Automation and Robotics in Construction XI
D.A. Chamberlain (Editor)

Construction Automation Research Database (CARD)

L. A. Ochoa-Franco, C. T. Haas, C. M. Dailey
Department of Civil Engineering, University of Texas, ECJ 5.200, Austin Texas USA 78712

A. E. Traver
Department of Mechanical Engineering, University of Texas, ETC 4.154, Austin Texas USA 78712

Abstract

A wealth of information is contained in the proceedings of the ten International Symposiums on Automation and Robotics in Construction [Ref. 1 - 10]. To date, a cataloged index of this material has not been available, making navigation through these volumes and studies of construction automation trends very difficult. To facilitate these data searches, researchers at the University of Texas at Austin have begun the compilation of a Construction Automation Research Database (CARD) which incorporates the information presented in the proceedings. This database includes information such as technology class, construction domain, stage of development, and country of origin of the papers submitted. Using standard database functions, the information can be cross-referenced and classes can be compared to identify construction automation trends. One such comparison reveals the clear emergence of prototype systems papers versus the relative reduction of conceptual system papers over the past four years. Another reveals the automation strengths of the major contributing countries. CARD is being developed using Microsoft® Excel™ and can be updated and transmitted easily among researchers in the construction community.

1. INTRODUCTION

Access to archival information on construction automation research over the last decade is limited. Proceedings from the ten International Symposiums on Automation and Robotics in Construction [Ref. 1 - 10], which are arguably the best compilations of research results in construction automation, are difficult to physically access and obtain, at least in North America. Commercial, full text databases and bibliographic databases such as COMPENDEX [11] that index and provide abstracts to conference proceedings are unlikely to ever include all the ISARC material. An immediate alternative is to develop a database in a widely used software package that can be updated and transmitted easily among researchers in the community. Advantages of doing so include the opportunity to incorporate additional useful information on papers such as technology class, relevant construction domain, construction area, construction activity automated, stage of development, country of origin, region of origin, and institute of origin. While some of this information may be subjective, the database can be useful for studying and identifying historical trends, and IAARC members may find it to be a useful reference tool.

This paper presents the structure of a Construction Automation Research Database (CARD) being developed at UT Austin. The rational for defining categories and subcategories will be explained. The Construction Specifications Institute's (CSI's) MASTERFORMAT [12]

system, for example, is used to categorize construction area and activity automated because it is a widely used standard for coding constructed facilities. Papers are also categorized using construction domain and technology fields defined by the authors. Using this database, the emergence of new areas of research and the level of activity in other important areas can ultimately be traced over the last decade. As well, it is possible to almost instantly generate a list of ISARC papers related to a particular class of technology, thus saving researchers valuable time otherwise spent manually leafing through stacks of the proceedings.

Additional insight should emerge from further development of the database and analysis of its contents. Information from ISARC proceedings 7-10 have been entered into the database to date, and information from all other proceedings will be entered before the project is complete. Some preliminary observations based on the data are presented here along with concluding remarks and recommendations for future improvements.

2. DATABASE DESIGN

Software selection for the database was based on several different criteria. To facilitate a wide variety of users, it was important that the software be inexpensive and flexible, and that the data be easily converted to other database programs. It was also desirable to have plotting and data analysis capabilities to enhance individual sorting tasks. Microsoft® Excel™, which met all of these criteria, was chosen for this project. The familiarity and short learning curve associated with Excel serve to complement the initial requirements. The basic database structure of Excel makes it a good choice for researchers who would like to incorporate this database with one of their own, since Excel databases can be easily "used" by other database programs.

2.1 Fields

The main goal in developing the CARD system is to classify the ISARC papers (and papers of other proceedings in the future) and to store this information in a flexible, useful form. To aid this development, researchers who frequently use the ISARC proceedings were surveyed. Results of this survey were used to establish the database fields. Basic fields were included as well as ones of special interest to the authors, such as the "stage of completion" of an automated system and the "region of origin" of the paper. The final database contains twenty fields. A brief description of each field along with its categories is presented in Table 1.

To take advantage of a widely used standard, CSI's MASTERFORMAT was chosen as a basis for two of the fields . The construction "area" and "activity" fields present a valuable reference tool using terminology already familiar in the North American construction industry. Areas such as sitework and concrete are well-defined and can easily be referenced to the investigator's current information searches. A general "area" category was generated to indicate papers such as this one which cover several different construction areas. The "technology" field in the main table allows researchers to trace activity in categories such as manipulators, machine vision, and locomotion. It will also aid in the search for all ISARC papers covering such subjects as computer-integrated construction and industrial manufacturing. An analysis of the construction "domain" field could yield automation trends in environmental and geotechnical areas.

The remaining fields in Table 1 are self-explanatory. Fields such as author, stage of development, and institution have limited categories defined by the nature and contents of the paper. While classification within these categories may be considered subjective, if done thoroughly and well, the resulting information can be useful.

Table 1.
Database Fields Defined in CARD's Main Table

NO.	FIELD TITLE	DESCRIPTION AND CATEGORIES
1	SOURCE	Identity of ISARC issue (or other proceedings)
2	AUTHOR 1	First author
3	AUTHOR 2	Second author
4	PAGE	Beginning page number
5	TECHNOLOGY	Technology areas defined by the authors: • application scoping and/or economics • control systems • manipulators • CIC (computer-integrated construction) • building systems • end effectors • machine vision • AI and/or expert systems • industrial manufacturing • natural language processing • CAD and/or simulation • ergonomics • metrology and/or positioning • sensing • navigation • locomotion • robots
6	DOMAIN	Main construction domain (construction, geotechnical, structures, water resources, environmental, planning and management, transportation)
7	AREA	Construction area defined by CSI's MASTERFORMAT
8	ACTIVITY	Construction activity defined by CSI's MASTERFORMAT
9	TASK	Reserved for future use
10	STAGE	Current development stage of automated system (conceptual, prototype, commercial)
11	SYSTEM	System code, key to a separate "system" database
12	COUNTRY 1	Country of origin
13	COUNTRY 2	Country represented by AUTHOR 2, if different from that of AUTHOR 1
14	REGION	Geographical region of origin (Japan, N. America, Europe, Australia, Asia, Middle East, Africa, S. America)
15	INSTITUTION 1	Institution of origin, key to a separate "institution" database
16	INST. 1 TYPE	Type of institution (academic, private, government, other)
17	INSTITUTION 2	Institution represented by AUTHOR 2, if different from that of AUTHOR 1, key to a separate "institution" database
18	INST. 2 TYPE	Type of institution, if different from that of AUTHOR 1 (academic, private, government, other)
19	SERIAL	Preceding ISARCs in which related papers were published
20	TITLE	Title of the paper

2.2 Auxiliary tables

Several of the fields of the CARD system related to additional information that was more easily handled in separate tables. The "systems" table for instance includes names, descriptions, and development stage of the automated systems described in the ISARC papers. A total of 152 systems were presented in the four most recent ISARCs. The system field in the main table includes a reference code number which serves as a key to the "systems" table. This approach is also used in the "institutions" fields, thus simplifying data-handling tasks for both on-screen and hard copy searches.

3. HISTORICAL AND TECHNICAL TRENDS

To examine the potential value of CARD, some preliminary analyses were performed. Sorts were executed using several different criteria and the results then charted to illustrate the data.

3.1 National technology foci

A sorting of ISARC papers by country of origin is illustrated in Figure 1. This data represents only the past four years, but clearly shows Japan to be the most prolific of the countries that contribute papers to the conferences. The United States, England, and Germany present similar numbers of papers, while France and the remaining countries (not charted) contribute smaller numbers of papers. Figure 2 shows a sorting of papers concerning selected technologies versus country of origin. The numbers of papers presented on control systems, manipulators, and CAD/simulation are shown for the four major contributing countries. While being somewhat subjective, analyses such as these could be used to indicate an area of strength or weakness associated with a particular country. They may also reflect fundamental differences in the way countries tackle technology development.

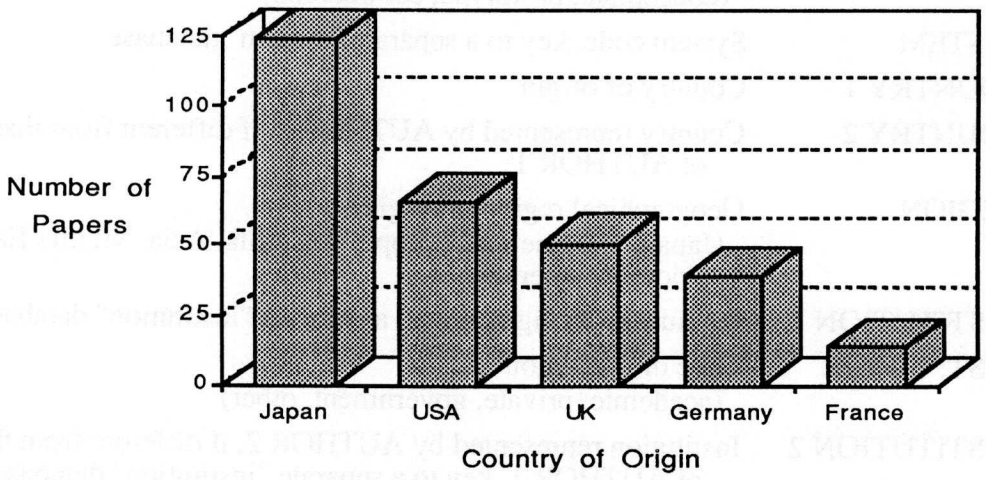

Figure 1. Number of Papers per Country

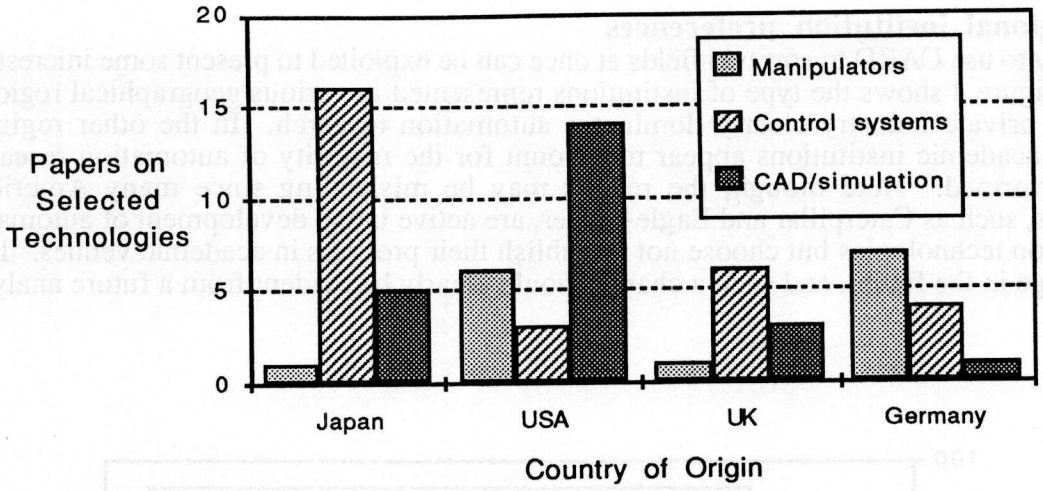

Figure 2. Number of Papers in Selected Technologies - per Country

3.2 Development stage of automated systems

An analysis of Figure 3 can reveal some interesting trends concerning the development stage of automated systems. Papers presenting conceptual systems have dominated the past ISARC volumes, however a comparison of 1993 with previous years shows that the percentage of papers regarding physical prototype systems has slowly increased to replace the conceptually-oriented papers of previous years. Additionally, the slight increase in the percentage of papers on commercial systems presents solid evidence that construction automation is maturing and is beginning to emerge in diverse ways as commercially attractive technologies. It is also evidence pointing to the increasing relevance of the ISARC proceedings themselves.

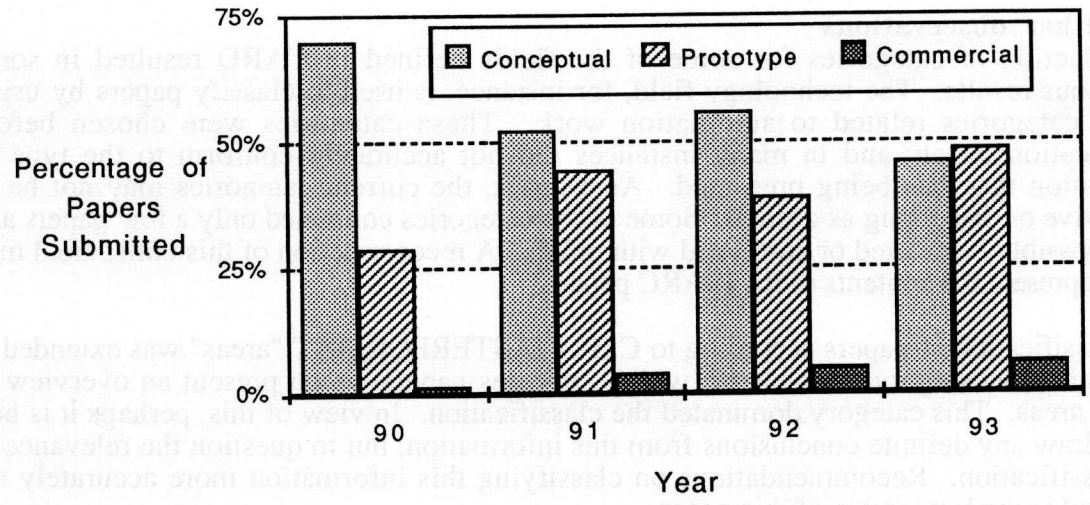

Figure 3. Development Stages of Automated Systems

3.3 Regional institution preferences

The ability to use CARD to sort two fields at once can be exploited to present some interesting results. Figure 4 shows the type of institutions represented in various geographical regions. In Japan, private industry clearly dominates automation research. In the other regions, however, academic institutions appear to account for the majority of automation research being performed. Here though, the results may be misleading since many American companies, such as Caterpillar and Eagle-Picher, are active in the development of automated construction technologies but choose not to publish their progress in academic venues. This may change in the future, and such a change would clearly be evident from a future analysis of CARD.

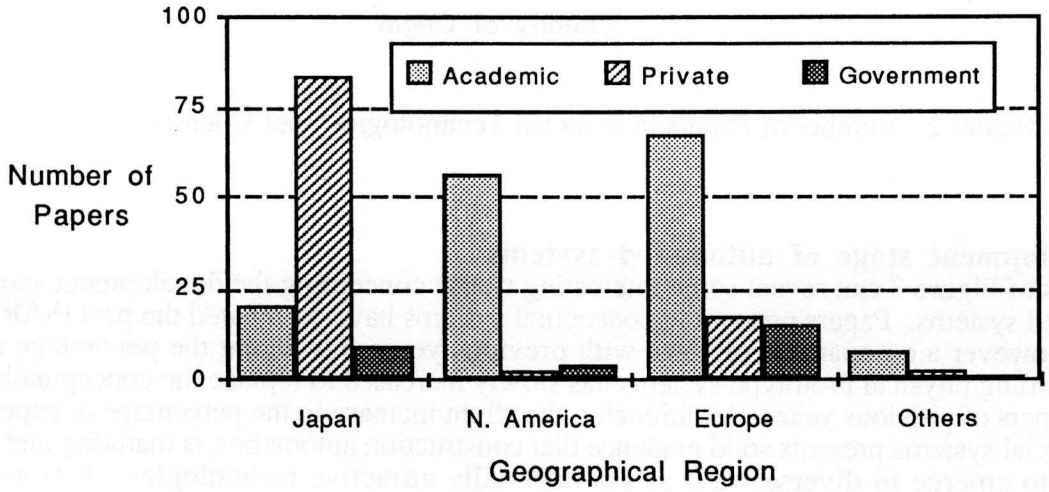

Figure 4. Institution Types Sorted by Major Geographical Region

3.4 Other observations

The selection of categories for some of the fields defined in CARD resulted in some ambiguous results. The technology field, for instance, is used to classify papers by using typical categories related to automation work. These categories were chosen before classification began, and in many instances did not accurately conform to the type of information that was being presented. As a result, the current categories may not be as descriptive or discerning as desired. Some of the categories contained only a few papers and could possibly be deleted or combined with others. A reconstruction of this entire field may better represent the contents of the ISARC papers.

The classification of papers according to CSI's MASTERFORMAT "areas" was extended to include a new category, number 17, which indicates papers which present an overview of several areas. This category dominated the classification. In view of this, perhaps it is best not to draw any definite conclusions from this information, but to question the relevance of the classification. Recommendations on classifying this information more accurately are presented in the last section of this paper.

4.0 CONCLUSIONS

The University of Texas is developing a Construction Automation Research Database (CARD) to categorize the wealth of information presented in the proceedings of ISARCs 1 - 10. To date, information on the four most recent ISARCs have been entered and some interesting observations have been made. Most importantly perhaps, the gradual emergence of prototype and commercial system papers to replace conceptual system papers was indicated with an analysis of the "systems" field of CARD. Another sort of database information clearly shows Japan to be the most prolific country participating in ISARC, and one sort revealed that the major source of ISARC papers in Japan is industry while in all other countries it is academia. Another analysis showed that the US produced the majority of papers on CAD and simulation while Japan produced the most on control systems. Other trends can easily be recognized by simple sorting of one or more data fields. The data can easily be presented in chart or graph form for inclusion in research papers. This compilation is presented in the familiar Microsoft® Excel™ software and could be useful to any member of the construction community involved in construction automation research.

5.0 RECOMMENDATIONS

Through the early stages of the development of CARD, the authors discovered several areas which warrant improvement. One improvement would include a modification of the CARD format to reflect a more standard relational database structure. Conversion of the auxiliary tables to normalized relations, for example, could simplify the classification, sorting and data analysis tasks for users familiar with relational database algebra. Additional descriptors of the ISARC papers such as keywords could also be included in relations, as could the remaining authors for each paper.

Classification within some of the CARD fields was difficult, and thus did not produce the desired information. The categories chosen for the technology field in particular need to be reevaluated and possibly restructured to better represent the contents of the ISARC papers. Some standards for classification of the papers are also needed to improve the consistency of the database entries.

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