Survey Results and Further Issues in Construction Automation Education

Dr. R. Navon
Lecturer, Faculty of Civil Engineering
Senior Research Engineer, National Building Research Institute
Technion - Israel Institute of Technology, Haifa 32000 Israel

Dr. L. Demsetz
Assistant Professor
Department of Civil Engineering
University of California, Berkeley CA, 94720 USA

Abstract

At the 7th ISARC, we compared two graduate courses in construction automation. This paper continues the discussion of automation as a component of a college or university construction program. The results of a survey of construction educators are presented. At over 40% of responding institutions, the automation of construction processes is covered either in a course specifically on automation or as a part of another course. Over 25% of survey respondents stated that one reason their college or university does not currently offer a course on construction automation is a lack of faculty knowledgeable in the area. A similar number noted that their curriculum did not have room for a course on automation. These results indicate that a standard module on automation might be of use to many construction programs. We discuss the merits and drawbacks of such an approach.

Introduction

As the proceedings of this conference show, research in construction automation is rapidly yielding results that can be implemented in the field. Will the many automated machines currently available in prototype form become widely used in the industry? The answer will depend in part on the cost-effectiveness of each machine. However, it will also depend on many human factors, including the way in which construction managers view automation. Research on innovation has shown that new technologies frequently require a "champion" to push for their adoption (see, for example, [1]). What is more, ideas for improving a new technology often come from the users of that technology [2]. It is important, therefore, that tomorrow's construction managers be aware of the state-of-the-art in construction automation. Because today's construction students are tomorrow's construction managers, it is also important to determine how automation can best be included in undergraduate and graduate programs in construction engineering and management.

A new topic such as construction automation can be included in existing educational programs in several different ways. At most schools, undergraduate programs must satisfy a greater number of constraints than graduate programs[1]. At the undergraduate level, therefore, a new topic can best be introduced through one or

---

1 In the U.S., many undergraduate construction programs must satisfy accreditation requirements. There is currently no accreditation policy for construction programs at the graduate level [3].

more lectures within an existing course or courses. Graduate programs usually allow more flexibility. At the graduate level, new topics can be covered in a special seminar or workshop (e.g. *current research in construction automation*). Such courses are likely to be offered only at institutions where faculty or staff are carrying out research on the topic, and are typically intended for graduate students (primarily doctoral students) pursuing research in related areas. New topics can also be covered in a survey class designed for any interested graduate student (e.g. *expert systems in construction*). Again, such courses are likely to be offered only where there is special faculty interest in the topic. As a topic becomes more mature, written texts become available, and the topic can be taught by most faculty members. In some cases, the topic will warrant a separate course (e.g. *productivity improvement*). In other cases, the topic will be incorporated into other courses (e.g. the use of computers in a scheduling course).

At the 7th ISARC, we compared two graduate courses in construction automation [4]. These courses can best be classified as survey classes. Both courses were initiated based on the research interests of the instructor and were open to all graduate students. The course at North Carolina State University attracted both masters and doctoral students. The course at the University of California at Berkeley attracted primarily doctoral students the first year it was offered; in the second year, it attracted both masters and doctoral students.

Our experiences in developing these courses resulted in many questions, both philosophical and practical. Should automation be viewed as an extension of current practice, or should it be treated as something fundamentally different? What is the appropriate balance between depth and breadth? In addition to on-site automation, should the course deal with off-site automation in the processing of materials and the prefabrication of assemblies? Should computer applications be included? Should students learn the technical details of automated equipment? Is a laboratory component to the course desirable? What depth of understanding of technical issues (both those related to automated equipment and those related to construction practice) is required in order to assess the economics of this new and developing technology?

A Survey of Educators

In an effort to determine current opinion on construction automation, we conducted a survey of construction educators. Our goals in conducting this survey were three-fold: to find out if and how construction automation is covered in degree granting programs, to assess construction educators' perception of the relative importance of construction automation, and to determine the perceived importance of the various topics that might be included in a course on construction automation.

The survey contained four sections. The first solicited information on the type and size of construction program available at the responding institution. As the field of construction automation matures, one instructional option (though not the only one) would be to introduce the topic alongside discussions of traditional construction equipment. Therefore, the second section of the survey investigated the extent to which construction equipment capabilities, management, and operation are covered in the current curriculum. The third section focused on construction automation -- whether or not it is included in the current curriculum and why; whether or not research on construction automation is carried out at the responding institution; and the desirability of hands-on experience in teaching and research. The final section addressed the relative importance of a wide variety of topics that might be included in a construction curriculum. An abbreviated version of the survey can be found in [4].

The survey was sent to 110 colleges and universities, primarily in the U.S. Although schools that offer only two year programs (Associate degrees) were not included, there is still great variation in the types of institutions surveyed. Some have large and well known construction programs. At other schools, construction is offered only as a single course within a civil engineering program. Some of the schools surveyed have active research programs in various aspects of construction, while others place a strong emphasis on teaching.

Survey Results

Sixty-one surveys were returned, representing 58 schools and departments[1]. We feel the response rate of over 50% is quite good for a survey dealing with a relatively new subject and conducted without the sponsorship of an academic society or industry organization. Table 1 summarizes the responses to the first section of the survey. Of the schools responding, ten have no formal construction program (in most of these cases, construction is included as part of the undergraduate curriculum in civil engineering). The majority of schools responding have formal construction programs at the graduate level. Slightly less than half have undergraduate programs, but these programs are on average much larger than the graduate programs. Only 28% of responding institutions have formal construction programs at both the undergraduate and graduate levels. Thus, if construction automation is to be introduced to the majority of tomorrow's construction managers, it must be covered in both the graduate and the undergraduate curricula.

type of construction program	% respondents with this type of program	average enrollment	maximum enrollment	minimum enrollment
undergraduate	47	129	310	10
masters	64	25	100	3
doctoral	52	6	15	1

Table 1. Size and nature of construction programs at responding institutions.

The second section of the survey dealt with construction equipment. The capabilities of heavy construction equipment (e.g. hoisting and earthmoving equipment) are covered at the undergraduate level in 69% of the responding schools, and at the graduate level in 50% of responding schools. Smaller equipment and tools are included much less frequently. The management of construction equipment is covered either in a specific course or as part of a broader course at all but eight of the schools responding. This near-universal treatment of construction equipment suggests that as the field of construction automation matures, one mode of presentation might be to parallel current instruction on construction equipment. As might be expected, computer simulation of equipment operation is more prevalent at the graduate level that at the undergraduate level. Hands-on experience on the operation of construction equipment is available at only a few schools -- for the most part, this experience consists of a visit to the local equipment operator training facility.

Third section of the survey focused on construction automation in research and teaching. Research on construction automation is currently carried out at over 40% of the responding schools. Hands-on experience was considered desirable in research by

---

1 At one university, surveys were filled out by three members of the same department. These three responses were averaged, and the result was used in the compiling overall statistics.

64% of the respondents and in teaching by 50% of the respondents. Construction automation is included in part of another course at over 40% of the schools responding. In most of these cases, additional comments indicated that the topic was covered in one or two lectures within either a course on construction management or a course on computer applications in construction. At the undergraduate level, this seems to be due in large part to the inclusion of a chapter on construction automation and robotics in a recent project management text [5]. Based on respondents' comments, it appears that when automation is described in one or two lectures, it is typically presented as a potential growth area, but one that must overcome significant obstacles. A brief discussion of robotics in general is usually included, and one or two conceptual or prototype automated systems for on-site construction are described.

Construction automation is covered in a course on automation at ten of the schools responding to the survey. Two of these courses (taught by the authors) were described in a previous paper [4]. As noted there, both devote considerable time to the motivation for increased automation, to the economic analysis of automation, and to a discussion of the state-of-the-art in automated equipment. Computer applications are discussed in one of these courses; in the other, prefabrication and inspection are included. Another difference is the inclusion of a laboratory component in one of the courses.

Although the survey solicited the syllabus of courses on automation, this information was provided for only one additional course. The course is similar in most respects to those taught by the authors. Many of the same topics are covered in all three courses, and each requires a term project investigating the automation of some aspect of construction or a related field. The main difference between this course and those reviewed in [4] is an increased emphasis on innovation and on the management of innovation. In addition, the course does not contain a lab component.

At one responding school, the format of the automation course is a research seminar focusing on expert systems and automation in building construction. Two respondents referred to robotics courses outside the construction program; the extent to which construction automation is included in these courses was not indicated. One respondent indicated that a course on automation had existed, but was no longer being offered. No information was provided by the remaining 3 respondents (other than to indicate that construction automation was covered in a course on automation).

Relatively few respondents indicated that automation in not currently relevant to construction education. At the undergraduate level, 12% felt this to be the case; at the graduate level, only 10%. Far more significant reasons for the absence of automation in the curriculum were a lack of space in the curriculum (indicated by 29% of respondents at the undergraduate level and 12% at the graduate level) and the fact that no faculty member was available to cover the subject (indicated by 24% of respondents at the undergraduate level and 21% at the graduate level). Additional barriers to the introduction of automation in the construction curriculum included the lack of written materials.

The final part of the survey addressed the relative importance of various topics in the construction curriculum. Unfortunately, many respondents did not complete all or parts of this section. Among those who did respond, automated and partially automated construction equipment compared favorably with more established aspects of the construction curriculum.

Implications for Construction Automation Education

There are several limitations of the survey results presented here. No distinction has yet been made between responses from schools involved in construction automation research and other schools. The former are likely to be better informed about the field, and therefore may be better judges of how it should be treated in the curriculum. On the other hand, a recommendation by this group to include automation in the curriculum may be somewhat self-serving. Differences between the responses of undergraduate and of graduate programs have not yet been assessed. Finally, there is the issue of bias. Respondents are to a large extent self-selected. Potential respondents with an interest in automation would be more likely to complete the survey than those who are not interested in the topic.

In spite of these limitations, the survey provides valuable insight into the current state of construction automation research and teaching in colleges and universities. A surprisingly large number of schools are involved in automation research. Perhaps because of this, automation is beginning to be covered in the construction curriculum. At present, the treatment is primarily through a small number of lectures within a more traditional course. However, a few schools offer seminars or survey courses specifically on construction automation. Major reasons for not including automation are a lack of faculty who can effectively present the topic, and a shortage of space in construction curricula.

One way to overcome these obstacles would be the development of curriculum "modules" on construction automation that could be used to supplement standard texts in construction equipment, methods, or management at the undergraduate or graduate level. These modules could present material for several lectures along with sample assignments. Their purpose would be to make it easy for an instructor not familiar with automation to include the topic in an existing course. One prototype for an undergraduate version of such a module exists in [5]; however, the rapid pace of development in construction automation threatens to render any traditional text out of date shortly after it is published. A more flexible platform that could be updated frequently would be better able to capture changes in the field. A computer-based curriculum module is one possibility; a brief pamphlet that could be updated annually is another.

These curriculum modules could provide several advantages. Ideally, they would be developed by a group of people currently involved in teaching and research in the area of construction automation. Pooling the resources of several people should result in a better, more balanced presentation than each might produce individually. Making the resulting curriculum module available to other schools would allow automation to be introduced into the curriculum by educators who are not actively involved in research in the area. Finally, distributing the material in a way that can be easily updated would provide the ability to rapidly disseminate new information.

There are several potential drawbacks to the idea of curriculum modules as well. The first is the practical problem of providing all users with up-to-date material. Computer-based material can reduce this problem, but at the same time introduces problems of hardware and software compatibility. A second drawback is the difficulty of presenting the material in a manner that would enable an educator not familiar with construction automation to cover the topic effectively.

Summary

The results of a survey of 110 colleges and universities indicate that there is significant interest in construction automation. Of the 58 responding institutions, 40% indicated that they are currently involved in construction automation research. Over 40% of respondents indicated that construction automation is included in the curriculum. Automation is typically discussed in one or two lectures within a course on construction management or a course on computer applications. Where automation is not included in the curriculum, the major reasons seem to be a lack of time within the curriculum (primarily in undergraduate programs) and the lack of a faculty member able to cover the topic (in both graduate and undergraduate programs).

References

1. Tatum, C.B.: Organizing to Increase Innovation in Construction Firms, *Journal of Construction Engineering and Management*, Vol. 115 , No. 4, pp 602-617.
2. Von Hippel, E.: New Product Ideas from "Lead Users", *Research Technology Management*, Vol. 32, No. 3, pp 24-27.
3. Yates, J.K.: Data-Base Systems for Evaluating Construction Programs, *Journal of Construction Engineering and Management*, Vol. 116, No. 4, pp 624-642.
4. Demsetz, L. and Navon, R.: Curriculum Development in Construction Automation, Proceedings of the 7th International Symposium on Automation and Robotics in Construction, Bristol, England, June, 1990, pp 24-31.
5. Hendrickson, C. and Au, T.: *Project Management for Construction*, Prentice Hall, Englewood Cliffs, New Jersey, U.S.A., 1989.