Teaching Robotics at the Postgraduate Level: Delivering for On Site and Distance Learning Students

Jenny Carter and Simon Coupland

***Abstract*— The MSc Intelligent Systems (IS) and the MSc Intelligent Systems and Robotics (ISR) programmes at De Montfort University are Masters level courses that are delivered both on-site and by distance learning. The courses have been running successfully on-site for 6 years and are now in the third year with a distance learning mode. Delivering material at a distance, especially where there is technical and practical content, always presents a challenge but the need to deliver a robotics module increased the challenges we faced significantly. There are two robotics modules though the second one is only available to those on MSc ISR. We have chosen to make the first robotics module, Mobile Robots, the focus of this paper because it was the first that had to be delivered and it is delivered to students on both programmes. This paper describes the rationale, delivery and assessment of the Mobile Robots module to students on the MSc IS/ISR with a specific focus on those students that are studying in distance learning mode. We believe it serves as a model for others attempting to teach robotics at distance.**

I. Introduction

The MSc Intelligent Systems (IS) and MSc IS and Robotics (ISR) programmes are delivered both on-site and by distance learning. MSc ISR (previously MSc Computational Intelligence and Robotics) has been running successfully on-site for 6 years and the more recent variant of the course, MSc IS, for 3 years. Both courses are now in their third year of running with a distance learning (DL) mode. The two courses share 7/8 modules, the eighth being a second robotics module for MSc ISR and a data mining module for MSc IS (see Figure 1). All modules are assessed by coursework only so there are no examinations. We believe this enables us to set realistic assessment exercises that stretches the students and encourages the investigation of novel areas. A significant number of our Masters students have published papers resulting from their work either on the final project or in some cases resulting from their module assessments. The courses have evolved and developed over the years and attract significant numbers of students, especially to the distance version – so for example around 20 new students enrolled at the beginning of the last two academic years. The courses can be studied in full or part time modes by on-site students and in part time mode by DL students. Full time students take a complete calendar year to complete an MSc programme and part time students can complete it in a minimum of two or maximum of six years, though three years is more typical.

One of the biggest challenges has been the development and delivery of the robotics module at a distance and this is why we have chosen to make the Mobile Robots module the focus of this paper.

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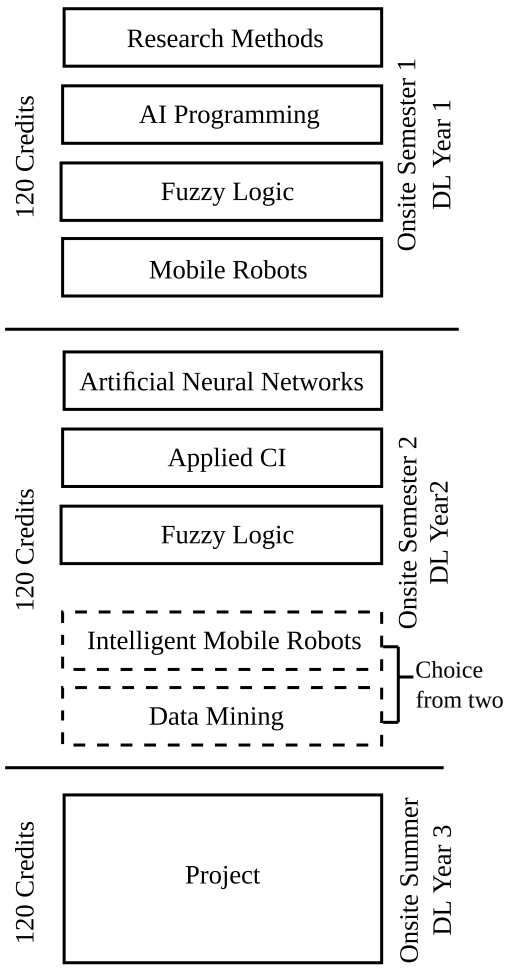

Fig. 1. Course Structure for MSc IS and ISR.

The remainder of this paper is structured as follows: Section II considers the background of the courses, their development and structure; Section III the approaches to learning that we have adopted for the course, Section IV gives a detailed account of the delivery of the Mobile Robots module and finally Section V draws conclusions from this work.

II. Background

The courses are delivered mainly by the members of the Centre for Computational Intelligence (CCI) at De Montfort

University. Their development enabled us to capitalise on the research taking place within the CCI and therefore on the strengths of the staff delivering the modules. It is generally preferred that staff members teach their special interests thus enabling research to support teaching and vice versa. There are significant benefits when a course is delivered by a team of people with a strong interest and research focus in the same areas. Initial decisions were necessary to determine the content of the courses. There are a large number of topics that could be considered but the areas of fuzzy logic, neural networks, evolutionary computing, knowledge based systems and logic programming provide an array of tools and paradigms that encompasses much of what is considered to be computational intelligence and thus form the basis of the content. The ability to get mobile robots to react intelligently to their environment is a highly developed research field and it is one that is being tackled within the CCI; it also provides an ideal application area for applying the previously mentioned techniques and therefore mobile robots modules were included. MSc ISR includes two mobile robots modules whilst MSc IS replaces one of these with a data mining module as an alternative application area for those less interested in pursuing mobile robotics work. In addition to the modules mentioned so far, a research methods module is delivered in semester 1 to ensure that students are equipped with the necessary skills to carry out literature searches, write project proposals and so on; and the Applied Computational Intelligence module enables students to pursue an appropriate area of their own interest in greater depth.

III. Approaches to learning

We aim to adopt an approach to our delivery of the courses that embraces modern technology in such a way that the students have appropriate learning experiences whether they are studying on-site or at a distance.

De Montfort already uses Blackboard[1] as a platform for providing e-learning materials for all students and this is used extensively though not exhaustively in all faculties. It was therefore an obvious choice as the main platform for the MSc. Decisions about the best way to use Blackboard and which other resources to employ alongside it were necessary and as both on-site and distance students study the modules concurrently the experiences need to be as similar as possible. Some practises have been adopted for all modules and this includes providing physical materials (e.g. textbooks, software, and other materials as necessary). We also record lectures and post them on De Montfort's streaming server (DMUtube). The students are able to view the lectures from within Blackboard and it has proved to be a popular method. Other methods adopted include sound over Power-point slides using tools such as Articulate Presenter; software demonstrations using screen and voice recorders. [3] define the term 'networked learning' to describe a particular kind of web-based or on-line learning. Their definition of networked learning is "'learning in which information and communications technology is used to promote connections: between one learner and other learners; between learners and tutors; between a learning community and its resources"'. In adopting this idea of networked learning, it is important for us to make sure that we are not simply providing materials in a variety of forms but that the learning is networked i.e. there is human to human communication taking place within each module. One way that we do this is to make use of an assessed discussion board on our virtual learning environment (VLE). It is assessed based on the number of contributions over the semester rather than the quality of the content. We have found this to be very successful and it is clear that it helps to create a virtual learning community amongst our students. Such communities are identified as being important for student engagement in e-learning by [2]. Our experience of using this mechanism has shown that it encourages students to become more of a cohort through communicating with each other whether on-site or at a distance and it helps the distance students in particular to feel less on their own. The discussion board component is worth 10% on every module and it is this that encourages students to use it initially. We find that as they get used to using it they become more involved and often answer each other's questions and so on. Other practises used, though to a lesser extent, are blogs which are used for keeping project journals and also as a way of putting current students in touch with past graduates from the course; a Facebook group; and more recently wikis for sharing subject related ideas and student presentations.

[1]http://www.blackboard.com/

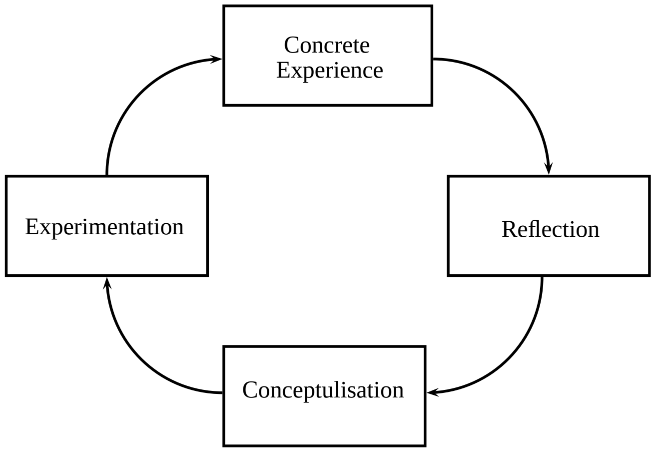

Fig. 2. Kolb's Learning Cycle [6].

In order to deliver the course effectively it has been useful to consider approaches to learning and teaching in higher education more generally. Most of the modules include both theoretical and practical work and the assessments are usually open enough to allow the students to investigate appropriate topics in their own way thus there is an attempt to facilitate experiential learning as defined by [6]. Kolb suggests that learners acquire knowledge according to the learning cycle shown in Figure 2. A further example of this approach in practise can be seen in the design of the OU module, Artificial Intelligence for Technology in [5], [9]. Here they use a learning cycle that is derived from [6]. These can be considered to be constructivist approaches to learning where students construct their own knowledge through various experiences within (and without) of the course. We believe it to be very important for our students to draw on non-course experiences as many of them have work experience: for example, DL students are often in full time employment, there is a wide variety of first degree subjects amongst them and a significant number already have PhDs. Due to these factors, often our students are interested in applying the knowledge gained from the MSc within their working environment or to their previous subjects or research area.

On-line learning in higher education is also considered by [1], who describes four levels of interaction as part of an on-line curriculum interaction model. Level 1 includes materials presented as text, Powerpoint presentations, videos etc. and relies on the students' own motivation. Level 2 has increased interaction amongst the students such as the discussion board activities used extensively on our MScs. Level 3 includes synchronous activities such as chat rooms and the final level, 4, is where the highest level of the e-learning community is offered and is where the learners and instructors engage in a variety of synchronous activities. Level 4 is achieved to some extent on our courses when we hold meetings, presentations, demonstrations (usually using Skype) with tutors and students. We plan to increases this as the course evolves further.

Dabbagh [2] defines pedagogical models for e–learning namely: open learning, distributed learning, learning communities, communities of practices and knowledge building communities. We believe that our approach incorporates aspects of the distributed learning model and to some extent, the learning communities model. Distributed learning is where the learners are in many different locations and can choose to study at times that suit them. Communication with the faculty staff and other students is through a variety of electronic means. Learning communities are groups of people who support each other in their learning activities and can be broadly defined as including "any social network or infrastructure that brings people together to share and pursue knowledge" [2]. The next section focuses on how we approach the delivery of the Mobile Robots module on the MSc.

IV. The Mobile Robots module

To be successful the mobile robotics module must combine hands-on practical work with advanced theoretical concepts. The teaching and assessment strategies have to work face to face and at a distance. For many students this module is their first exposure to programming robots and the first time they have come across the inherent challenges such as hardware limitations, behavioural debugging and dealing with uncertainty. To best support our diverse student population we have developed a clear delivery strategy which we believe serves as a model when delivering a first semester postgraduate robotics module. Our strategy is depicted in Figure 3.

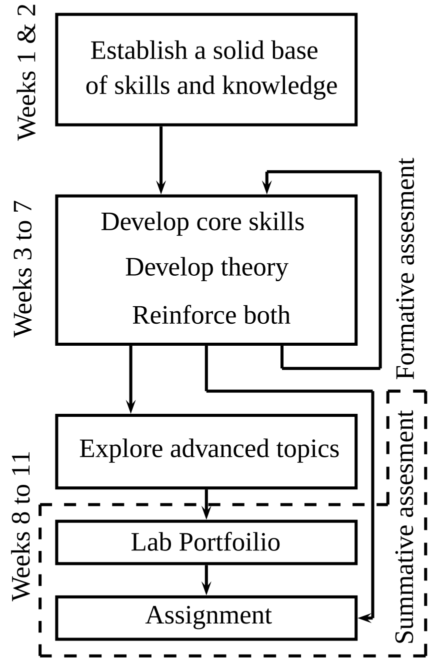

Fig. 3. Teaching and Assessment Strategy for Mobile Robots.

A. *Establishing a Solid Knowledge and Skills Base*

Arguably the most important and probably the most difficult to teach a at distance part of the module is the first two weeks. It is vital that students come out of these first two weeks with the core knowledge and skills to make progress on the module. The students come on the module from a diverse set of backgrounds, some may have good knowledge of the topics covered in these first two weeks, others may have limited or no experience. For on-site students it is relatively easy to judge a student's starting level through body language and informal questions. For distance learners a different approach must be taken. We supply a range of learning materials in these early weeks, the compulsory material covers topics at a fairly high and abstracted level but contains pointers to deeper material which gives more detailed explanations and worked examples. Students are strongly encouraged to dig down in the material until they are confident in their understanding and are able and motivated enough to do this. To establish the core competencies needed by the students a set of multimedia materials are provided to the students. These materials cover what might be termed housekeeping issues, but are essential to progress in the module, topics include:

- Building the robot model.
- Changing the batteries in the robot.
- Updating the robot's firmware.
- Basic operation of the robot.
- Installing the BricxCC IDE.
- Using the BricxCC IDE: writing your first program, compiling, uploading and executing.
- Installing GCC with OpenGL and OpenCV.

- Setting up compiler short cuts and makefiles.

The media covering these topics are videos of lectures, videos of staff using the robots, video tutorials of software, lecture slides, documentary notes and textbook sections. An example taken from this material is given in Figure 4 which is taken from a set of instructions detailing how to modify the default Lego model for use in the module.

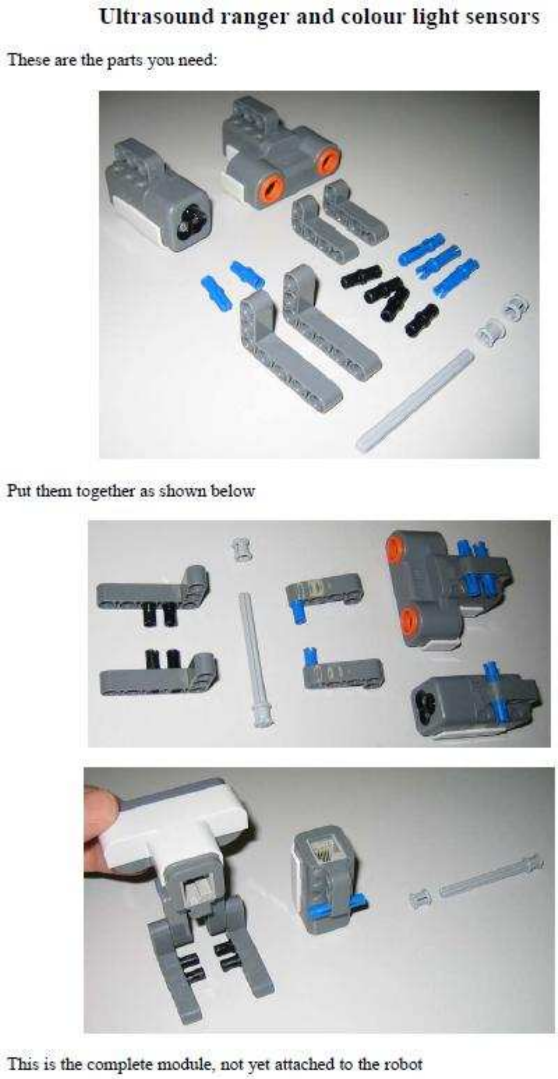

Fig. 4. Instructions for Robot Modifications.

B. Developing Core Skills and Theoretical Underpinning

Through weeks 3 to 7 students are presented with a range of theoretical topics:

- Sensors and actuators.
- Low-level control.
- Real-time programming.
- High-level control.
- Behavioural control architectures.

The content and delivery pattern of this phase of the module is cumulative by design: each topic depends on an understanding of the previous topic. From a technical standpoint this can be seen as a bottom up approach to teaching robotics. We start from a basic understanding of how a reading of an environmental phenomenon can be taken by a machine, through control strategies for simple actuators, programming issues associated with such devices to higher level, abstracted control strategies. We deliberately take this approach to avoid glossing over important issues and sources of uncertainties in mobile robots. We could take the opposite approach and begin with a high level view and then drill down to what is really happening. We have chosen the bottom up approach as it gives students an explanation for the idiosyncrasies of robot control from the outset. When the students come to write a high level control program, let's say obstacle avoidance using an ultrasonic range sensor, and the robot fails, crashing into an obstacle, the students already know what may have caused the fault. They are aware that different material reflect sound in different ways, that ultrasonics sensors have conical wavefronts not perfect straight lines and that perhaps the thread checking for obstacles is not run frequently enough.

One very important aspect of this phase of the module for distance learners is the high level of formative assessment and feedback given on a weekly basis. The students undertake a lab based piece of work every week which in some way gives a practical insight into the theoretical material. This lab work is assessed and marks and feedback are given to the students using the Blackboard virtual learning environment. The grades are purely formative and give the students a clear measure of the level they are working at and what they can do to improve. It is important that the deliverables for these formative labs are short and concise or the level of marking quickly becomes burdensome. Clear guidelines are given to the students in this regards and lengthy submissions penalised. Two of these lab pieces form part of the summative assessment going in to the lab portfolio as discussed later on.

At the end of week 7, students have covered all the core aspects of mobile robots in theory and practice. They are aware of the issues that arise when working with robotics and have a practical experience of working with robots.

C. Exploring Advanced Topics

Having established all the key knowledge and skills the students need to meet the module learning objectives, we then take a brief look at some of the more challenging topics in robotics namely:

- Robot/computer vision.
- Collaborative robots.
- Computational intelligence in robotics.

The second module, intelligent mobile robots (see Figure 1) covers in detail what most academics consider to be the advance topics in robotics: navigation, localisation and path planning. These topics are not covered in the mobile robot module, where we look at this different set of advanced issues. Each of the subject areas listed above is covered by one weeks worth of materials. The lab work on vision systems and collaboration is summatively assessed as part of the lab portfolio, giving the best students an opportunity to excel. A significantly advanced piece of software is provided to the students on each of these topics. Since only one week is given over to each of these topics, it is unreasonable to expect any of the students to begin work on any of these topics from a blank sheet of paper.

For the robot vision lab the students are given a working face recognition program which uses hue masks [7] and morphology operators [8] to identify a human face. The software makes extensive use of the OpenCV library. The students task is to choose an item for which they will modify the face recognition program so that it recognises this new object. The lab brief gives the best students the opportunity to showcase their technical skills and the knowledge of scientific method. Results from experiments showing classification rates and statistical analysis are not uncommon amongst the top 20%.

For the collaborative robot lab the students are given a simulated blackboard [4] server and four simulated clients who connect to the blackboard[2] via TCP/IP. All the networking is taken care of and the students' task is to decide what information should be transmitted and when that information should be transmitted. Students at the lower end of the spectrum tend to struggle with this work, although most get a pass mark. Students at the high end take the work much further implementing multi-threaded communication systems and advanced visualisation tools.

The final topic covered on the module, computational intelligence and robotics, is only covered at the theoretical level. The didactic material covers areas where computational intelligence has been shown to be useful in robotics with examples from the literature and from work in our own lab.

D. Assessment

Assessment of robotics work is generally challenging, these challenges are compounded when assessing work from distance learners.

Our assessment rationale is clear – we assess each student against clear set of learning outcomes. On completion of this module, the student should be able to:

- Demonstrate a comprehensive understanding of the principles and techniques used in building and controlling autonomous mobile robots by the design and implementation of adaptable controllers for autonomous mobile robots on a real robot system.
- Demonstrate a comprehensive understanding of the theoretical principles of the techniques used in building and controlling autonomous mobile robots and of the advances that are being made in this field.

The scale of assessment must clearly differentiate between pass and fail and between pass and distinction. To pass, a student must demonstrate that they have met the learning outcomes. To achieve a distinction students must meet the learning outcomes, show high levels of skill in the controller design and implementation and demonstrate a deep theoretical understanding of the issues covered on the module. This summative assessment against these criteria is done with two submissions, the lab portfolio and the assignment. The lab portfolio contains work from weeks 4, 6, 8 and 9. These labs allow the students to demonstrate a breadth of understanding: week 4 covers low level programming and sensors, week 6 covers behavioural control, week 8 covers vision systems and week 9 covers collaborative robotics. Weeks 4 and 6 labs are relatively straight forward and weeks 8 and 9 are more challenging. It is important that the portfolio covers a wide breadth of topics and that the assessment allows the students to demonstrate their theoretical understanding of the work covered. The assignment is submitted after the main teaching period. The students have to build a robot controller to perform line following using a behavioural architecture of their choice. This allows each student to demonstrate all the technical knowledge they have acquired throughout the module i.e.:

- They must choose an appropriate architecture and justify that choice.
- They must build a controller to behave in line with the specification.
- When the controller fails they should show an understanding of why the failure occurred.
- They should attempt to measure the performance of their controller, choosing appropriate metrics.

Some of these are easily assessed through documentary evidence, however controller performance needs to be demonstrated through the real-time operation of the robots. For onsite students this is done through formal demonstrations, for distance learning we offer them a live video demonstration (usually via skype) or allow them to submit a video of their controller on their robot with audio commentary on the robot's performance.

TABLE I
STUDENT PERFORMANCE 2007 – 2010.

	07/08		08/09		09/10	
Numbers	OS	DL	OS	DL	OS	DL
Enrolled	5	0	0	6	9	6
Failed	1	0	0	0	0	0
Pass	1	0	0	0	5	4
Distinction	2	0	0	5	4	2
Deferred	0	0	0	1	0	0

TABLE II
STUDENT PERFORMANCE RATES 2007 – 2010.

	OS	DL
Failed	8%	0%
Pass	46%	36%
Distinction	46%	64%

E. Student Performance

Table I gives the student numbers and pass rates on the mobile robots module over that past three years and table II

[2]Not to be confused with the Blackboard virtual learning environment discussed in this paper.

distils these numbers in to fail, pass and distinction rates for on-site (OS) and distance learners (DL). It seems that study at a distance presents no barrier to students achieving the highest standards on this module, in fact a slightly higher rate of distance students achieve a distinction on this module.

V. Conclusion

Delivering courses at a distance is a topical area. With the many available mechanisms for interacting with learners electronically there are a number of choices to be made regarding the approach to take. In this paper we have described some of the decisions we made when developing the MSc Intelligent Systems and the MSc Intelligent Systems and Robotics for on-site and distance delivery. We have provided a case study of how this applies to one of the most practical modules, namely, Mobile Robots. We have discussed our strategy for the delivery of this modules namely: firm basis of practical skills, build theory and practical with frequent feedback and give space to those most able to push their skills and knowledge as far as they wish to. The pass (more so the distinction) rates give over the past three years show how successful this final point has been, particularly for distance learning students. We believe that by following this model it is possible to teach a technical, practical subject through a distance learning model, and shown that a lack of contact is no obstacle for well motivated and determined students. The module and the course are successful and sustainable with a total of 55 students currently enrolled (11 on site, the rest as distance learners). The course continues to evolve as the available technologies improve; additionally we gather feedback from our students regularly, using the responses to inform future developments. We hope to continue in this way ensuring that our students benefit from a carefully crafted course that makes appropriate use of current e-learning research and associated technology.

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