be organised according to complexity. Three levels of complexity are currently defined by the applicability of five types of function performed, as listed in Table 1.

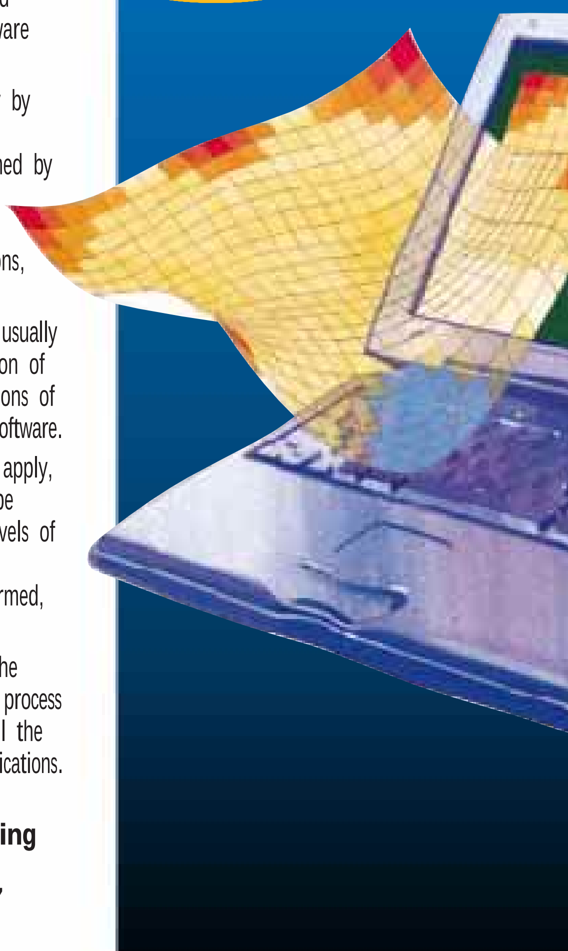
We envisage that by linking criticality to the degree of rigour applied in the construction process the guide will be a viable document for all the projects building new metrology software applications.

For further information or to participate in the data gathering exercise please contact:
David Brinkley, 0171 446 1477
e-mail: brinkley@logica.com
or visit the GDSM page on the SS*f*M web site

Level of Complexity	Types of Function Performed
1 - Low (data processing only)	the application processes the metrology data (also in complexity levels 2 & 3);
2 - Medium (commanded data read out & processing)	the application reads data directly from the measurement system (also in complexity level 3);
3 - High (substantial/complete control within the metrology process envelope)	application decides when to read the data; application validates all the readings, e.g. stability verification, range and function verification; the application controls the test environment using direct control inputs;

Table 1: Functions relevant to each complexity level

"a viable document for all the projects"



Up a GUM tree?

The ISO Guide to the Expression of Uncertainty in Measurement (GUM) is a key document used by National Measurement Institutes and industrial calibration laboratories as the basis of evaluating the uncertainty in the output of a measurement system.

The system is modelled using a functional relationship between measured quantities $x = \{x_i\}$ (the inputs) and the measurement result y (the output) in the form

$$y = f(\mathbf{x}).$$

The (combined) standard uncertainty of y is then evaluated from

$$u_c^2(y) = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{\partial f}{\partial x_i} \frac{\partial f}{\partial x_j} u(x_i, x_j),$$

where the quantities $\partial f / \partial x_i$ are referred to as sensitivity coefficients, and $u(x_i, x_j)$ is the covariance of x_i and x_j, with $u(x_i, x_i) = u^2(x_i)$, the variance of x_i. The GUM recommends that the uncertainty in the measurement result y is expressed as a confidence interval at some probability level (typically 95%). The half-width of this interval is the expanded standard uncertainty $U_c(y)$ obtained as the product of $u_c(y)$ and a coverage factor k.

"GUM is a key document used by National Measurement Institutes"

To apply the GUM approach, two main assumptions must hold:

- The adequacy of the formula for $u_c(y)$ which is derived by propagating uncertainties in a first-order approximation to the model of the measurement system.
- The distribution of y is known, e.g., Gaussian or Student's-t, in order to obtain the value of k.

Some GUM users are experiencing problems in meeting these conditions, although it is important to confirm that they apply for a given application. NPL is involved both in-house and in collaboration with other National Measurement Institutes and standards bodies, in activities to promote sound methods of uncertainty evaluation. Although the GUM is a far-reaching document, and is appropriate for many applications, NPL's work includes presenting extensions and enhancements to the GUM to cover situations in which the assumptions indicated above do not apply or are untested. It is also an intention to provide "easy-to-use" computer-based approaches. Sampling techniques, such as Monte Carlo simulation, provide an alternative approach to uncertainty evaluation in which the propagation of uncertainties is undertaken numerically rather than analytically. Such techniques are useful for validating the results returned by the application of the GUM, as well as in circumstances where the assumptions made by the GUM do not apply. In fact, these techniques are able to provide much richer information, by propagating the distributions (rather than just the uncertainties) of the inputs x through the measurement model f to provide the distribution of the output y. From the output distribution, confidence intervals or confidence regions (in the multivariate case) can be produced, as can other statistical information. The first box shows how sampling techniques can be used to evaluate the uncertainty $u_c(y)$.

"easy-to-use" computer-based approaches"

STANDARD UNCERTAINTY OF THE OUTPUT

Form N samples $\mathbf{x}_k$ of the measured quantities $\mathbf{x}$.

For $k = 1$ to N, evaluate y_k from $y_k = f(\mathbf{x}_k)$.

Evaluate sample standard deviation for the y_k to give $u_c(y)$.

The input data $\{x_k\}$ for this process can be provided in a number of ways. One way is to generate random samples $\{x_k\}$ from the (possibly joint) probability distribution for the inputs x. For example, x may be described by a multivariate Gaussian distribution with prescribed mean vector and covariance matrix. Alternatively, the components of x may be independent and each follow a given univariate Gaussian or uniform distribution. The application of the sampling scheme corresponds to a "Monte Carlo" simulation (MCS). The scheme is not difficult to implement in general terms. Just the model and the input distributions (but not its sensitivity coefficients as required by the GUM approach) are needed. Sampling techniques can also form the basis for calculating expanded uncertainties or confidence intervals. Given the y_k as determined in the first box, the second box shows how to evaluate the 95% confidence interval for the measurement result y.

CONFIDENCE INTERVAL FOR THE OUTPUT

Sort the values $\{y_k\}$ into non-decreasing order.

Form the 2.5-and 97.5-percentiles in this list to define the required confidence interval.

In the use of MCS to validate the results produced by the GUM in any individual case, the GUM results can be accepted if the resulting uncertainties agree to within, say, two significant figures (which is adequate for most purposes). If

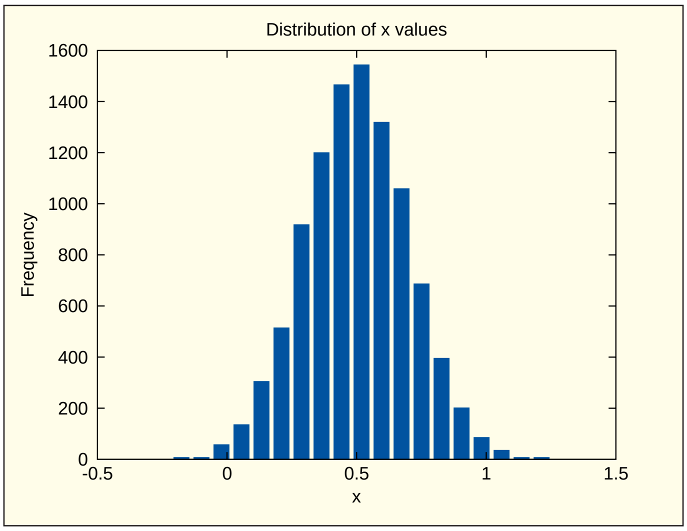


Figure 1:
Sampling distribution for input x

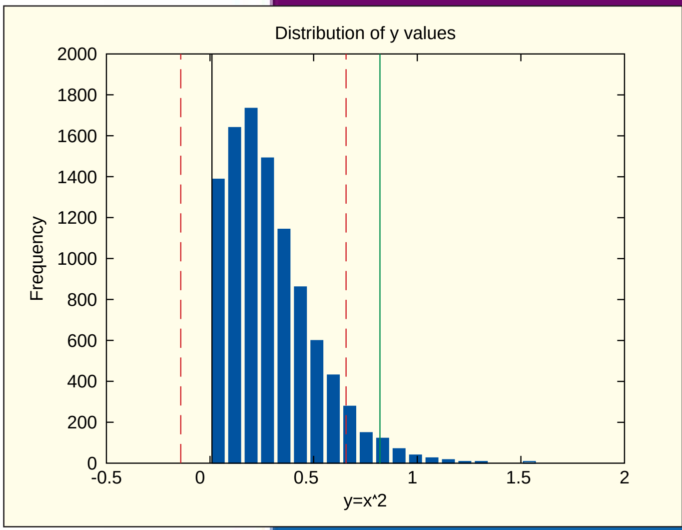


Figure 2:
Sampling distribution for output $y = x^2$. The 95% confidence intervals evaluated according to the GUM (broken lines) and using MCS (solid lines) are also shown

such agreement is not observed then either a mistake has been made in applying the GUM (e.g., in determining the sensitivity coefficients) *or* the conditions for its application do not hold. If the latter applies, it would be appropriate to regard the MCS results as being scientifically more sound.

Monte Carlo simulation can be a good bet

Both GUM and MCS work with the same model and input distributions, and the quality of the results obtained depends on the quality of this information. Moreover, MCS requires a value to be specified for N, the number of Monte Carlo trials. We have found $N = 10\ 000$ to be satisfactory in many cases.

Figures 1 and 2 illustrate the use of the GUM and MCS for the simple model $y = x^2$. Figure 1 shows the sampling distribution for the input x which is chosen to be Gaussian with mean 0.5 and standard deviation 0.2. Figure 2 shows the corresponding sampling distribution for y. Each distribution is based on a sampling size of $N = 10\ 000$. We also indicate in Figure 2 the 95% confidence intervals evaluated according to the GUM (broken lines) and using MCS (solid lines) as described above. The fact that these intervals are appreciably different reflects the non-Gaussian behaviour of the output y. The 95% confidence interval evaluated according to the GUM is clearly not reliable because it includes infeasible (negative) values of the output y.

This work forms part of the current activity within the Uncertainties and Statistical Modelling project of SS*f*M.

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The Impact of Year 2000 on Metrology

The so called "Millennium Bug" has made national and international headlines and raised public awareness of the problems that can arise with legacy software. NAG, in collaboration with NPL, has investigated the impact of the year 2000 in metrology as part of the Software Re-use project in the SS*f*M programme. This project aims to solve some of the problems of legacy software and software re-use in metrology by designing a library of re-usable metrology functions: the first part of the project is an investigation of legacy issues.

Millennium legacy - the bug is more of a worry than the dome

The Millennium Bug is a particular instance of problems that can occur with legacy software. The most apparent feature of this particular problem is the use of 2 digits to represent the year elements in dates, which does not in itself create problems provided all dates of interest are in the same century. However related to this feature is the possibility of incorrect logic being used in date based computations. As a result, computer systems or any equipment based on microprocessors may fail, malfunction or corrupt data.

A precise definition of "year 2000 conformity" is given by the BSI committee BDD/1/3 in terms of four rules: no value for the current date will cause any interruption in operation; operations on dates behave consistently for dates prior to, during and after year 2000; the century in any date must be specified explicitly or can be unambiguously inferred; and the year 2000 must be recognised as a leap year.

To provide a solution to the Millennium Bug you need to determine whether it is actually a problem in practice. Whilst it is recognised that many systems will exhibit some form of problem, a large number systems will not be affected at all. It is therefore necessary to gather information about the exposure of a particular computing environment to the problem. It is also necessary to analyse the risks involved to determine the seriousness of such problems. There are various approaches to solving the Millennium Bug (i.e. achieving year 2000 compliance): in the case of externally supplied software, you can seek a statement of compliance from the supplier; or, if available, you can inspect the software source, or the software can be tested, for example by turning the machine clock forward. There are tools available to check source code by looking for particular strings or uses of particular functions in the code. There are also packages for testing compliance by simulating the operation of software at various key dates.

In order to assess the extent to which the metrology programmes are affected by the year 2000 problems, we used information from those responsible for the software in the various metrology areas. The initial status reports on each metrology programme provided a general overview with respect to specific programmes. We went on to ask detailed questions (expanded from the BSI rules) of individuals with knowledge of software in particular metrology programmes. We found that most software in metrology does not use dates and some program suites (such as production of certificates) go out of their way to avoid using dates. Where dates are used, some manipulations are done using Modified Julian Date (MJD), which is a count of the number of days from a fixed date in the past. In particular, this is the approach adopted by the Time and Frequency programme in their software.

In general, the metrology programmes are confident that the year 2000 problem is largely under control. This confidence stems from detailed knowledge of the operation and requirements of each measurement system but that alone may not be sufficient to guarantee consistent operation into the next Millennium. To achieve this the emphasis must move to the verification of operational characteristics consequently the use of consistency checks using calibrations done both before and after January 1 are considered to be vitally important.

For further information contact:
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Robin Barker (NPL) extension 7090, e-mail: robin.barker@npl.co.uk

siratechnology centre

DTI chooses Sira for data visualisation project

A project to improve modelling techniques in metrology has been awarded to Sira by the National Measurement System Policy Unit (NMSPU). Part of the DTI's software support for metrology programme, the one-year project relates to visualisation of data and visual modelling.

This fast-moving field is seeing the development of a wide range of software tools. Many of the technologies involved were developed in other areas, such as medicine, entertainment or IT, and may not be widely known to those working in metrology. To make the best use of data visualisation, the metrology community needs to be aware of the advances taking place in other areas and to adapt them to their own requirements.

On awarding the contract, Roy Crouch from the NMSPU, commented: "Sira's proposal was successful because, as well as their strong core expertise, they were able to offer a range of technology transfer services".

When completed, the project will issue a written report which will include a number of case studies. An interactive forum and a training course will be organised by Sira to further disseminate the study results.

Sira's chief executive Professor Richard Brook, who is the project director, added: "We are very pleased to be working with the NMSPU to help transfer skills, knowledge and techniques to the metrology community, especially as the project closely parallels work being carried out in our own research and technology transfer programmes".

Making visualisation come alive

Automatic Fault Tree Generation

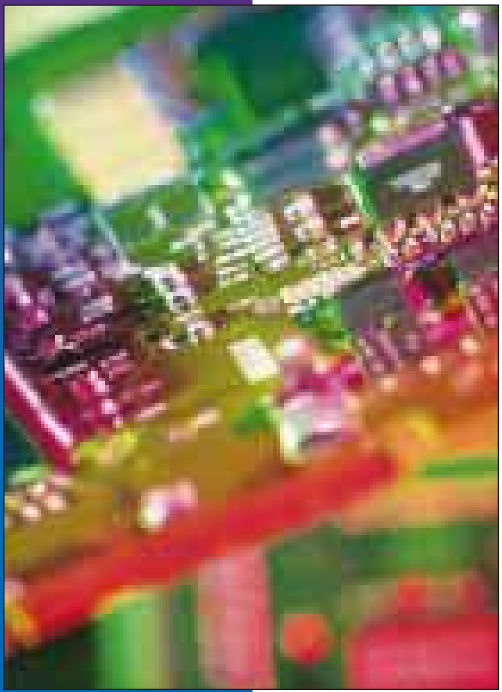
Manual generation of Fault Trees is known to be very error prone mainly because it is difficult to show it's correct in terms of the system specification. NPL is developing a prototype automatic Fault Tree generation tool which:

- takes as input a model of a system and the effects of faults occurring in that system (modelled in Prover)
- automatically generates a Fault Tree given its top event and basic events
- produces output for a reliability tool in this case FaultTree+

The Fault Trees generated will be as correct as the original specification and can be self validating in that they can be proved to conform to the original specification using Prover.

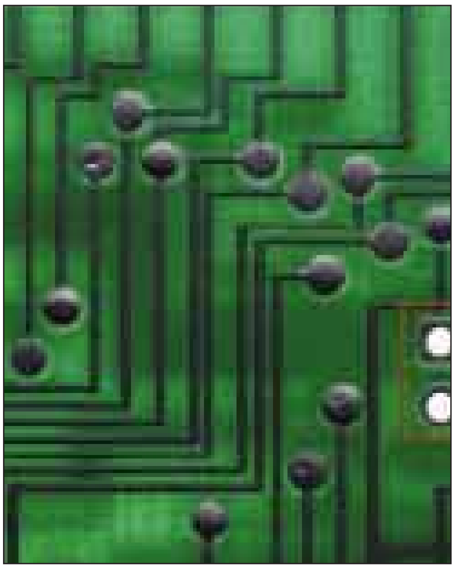
For further information contact: Graeme I Parkin, extension 7104, e-mail: graeme.parkin@npl.co.uk

National Measurement Conference 99 'Measurement for Success'



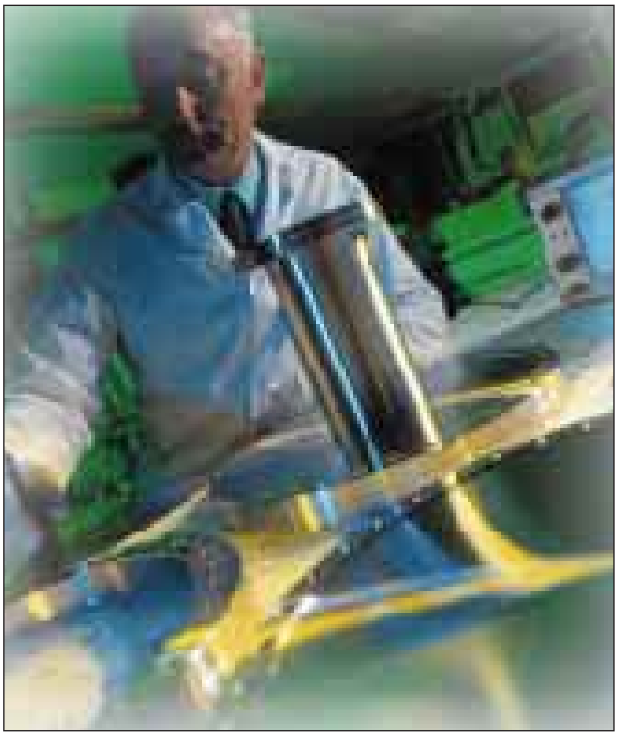
Brighton, 2-4 November, 1999 (Incorporating BEMC 99)

The National Measurement Conference 99 is a three-day meeting devoted to the advancement of measurement technology and practices within the UK. It provides a forum for the dissemination and discussion of technical developments and innovation in measurement science in industry. The conference will focus on issues relating to:



- calibration and measurement techniques
- laboratory accreditation and quality
- consumer protection/trading standards
- general matters of interest to the measurement community including automation, process control, international recognition of certificates, Foresight etc.

The conference offers a unique opportunity for participants to network with colleagues in the measurement industry and to benefit from recent advances in measurement technology. Alongside the technical sessions there will be an exhibition of measurement providers, instrument suppliers and accredited calibration laboratories. A series of workshops and seminars will also run during the conference, addressing common issues of interest to participants, such as the calculation of uncertainties. The conference will also host several National Measurement System Technology Transfer Club meetings, including the SS*f*M Club.



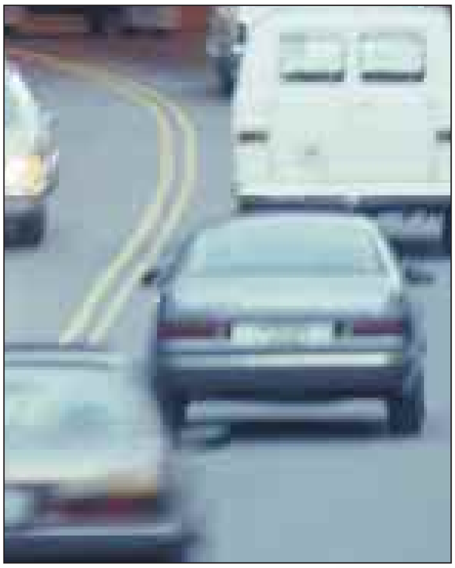
The conference will incorporate BEMC 99, the 9th International Conference on Electromagnetic Measurement. Registration will provide access to all sessions of both conferences.

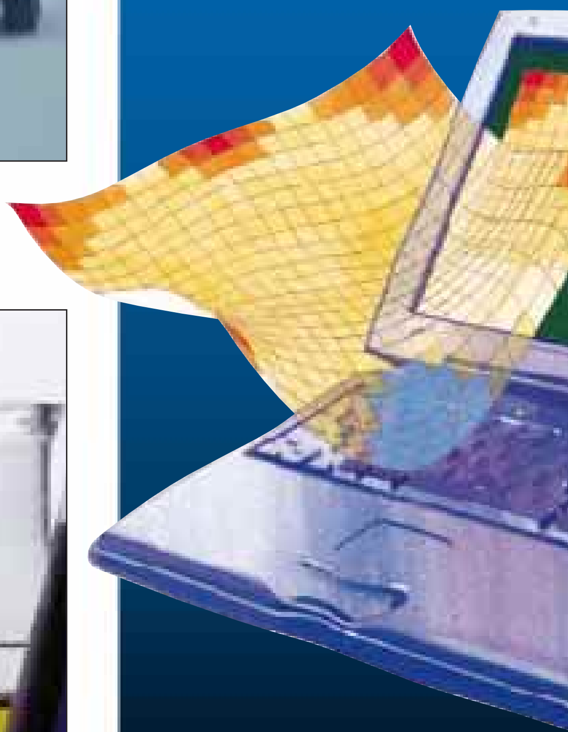
This first call for papers was released in January 1999. Oral and poster papers are sought in the following subject areas:

- metrology for process control
- measurement for the food industry
- metrology for healthcare
- advances in metrology
- metrology for the utilities
- instrumentation
- metrology for telecommunications
- metrology regulation/standardisation
- metrology for defence/aerospace
- legal metrology
- environmental metrology
- consumer protection and measurement
- automotive metrology
- quality and registration (ISO 9000)
- co-ordinate metrology
- laboratory automation and software for measurement
- measurement for engineering
- laboratory accreditation, ISO Guide 25
- electrical metrology (for BEMC 99)
- international recognition of accredited certificates
- chemical and pharmaceutical measurement
- laboratory intercomparison
- biochemical measurement
- best practice for knowledge transfer
- analytical measurement
- foresight

The conference is hosted by the National Measurement Partnership programme (NMP). The programme aims to promote and support better measurement practise in the UK and empower industry to obtain maximum benefit from the National Measurement System.

For further information on this conference or the National Measurement Partnership programme contact:
Debbie Hall at:
NMP Conference Secretariat, NPL, extension 6602,
fax: 0181 943 7099
or e-mail: nmp_sec@npl.co.uk





Virtual Features

Geometric tolerance assessment is important for pistons

Manufactured components coming off the production line are regularly assessed in industrial inspection laboratories using co-ordinate measuring machines. Data obtained by measuring each real feature on each component is analysed for comparison with design specifications. For instance, if a real feature is nominally circular, an associated feature in the form of a best-fitting mathematical circle would be determined for the measurements and its parameters (radius, e.g.) compared with the corresponding values specified in the engineering design. However, if the real feature were to be measured at a different set of points then, owing to the fact that no manufacturing process is perfect, the resulting best-fitting curve or surface would be different. This imperfection, or *form error*, arises from generally repeatable aspects of manufacturing-machine performance such as deformation due to machine-tool elasticity and workpiece fixturing.

Recently-completed work carried out by NPL in conjunction with European partners as part of a project funded by the EU and DTI provides a methodology for assessing the influence of form error in industrial inspection.

The approach enables the number of measurement points to be chosen appropriately, permits measurement bias to be corrected, and quantifies the uncertainty in the fitted parameters. It is based on deriving and using a *virtual feature*, a mathematical definition of the curve or surface of the real feature, which is expressed as the sum of an associated feature and a form-error function. The virtual feature is constructed from detailed measurements of a representative real feature and embodies the key steps:

1. Fit an associated feature (e.g., a circle) to detailed representative measurement data.
2. Take the parameters of the associated feature as reference parameters for the real feature.
3. Calculate the residuals of the associated feature and obtain the form-error function by fitting a suitable mathematical function to their values.
4. Define the virtual feature as the sum of the associated feature and the form-error function.

Following its construction, the virtual feature can be used to:

- synthesise real measurements according to a range of probing (measurement) strategies
- derive detailed statistics for the fitted parameters
- deduce the uncertainties associated with candidate probing strategies
- design optimal probing strategies and to correct the measurement results for systematic bias

For instance, suppose a nominally-circular feature (such as a section of a sphere) is represented by a virtual feature consisting of a Gaussian

The cross-section of a piston should be a circle associated circle and a Fourier series. The circle is represented by its centre co-ordinates and its radius, and the Fourier series as a sum of cosine and sine terms which represents the variation in the radial departure of the real feature from the nominal form. For any choice of probing strategy the virtual feature can be evaluated at the stipulated points and the resulting data analysed.

Figure 1 shows detailed measurements of radial variation as a function of angle of a section of a sphere of nominal radius 12.7 mm. A strong

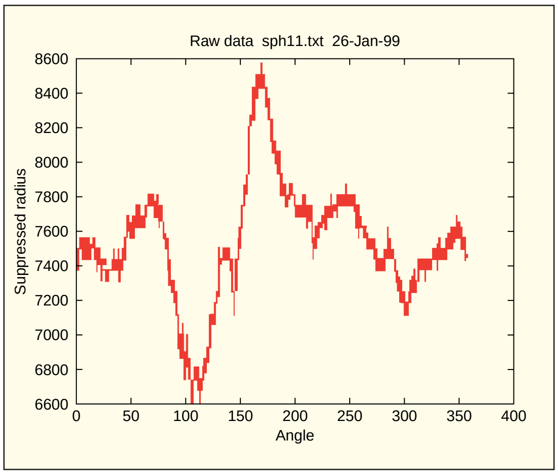


Figure 1:
A plane section of a nominally-spherical artefact in the form of measurements of section of a sphere as a function of angle in degrees

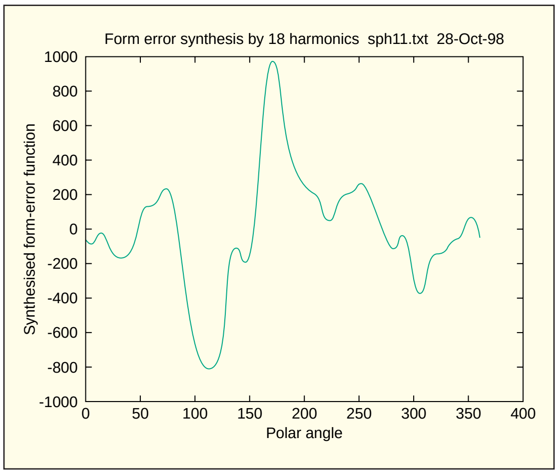


Figure 2:
The synthesised form-error function for the data of Figure 4

(non-random) variation with respect to angle is evident. A validated virtual feature in the form of the sum of a circle and a Fourier series was derived for this data. Figure 2 shows the Fourier part of the synthesised function.

Uniformly-spaced samples of size $n = 4$ were synthesised using the virtual feature for a large number of positions for the first point in the sample, thus simulating the measurement of different sets of points. Figure 3 shows the resulting variation in the value of the radius. These values range from approximately 300 nm smaller to 300 nm larger than the value determined from the complete set of data.

These calculations were repeated for sample sizes varying from $n = 3$ to 20, thus providing the basis for assessing the performance of a range of candidate probing strategies. Figure 4 shows the ranges of values of the radius for these sample sizes. The figure is presented as a set of vertical bars, one bar for each sample size. The midpoint of each bar is indicated, as are the extreme values, i.e., the minimum and maximum radius values obtained from the synthesis. The "reference" radius, i.e., that for "infinite" n is shown as a blue horizontal line.

For any particular value of n the corresponding bar provides an estimate of the bias computed from samples of this size by taking the difference between the value at the midpoint and the reference radius. The endpoints of the bar can be interpreted as providing a confidence interval associated with the midpoint value. Correction of the values obtained from analysing subsequent *real* features for probing strategies with this value of n can be made and the ensuing uncertainty taken as the half-width of this confidence interval.

The use of virtual features provides a practical approach for assessing the influences of form error in geometric tolerance assessment and allows the bias and uncertainties in the parameter estimates to be quantified. The approach is already being used in some of the more challenging calibration problems at NPL.

For further information contact: Maurice Cox extension 6096, e-mail: maurice.cox@npl.co.uk

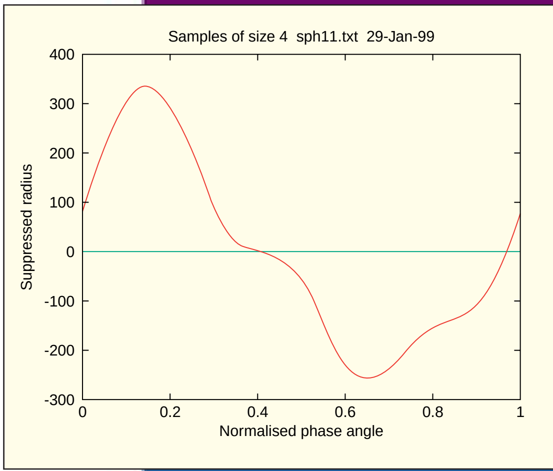


Figure 3:
The sequence of suppressed radius values obtained for sample size n = 4

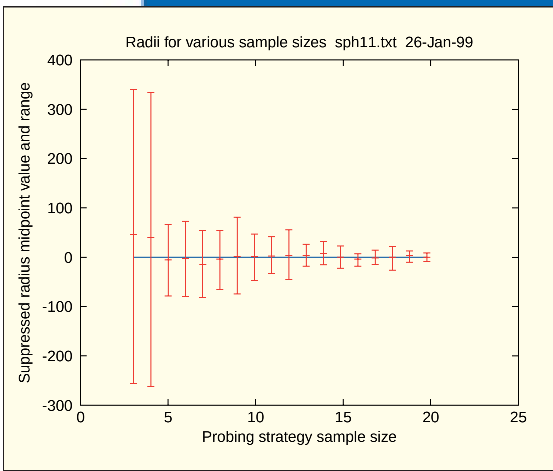


Figure 4:
The ranges of estimates over many synthesised data sets of the (suppressed) radius for probing strategies with different sample sizes

Interactive Web Pages for Metrology

The world wide web

The last year has seen the NPL Web Site enhanced by the addition of the SS*f*M web pages. These have been produced as part of the SS*f*M Web Site project in the programme's Generic Technology Transfer theme, but are only one element of the project. Two further elements examine the rapidly developing technologies allowing interactive manipulation of web page content, such as JAVA and DHTML, to produce two major pieces of work.

The "Guidance and tools for interactive Web pages" document will examine web page authoring best practice, provide guidance on the use of interactivity available and review a range of the development tools available. It will be a valuable document for both novice and experienced web page authors in the enhancement of services provided to National Measurement System users.

The "Examples of interactive Web pages" will consist of specific examples illustrating the technology as well as directly supporting the guidance document by example. These will of course become part of the SS*f*M web site as they are published.

It is hoped that this project will inform and stimulate comment and discussion about the application of interactivity on web sites, leading us into an exiting time of development of this area for the National Measurement System.

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http://www.npl.co.ul/ssfm/

What is Data Fusion?

Data fusion is the technology whereby often large amounts of diverse data may be combined into a consistent, accurate, and intelligible whole. There are several distinct flavours of data fusion: in some scenarios, for example, the data corresponds to different attributes of the same object; in others, the data is effectively repeated measurements of the same attribute. In the former case, the data has to be fused in an intelligent manner, taking into account the different natures of the attributes, to gain as complete a picture as possible of the object from its component attributes; for the latter, the redundancy in the data will be used to reduce error as much as possible, and perhaps produce some fault-diagnosis on the sensors that are producing this data. There is also a distinction to be made between the use of data fusion to obtain results, or the related purpose of reducing the uncertainty associated with these measurement results.

The work done under the SS*f*M programme will be parallel and complementary to that of the projects running under INTErSECT's (a Faraday Partnership run by NPL and Sira) "Data fusion, management and complex system design" theme. In the latter, complex engineering and pharmaceutical problems will be the motivation behind research. The SS*f*M project will be more directed to applications within primary metrology; the focus here may be more towards reducing uncertainty, but the framework behind the two projects is the same.

The techniques used in data fusion are as diverse as the problems are disparate. Starting from a survey, the projects will categorise the various distinct data fusion problems, and list the appropriate solution techniques. This will allow users more easily to identify precisely which range of techniques is applicable to their problem. This is in contrast to the current situation in which new-comers to data fusion are faced with a number of techniques, and there is a risk of choosing a non-optimal, or even inappropriate technique.

Once this initial map of data fusion is in place, the projects will then proceed to develop a generic approach to data fusion, whereby salient features of techniques and their implementations would be identified (such as numerical stability, and speed of processing), and methods for comparing different techniques would be produced. Further work would involve examining ways of validating the results of data fusion.

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How good is the mathematical model you use?

Mathematical models are used in many different applications, from economics, through engineering to fundamental physics. They share the feature that they represent an encapsulation of a problem domain, such that the user can learn about the problem by studying the model. If conclusions drawn from the model are to be valid, it is necessary to validate the model, as being part of the process which converts data to information.

Model building is a design process, in which validation is used to test the success of the design and also to indicate where improvements can be made. As an example, a given polynomial fit may or may not be acceptable; if not, would a polynomial fit of a different degree be better, or is the data fundamentally unsuitable for a simple polynomial fit?

The SS*f*M Model Validation project addresses such issues in the context of metrological models. The first deliverable (a survey report) is available [NPL Report CISE 19/99] in which many of the key problems and methods are analysed, drawing upon modelling practice in metrology and other numerate disciplines such as climate modelling, structural engineering, population ecology, etc.

Subsequent activity in this project will test validation practices on metrology case studies. NPL has also been awarded the contract to produce a Best Practice Guide on validating discrete models (as used in data approximation) in metrology.

For further information contact: Alistair Forbes, extension 6348, e-mail: alistair.forbes@npl.co.uk

Can a measuring instrument be tested as a black-box?

In considering the question of Measurement System Validation, a key issue is whether or not it is appropriate to test an instrument as a whole and therefore effectively ignore any software that may be embedded within the instrument.

Most metrologists when testing an instrument would effectively test its calibration. Say, take two artifacts having known properties at the limits of the range of the instrument, and check that acceptable results are obtained. This method is simple, direct and easy to interpret. But is it sufficient?

Let us consider the case of a pressure transducer. In the study undertaken for the nuclear industry last year, NPL analysed the embedded software being produced by Druck Ltd. The software was fine and the their instrument would be adequately tested as a black-box. However, that assumes the software is correct and since a non-linear correction is applied, one could easily produce an incorrect version of the software which would pass the test and yet be seriously in error.

Reader views on this issue would be welcome; please contact: Brian Wichmann, extension 6976, e-mail: brian.wichmann@npl.co.uk

Update on Automatic Test Generation

Automatic test generation is something many people want but is notoriously difficult to achieve. If achievable the cost savings are obvious.

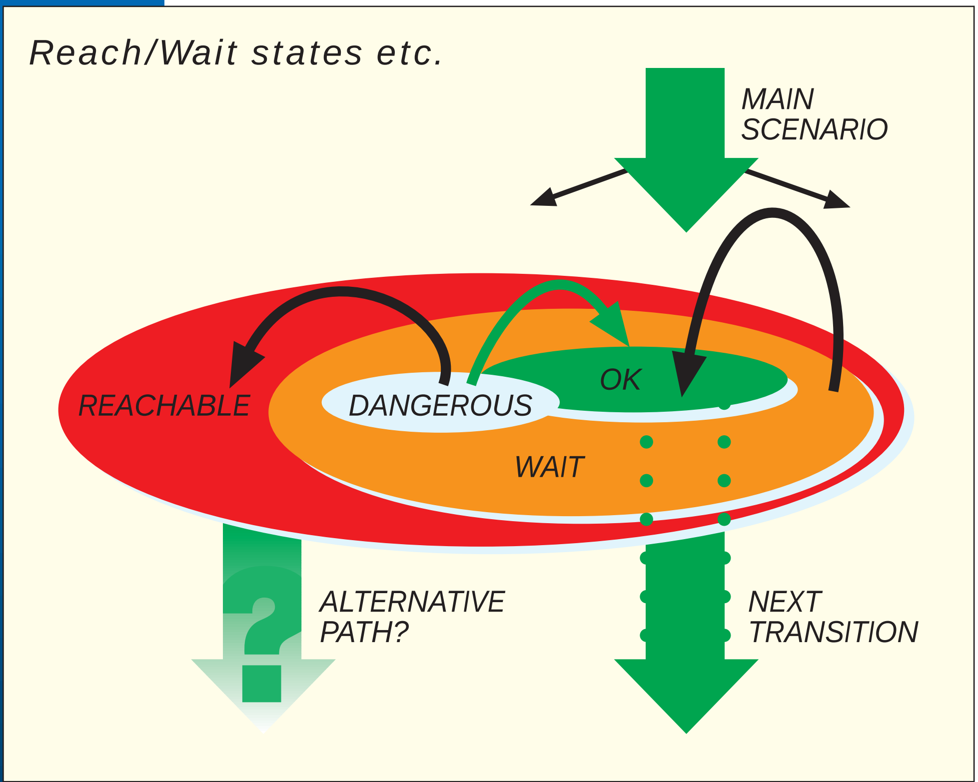
Using a unique algorithm developed at NPL a tool is being produced to automatically generate tests in TTCN from a specification of a system. Currently supported specification formats are SDL and a simple state transition language (SPIL developed at NPL).

Currently from a SPIL specification of a protocol V5.1 (ETS 300 324-1 - V5.1 interface for the support of Access Network) tests are being generated to run on a Siemens K1197 to test an implementation of V5.1 developed by Comprador Communications Limited. Results of this work will be available at the end of May 1999.

The SDL version of the tool will also be available at the end of May 1999, for evaluation by the participating SME's of the CRAFT project within the SMT Framework IV programme. A version of this tool has been demonstrated to the participants of the CRAFT project with very positive feedback in terms of how it compares with existing tools.

Future work includes transferring this technology into testing of objects in a CORBA environment. It is also hoped to apply it to Fieldbus.

For further information contact: Frank Brady, extension 6035, e-mail: frank.brady@npl.co.uk



The diagram illustrates the generation tool's view of the possible IUT behaviours following a test case transition. It uses this to elaborate the basic test case scenario with verdict assignment, and to decide if any preemptive actions or alternative scenarios will be needed in the test.

Performance Testing of Biometrics

Many physiological features such as fingerprints, face, and iris patterns, are unique to the individual. By measuring and comparing these features, biometric systems are able to recognise or verify the identity of an individual automatically. This technology has been successfully piloted in systems for border control, benefits payments, bank machines, access control and many other applications. The performance of biometric systems is commonly stated in terms of the percentage of false accepts and false rejects. However figures quoted by the vendor, obtained in conditions ideal for their device, can be unrepresentative of performance on a real application. To address this problem NPL, together with a group of developers and users of biometric systems in the ESPRIT project BIOTEST, has developed a set objective performance metrics allowing real-world performance to be derived and inter-comparisons between devices to be made.

The BIOTEST approach considers three complimentary aspects to overall performance: Accuracy, Usability and Vulnerability.

A fingerprint device being used in a comparative trial

Accuracy:

How well does the system identify the individual? BIOTEST's approach is to measure the False Acceptance Rates (FAR) and False Rejection Rates (FRR) accurately in the laboratory, using either a stored database of samples, or through trials with end-users. These tests are extended by an assessment of the other factors that will typically determine the performance attained in the field.

Are all false rejections due to a small number of poor enrolees, or is everyone equally likely to be occasionally rejected? Additional measures distinguish between these situations, even when the FAR and FRR are identical.

Usability:

In practice, users of a biometric device will not conform to the manufacturer's expected behaviour. People may incorrectly align a finger for a fingerprint device, or present the wrong hand to a hand-geometry device. The frequency with which these snags occur will have a bearing on the observed rejection rate. Usability issues have a broader influence than this, though; for many applications, ease and acceptability of use are primary measures of performance. Feedback from the tests will inform manufacturers of ideas for improvement.

Vulnerability:

Tampering, mimicry, and physical simulation of biological features may all threaten to increase the FAR above its reference value. BIOTEST has adapted IT security ideas to evaluate the risk of compromise from these and other potential attacks.

Based on our work in the project, NPL has established a testing service for biometric systems. We are now conducting independent performance assessments of verification devices using a variety of biometric technologies. Requirements for accuracy, usability and security, and the relative importance of each aspect, will vary between applications, and our approach is tailored according to the customer's objectives. We also offer consultancy on many aspects of biometric testing and are involved in the early stages of standardisation and certification of biometric systems.

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SS*f*M


Scientific Software


Techniques for High Integrity

AMCTM 1999

Over 80 delegates attended the international workshop on Advanced Mathematical and Computational Tools in Metrology at Lady Margaret Hall, University of Oxford, 12 - 15 April, organised by NPL as part of the SS*f*M programme. In his opening address, workshop chairman Maurice Cox, NPL, explained that the aims of the workshop were to:

- present and promote reliable and effective mathematical and computational tools in metrology
- understand better the modelling, statistical and computational requirements in metrology
- provide a forum for metrologists, mathematicians and software engineers and encourage a more effective synthesis of skills, capabilities and resources
- support young researchers in metrology and related fields

These aims were reflected in the workshop programme, covering a wide range of metrological and numerical disciplines. In the first session, Dave Rayner, NPL, gave an overview of the SS*f*M programme, its themes, objectives and projects. In addition to over 35 invited and submitted presentations during the first three days, the fourth day was devoted to less formal parallel Special Interest Groups (SIGs) on:

- Data fusion in metrology (chaired by F Pavese, IMGC, Italy, and G P Kelly, NPL)
- Metrology software engineering (chaired by D Richter, PTB, Germany)

There was also a joint session on the EC Framework V programme (FV) featuring a presentation by Dr Graham Hazeldean, NPL, highlighting the programme objectives, funding mechanisms and project proposal procedures.

The workshop, the fourth in a series of EuroConferences co-ordinated by F Pavese, IMGC, Italy, also received support from the EC Training and Mobility Programme to fund 13 young researchers from universities and research institutes to attend the workshop. Collected papers associated with the workshop will be published by World Scientific. The fifth workshop is due to be held in Spring 2000 and details of these workshops can be found on the SSfM web site.

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If you have a general enquiry or do not know who you should contact please call our general enquires number and we will be pleased to help you.

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