PUTTING STATISTICAL IDEAS ACROSS TO INDUSTRY

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Introduction

Of all the major sciences it is computer science and statistics in which the need for qualified personnel in government and industry is possibly greatest. With respect to statistics, particularly in industry this need is not always translated into "demand".

A recent paper by Baines (1984) refers to the growth in the use of statistical methods by industry in the past 30 years and the associated main trends in the practice, scope and methodology of industrial statistics are identified and discussed along with the need for the development of new and improved methodology in areas such as process control where computers are recording measurements of several hundred variables every few seconds.

Relevant to both the training of students and involvement of academic Statistics Departments with industry is the following quotation from Baines:

> *There is little doubt that the flow of industrial problems requiring new or improved statistical methodology will continue. In the future, industrial statisticians will have less effort available for methodology research, and there will be a growing need for more of this research to be done by academic statisticians. The pressure on academic Statistics Departments to undertake more sponsored research, and the pressure on industry for more information and economic experimentation and data analysis, should encourage the co-operation between industrial and academic statisticians for the required transfer of methodology research to take place. Thus it is expected that the trend of improving methodology available to the industrial statistician will continue, with an increasing participation of academic statisticians in the associated research.*

A major motivation for the statistician to pursue the application of statistics in industry is the new insight it often generates, and the need which often arises to appeal to deeper results in mathematical statistics before simpler questions can be answered. From the academic department's point of view the motivation for collaboration with industry should be high. Professional development of staff involved with mathematical/statistical degree courses is necessary in a variety of forms, particularly in an Institute of Technology whose teaching programs aim for a successful compromise approach to the traditional sequence of probability theory, sampling theory, data reduction, inference, special topics and techniques, and suitable reference to and practice with real world problems.

The academic department must maintain awareness of the style and needs of industry and associated developing techniques (eg. robotics), through contact, funded collaboration and consultancy work. It must maintain subject expertise and liveliness through original research and be alert to new developments through scholarship and contacts. For the statistician the need for interdisciplinary contact is especially important and wide ranging.

From the industry point of view progress in industrial research and development depends crucially on the availability of highly trained ability and supply of able minds. J.G. Sekhon (1985) in a study of the low incidence of mathematics PhD's in industry in Australia comments: "the future of Australian industry is being directly threatened by the conjunction of the small number of PhD mathematics graduates and the exceedingly small number that elect to enter industry". The study also highlighted that research in industry can be very different from research in an academic setting with "the former characterised by team effort, time and financial constraints, and by projects which cannot reflect one's own interest. The lack of mathematical sophistication or generality is of no major concern to industry, as long as mathematics enables the problems of direct interest to industry to be solved economically and effectively".

Recommendations arising from Sekhon's study and in fact in the process of implementation at the Western Australian Institute of Technology are that:

- research topics should be jointly determined by academic and industrial interests;

- the general practice of having a single supervisor should be replaced with a panel of two or three supervisors, drawn from academic and industry;

- work performed in industrial laboratories be accorded recognition for higher degrees; and

- as an alternative to a single thesis, serious consideration should be given for a series of papers describing solutions to problems of industry.

The study also perceived a need for an alternative model of doctorate education, akin to that prevalent in the USA, with substantial taught components and less emphasis on original enquiry.

Increasing Collaboration

The above refers to the supply and availability of suitably trained graduates for industry. Of perhaps equal importance is the vehicle for direct and effective collaboration between academic departments and industry. At the Western Australian Institute of Technology (WAIT) for example, staff interaction with industry is used to strengthen the links between statistical theory and the problems of industry and is facilitated by the formal identification of a consultative group, the Computing and Mathematical Systems Group, within the School of Mathematics and Computing and student involvement through projects with industry. The group was formed in 1981 with the assistance of funding from the Institute for purposes of encouraging and conducting contract research and development and consultative work for industry. The group has provided the vehicle for increased interaction between an academic department and industry, particularly with respect to responding to and understanding the statistical needs of industry. Examples of recent major funded collaborative work with industry include :

(1) Robotics – measurement and prediction of bone shapes for automatic deboning of carcasses.

(2) Mining – algorithm and software development for optimal strategies for open pit mining, (Caccetta and Giannini, 1985).

(3) Environmental – strategies for reafforestation of completed mine sites. Assessment and modelling of physiological and meteorological factors associated with transpiration for different tree species; sampling strategies, (Fox, 1986).

(4) Mining – quality assurance and control associated with differences in ash content between successive daily train loads of coal, (Perriman, 1985).

(5) Engineering – statistical model development and analysis associated with factors initiating corrosion of steel reinforcing in concrete cladding on high rise buildings. A model based approach for inference concerning $P[Y < X]$ and forecasting of future damage, (Perriman, 1986).

(6) Image Analysis – texture based detection of surface defects, (White, 1986).

In Australia the formation and identification of similar groups within a number of academic departments in Universities and Institutes of Technology has been an effective vehicle for increased participation of academic statisticians in relevant research and development for industry.

Other recent initiatives in Australia for increasing collaborative work in statistics and mathematics between academe and industry include

- the emergence of a Division of Applied Mathematics of the Australian Mathematical Society with associated scientific journal, a regular series of meetings and a "Directory of Applied Mathematicians in Australia".

- an annual meeting of "Mathematics-In-Industry Study Group" involving the bringing together of mathematics and industry scientists for intense collaboration over one week.

- the growth of SIROMATH Pty Ltd, the mathematical consulting company of which CSIRO (Commonwealth Scientific and Industrial Research Organisation) is a joint shareholder. SIROMATH has enjoyed a spectacular growth in statistical consulting with industry. In addition industrial involvement is a high priority consideration for the CSIRO in general and for the Division of Mathematics and Statistics in particular.

- An Australian Government Initiative through the Department of Industry, Technology and Commerce is the establishment of a national Teaching Company Scheme. The Scheme aims "to establish dynamic new partnerships between industry and tertiary institutions to raise company performance and attune academic endeavour to the modern industrial environment". Tertiary institution staff contribute to the planning and direction of an approved project with actual work being undertaken by "teaching company associates" – high calibre graduates recruited on 2 - 3 year contracts with financial support of up to $15,000 p.a. provided to cover half their salary costs, the company partner meeting the remaining project costs.

The Nature of Collaboration

Perhaps the single most important skill an academic statistical consultant has to offer industry is the ability to define the precise problems to be solved and to extract significant features from technical details so that they can be analysed and put to practical use ie. the ability to construct mathematical or stochastic models of industrial processes so that their future course can be predicted and controlled, and important aspects optimized.

In working with industry the academic statistician may also find that the goals of applied problems may not be as well defined as those of a formal problem and it may often be more difficult to decide when a solution has been reached.

The following are some perceptions of industry's requirements in statistics:

(1) Industry needs results fairly quickly. It is not necessarily looking for neat and analytical answers if numerical solutions can be obtained more quickly and cheaply.

(2) Many large industrial organisations (at least in Australia) still prefer to "contract out" for the conduct of statistical based investigation rather than maintain a full-time statistical group.

(3) Clients in industry expect – (a) a well set out formal proposal with a clearly defined set of milestones to be achieved in a specific time scale, and (b) a consulting fee on a par with that expected from industrial consultants. Under-pricing your product may be interpreted as a failure to understand the complexity of the problem.

(4) Client satisfaction and scientific rigour are compatible.

(5) There is increasing scope for Universities and Institutes of Technology to provide short courses for both statisticians and non- statisticians in industry.

Implied Recommendations for the Teaching of Undergraduate Statistics

(1) Emphasis be placed on the role of probability models as models for data.

(2) The teaching of effective data analysis through likelihood inference be based on an interactive package such as GLIM.

(3) Survey design, in particular sampling schemes, be an integral part of any undergraduate statistics course.

(4) Greater emphasis be placed on discrete probability models in contingency table analysis and for general categorical and discrete data.

(5) Practical examples be based on real data, preferably from consultancy problems rather than published data sets. The background and implication of the analysis associated with consultancy problems help make clear the real contribution to research of statistical modelling and data analysis.

(6) Students need to take full advantage of computing facilities in their course.

(7) Care must be taken in an undergraduate course not to "over stuff" courses with a pot-pourri of statistical techniques, but rather cultivate a solid, model based foundation of statistical theory.

(8) A unit in mathematical modelling is a valuable adjunct to the education of mathematicians and statisticians for both model building and appreciating and understanding further the relevance of mathematical and statistical theory.

(9) Desirable numerical procedures for statistical analysis such as: splines and applications, optimisation and search algorithms, forecasting, random number and synthetic variate generation, graphics package standards be available to students of statistics. Topics such as these are valuable when the need arises to extend standard procedures.

Mathematical education is of course essential to the development of a statistician. As Sir James Lighthill (1975) says: "One thing that distinguishes mathematicians from nonmathematical users of mathematics is that a mathematician knows what a proof means. And that is a great weapon in one's armoury in all sorts of practical uses of mathematics: if you know when mathematical argument is a deduction from the assumptions, and you know when it is just a bit of brilliant guessing!"

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