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Abstract. The MSc Applied Instrumentation and Control has been delivered at Glasgow Caledonian University since 2004 to full time students but also to a population of distance learners employed in professional engineering roles. An account is presented of the programme philosophy and of the means employed for both modes of delivery. The origins and destinations of the alumni population, both in terms of geography and employment sector, are reviewed. Finally, the evolution of the course content towards an integrated systematic approach to instrumentation and control is considered.

1. Introduction

Glasgow Caledonian University has provided education in Instrumentation in one form or another for nearly 30 years. Initially this took the form of an honours degree combining physics and instrumentation. While the graduates of this programme proved attractive to employers, it became apparent that the instrumentation discipline suffered from poor recognition among potential school leaving applicants, with a consequent impact upon recruitment. It was decided to move away from undergraduate provision and concentrate on postgraduate education in order to balance employer demand with applicant supply.

The resulting MSc in Applied Instrumentation and Control (AI&C) was approved in 2004 and accredited by the Institute of Measurement and Control in 2005. The programme continues to be offered, having undergone periodic revision, reapproval and reaccreditation.

The aims of this paper are to give an account of the philosophy of the programme, both as initially conceived and as an evolving entity, to review the origins and destinations of the students who have participated in the programme and to consider the future development of the programme in the light of progress in the discipline and the developing needs of industry.

2. Programme Philosophy

A survey of Masters level programmes titles offered in the UK reveals that the terms 'instrumentation' and/or 'control' are found with collocations including *signals, sensors, management, systems engineering, embedded systems and automation*. This gives an idea of the map of overlapping cognate disciplines in this domain. There is ample room for a range of offerings covering material as disparate as the mathematics of advanced control theory to the realisation of embedded electronic systems.

In the present case it was decided to centre the programme design upon the following:

- The physics of the sensor element and statistical nature of the measurement process, together with the ubiquitous sensitivities to unwanted inputs.
- The elements of control theory as used in realistic industrial applications, with something of an emphasis on process control. Classical and modern design tools are considered together with advanced modelling and system identification techniques.
- The generic skills required of the professional engineer in the areas of ethics, safety and project management.

The full set of module learning outcomes was mapped to the appropriate UK-SPEC threshold statements as well as to the QAA qualification descriptors at Masters level. Throughout its life the programme has been accredited by the Institute of Measurement and Control as meeting the educational requirements for CEng registration.

3. Modes of Delivery

3.1 Overview

From the outset, it was intended to deliver the programme in modes which permitted the greatest degree of flexibility in order to facilitate access by the widest range of participants, in particular those who were in relevant employment and sought to improve their knowledge and level of qualification in the Control and Instrumentation (C&I) domain. To this end the programme was initially offered in three modes of delivery.

Table1. Modes of Delivery

Mode of delivery		duration
Full Time	structured	1 year
Part Time	structured	2 years
Distance learning	flexible	2-5 years

Both the Part Time (PT) and Distance Learning (DL) modes of attendance were restricted to applicants who occupied relevant industrial roles. The rationale for this restriction was to ensure that these students would be exposed to practical activities, in the course of their employment, which would replace the practical elements of the taught course. In addition, PT and DL students would write their dissertation on the basis of project work undertaken in the context of their employment.

Modules were delivered in consecutive three week blocks with lecture content condensed into the first week of delivery. This was done to permit the attendance at lectures of part time students, visiting distance learners and CPD attendees. The Part Time mode did require attendance at lectures for one week in six during term time but it soon became apparent that the distance learning mode of attendance was sufficiently flexible as to effectively subsume the PT mode. Any student with the time and proximity to access the PT route could do so via the DL route, benefitting from the additional flexibility thereof. While the DL route required no attendance, DL students were nonetheless welcome to attend lectures or use the laboratory facilities by arrangement. Therefore it was decided to withdraw the PT MoD and continue with the FT and DL modes.

3.2 The Distance Learning MoD

It is recommended that students undertake up to four modules per annum, completing the taught elements of the programme in between two and five academic sessions. Coursework submission dates and examination dates are be agreed with the programme leader when the student is registered on a particular module as these dates will have to coincide with the appropriate assessment period in January, May and August. For each module with an examination, at least two diets per year are offered. Arrangements are made for distance learning students, who live more than 100 miles from the University, to sit examinations at a suitable higher education institution close to their home, however students may opt to sit the examinations at the University.

Initially, the main physical means of delivery was a printed learning pack, meaning that the programme operated as a tutor supported correspondence course. In recent times the content has moved onto the University's Blackboard™ based Managed Learning Environment (MLE). The MLE supports text resources, audiovisual material, and interactive test material. Coursework assignment and feedback is handled by means of the Turnitin™ – Grademark™ platform which provides the marker with a suite of grading and feedback tools.

The MLE also provides a number of social media type communications facilities, however these have not be deployed widely in this programme. Individual students, working to an individually negotiated schedule, do not naturally form a virtual cohort and there has been, as yet, little uptake of such services. This may change as the demographics of the student population evolve. On the other hand, the support of a number of individual distance learners is a resource intensive process, a fact not always apparent to institutional management who hear no footfall.

Tools used to support distance learners include email, telephone, VoIP and Camtasia™ commentaries on submitted work. It is amusing to observe that the cameraphone proves to be an invaluable tool for the debugging of prototype circuits!

Other resources provided for DL students include access to the full National Instruments LabVIEW™ development suite for the duration of their registration, together with a practical pack comprising a USB data acquisition device and electronic components for the completion of some practical coursework.

Distance Learning students carry out their project in their workplace. It is anticipated that most students will get full support from their companies for the project to be undertaken, as this will be a substantive piece of work and likely to be of direct benefit to the company. All

industrially based placements require that, in addition to the academic supervisor, an industrial mentor be appointed to take responsibility for the student in the workplace. For distance learning students this role is likely to be fulfilled by their line manager.

4. Origins and destinations

A marked difference is observed in the make up of the Full Time and Distance Learning populations. Aggregating the recruitment over the whole life of the course, 85% of the FT students have held 'international' status, as opposed to 'home' or EU, whereas home students represent approximately 50% of the DL population.

The programme has, therefore, been relatively successful in its goal of targeting potential UK students, working in C&I roles who have a desire to further their level of academic qualification, generally with a view to obtaining professional status. A striking feature of the applicant population, however, is the number of applicants, now working in senior positions, whose highest formal qualification is at HNC or HND level. While it is generally straightforward for such applicants to demonstrate graduate equivalence through an RPL (Recognition of Prior Learning) process, it is less evident that they would possess a level of mathematical preparation sufficient to permit them to approach the mathematical elements of the MSc programme with confidence. Such applications have to be considered with great care.

Distance learning students are already employed in C&I related roles in industry at the point of application and it is possible to identify patterns in the applications. Manufacturing, energy, utilities, transport and C&I equipment suppliers are all present in the list but the biggest single employment sector is that of Oil&Gas.

Among the FT students, while some arrive with prior experience, it is generally necessary to look to declared employment destinations rather than origins. A pattern similar to that of the FT population is seen, with a predominance of Oil&Gas destinations among a similar range of other occupations. The prominence of Oil&Gas sector destinations is explained in part by the strong representation, in both FT and DL populations, of students from countries, such as Nigeria, where the Oil&Gas sector represents a relatively large part of the economy.

A recent survey of 76 international graduates of the FT programme found that 7% were pursuing further study in the UK, 26% were employed in UK based engineering roles, 12 % had taken up or returned to education roles abroad while 55% were employed in engineering roles in their home country or a third country.

5. Future directions

In addition to the core measurement and control content outlined above, the programme has made use of a number of case studies, typically equivalent in size to half a module, dropped into portmanteau modules. This arrangement provides some flexibility for both resource allocation and course content. These case studies will naturally reflect the interests of the teaching staff and that may tend to give the whole programme a particular overall complection. This is a tendency which may be either counterbalanced or encouraged depending on the intended character of the programme.

In the early days of the programme these case studies tended to focus on particular sensor types from a physical or chemical science point of view. More recently, however, the emphasis has moved more to the application of measurement data, particularly in the area of asset health management. The availability of reliable data is assured through the application of 'classical' condition monitoring techniques. Students are then introduced to systematic fault detection and isolation (FDI) which is developed in a state space formulation, which helps to bring together the knowledge gained from the previous measurement-oriented and control-oriented modules.

The final link in this chain is the application of systematic Prognostics and Health Management PHM which seeks to build appropriate instrumentation into complex systems from the outset. Commercial of the shelf software tools supporting the PHM instrumentation design analysis exist but they are not widely adopted as part of the design of complex systems. An example of such solutions is Maintenance Aware Design environment (MADe) [1] which allows informed decisions related to the level and instrumentation required to be installed on a system to guarantee a certain level of operational availability. This tool is available to the students as part of the taught programme and has also been used successfully in individual projects. [2]

It is likely, in future developments of the programme, that this focus on a systems engineering approach to asset health management will provide a motivation for the development of measurement systems material which meets the needs of what is frequently termed Industry 4.0.

6. Conclusion

The MSc Applied Instrumentation and Control delivered by Glasgow Caledonian University to both full time students and to distance learners in professional employment continues to be in good health. Applicant and employer demand remain strong, within the constraints of the current economic situation, and the basic conception of the programme remains relevant. The means by which the programme is delivered, and the range of advanced applications considered, have evolved to meet the changing opportunities afforded by technological change as well as the needs of the market. This is a continuous process requiring a degree of agility from the programme team as well as the host institution.

7. References

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