Robotic Assembly for Mobilization Construction

by Thomas M. Gatton[1]

ABSTRACT

The United States Army Construction Engineering Research Laboratory (USA-CERL) in Champaign Illinois is currently investigating the use of robotics to assist in the rapid construction of numerous wood framed buildings during a mobilization. These structures are predesigned to use typical residential construction techniques. Presently, robotics have been identified for use in four construction activities:

1) Wood Framing
2) Painting/Spraying
3) Site Work
4) Concrete Work

To date, robotization of framing has been studied to rapidly produce the following major building components:

1) Roof Trusses
2) Floor Trusses
3) Wall Panels

A factory environment (whether fixed or portable) is necessary for the use of available robotic technology. Robotics can be used in the production of building components following an industrialized building approach. This approach allows the building to be broken into manageable envelopes of space and components. This reduces many of the obstacles to using robotics for construction which are caused by building size. The industrialized building approach provides a conceptual framework for a flexible building manufacturing system.

Initial research indicates a potential for a 'Universal CAD/CAM Framing System' and robotization of up to three-quarters of the building fabrication effort through industrialized building techniques. At this time, plans are being made by USA-CERL to design and develop a portable robotic factory for rapid building component production.

[1]U.S. Army Construction Engineering Research Laboratory (USA-CERL)

ROBOTIC ASSEMBLY FOR MOBILIZATION CONSTRUCTION

The United States Army Construction Engineering Research Laboratory (USA-CERL) in Champaign Illinois is currently investigating the use of robotics to assist in the rapid construction of a large volume of wood frame buildings during a mobilization. Briefly, the mobilization situation would require construction of new housing and support facilities beyond what is now available at designated Army installations. These new facilities need to be built very quickly and within an atmosphere that may be short of the necessary manpower and other resources at that time. Typical residential wood frame construction techniques, materials, and equipment would be used to complete the projects. The individual buildings at each project consist mainly of standard designs which are adaptable to different sites. Typical standard facilities are barracks, dining, administration, and supply buildings. The quantity of construction required at each installation for mobilization is quite substantial. A typical installation project may consist of hundreds of buildings with a gross square footage in the millions. The production of such a quantity would be difficult to accomplish on schedule within the present local building environments. This problem has required the investigation of alternatives in rapid building technology, specifically the potential for robotics in building construction to reduce time, materials, and manpower requirements as well as improving quality and production efficiency.

USA-CERL has identified four areas of research:

1) Applications to existing construction processes using available robotic technology.
2) Development of new robotic technology capable of performing existing construction processes.
3) Defining new construction processes compatible with available robotic technology.

4) Development of new robotics technology and associated new construction processes.

Of these areas, USA-CERL has decided to focus present efforts on the application of available robotic technology to existing construction processes. This is to minimize time and cost for development. It has been said by Professor Wilf Heginbotham that "Industrial success will come only from a cascade of simple cost effective applications." In a study for the Army by the National Science Foundation titled "Robotics and Artificial Intelligence to Reduce Risk and Improve Effectiveness", a panel of experts recommended the use of available robotics technology with a view of upgrading systems as new technology becomes available. This upgrading process would take the form of predicting implications of future robotic technology upon systems chosen to utilize available technology. This type of analysis would insure some foresight in the selection and development of an upgradable system. These criteria were crucial in identifying applications which would meet the mobilization requirements and satisfy Army guidelines. Utilizing available robotic technology to fit within existing construction practice is the most direct approach to addressing mobilization construction objectives within the context of achieving results within the short term.

Initially, a literature search was performed to identify existing applications to construction and related activities. This included past work done as well as ongoing and planned activity. Documentation and expertise in this field were not widespread but investigations revealed work being done by the following agencies among others, Carnegie Mellon University, Japanese Minsitry on Construction through various Academic and Industrial groups, The United States Air Force ICAM Project, and the Department of Naval Research. The necessity for a central clearinghouse or point of contact to collect and distribute information concerning Robotics in Construction was evident in order to insure access to interested parties. This would insure elimination of duplication of work by researchers as well as availability of related information for the development of future plans.

Upon identification of existing applications and related research, the next step was in the classification of robotics capabilities and uses. Three main capabilities were identified:

1) Material transfer (including self-mobility).
2) Material manipulation
3) Sensor

Typical use of robots were identified. These include the following seven applications:

1) Material handling
2) Machine Loading
3) Spraying
4) Welding
5) Machining
6) Assembly
7) Inspection

Next, a breakdown of Mobilization construction operations and equipment resulted in seven categories:

1) Site Work
2) Foundation Work
3) Framing and Sheathing
4) Mechanical and Electrical
5) Finish Work
6) Roofing
7) Equipment Analysis

Each category was further analysed to isolate the characteristics involved in the individual tasks. These characteristics were made considering the implementation of robotics into construction processes and consisted of the following factors:

1) The accurate positioning of the robot for the task(s).
2) Feed and/or location of the material used in the operation.
3) Mechanics of the connection or material fixation process.

These factors illustrate that construction is a complex assembly problem involving building components and their connections. By comparing these factors to robotic capabilities potential areas for further investigation and specific robotics applications were identified.

The Standard Mobilization Facility Designs were developed for the Corp of Engineers specifically to satisfy Army needs. This included the integration of 'modular' concepts that improve the potential for rapid construction. Specifically, modular designs infer the repetition of details and dimensions. This allows duplication of the same construction material and assembly operation which can be performed more efficiently than a series of unique operations. Detailed analysis of the material and assembly operations of a typical project revealed that approximately 90% of the buildings utilized identical components for framing. These components were:

1) Roof Trusses
2) Floor Trusses
3) Wall Panels

Wall panels, however, had variation in its length as well as window and door placement. Automated framing techniques are used in the production of these in commercial housing markets. Generally, these consist of jigging fixtures which hold the lumber while a stapling or nail-plate clamping connection is made. Operators are generally involved in simple member placement and machine interaction. Production of each type of component involves the utilization of specialized equipment. However, task breakdown of each operation revealed that the development of a flexible jig system that would handle all three types of components may be feasible with some additional mechanical systems for feed and connection automation. The ultimate extension of this system would be a CAD/CAM system capable of producing a wide variety of wood-framed components. Wide use of these building components in the building industry may substantiate commercial viability.

A preliminary analysis of economic feasibility was conducted to assess the possibility of this basic approach. Concepts utilizing the existing production systems for each type of component were developed. Reasonable production rates were established and considerable reduction in time, manpower requirements, and materials were projected. Generally, the efficiency with which the production equipment was used increased substantially by integration with robotics. Additionally, the consistency of the operation improved over man-operation. Some assumptions about materials feeding and the possibility for automated connection were made. Present plans for implementation include a portable robotic factory that can be moved to the site eliminating shipping of the final components and insuring their immediate availability for construction. Further motion and time studies will verify system production and operation and further refine and enhance operations. The auxiliary mechanical systems for automated feeding and connection will be further investigated for feasibility. The automatic feeding may be solved by simple stacked bins that would require the robot to perform simple pick and place operations. Automated connection may be possible through development of an automated plate feeding mechanism. This system would position the nail plate upon the face of the press prior to the clamping process thereby eliminating the need for loss of valuable time in placing these items individually. Supporting resources of energy and materials will also be identified. These include electrical, hydraulic, and lumber transport among others. Simple life cycle costing and other economic evaluations may show a potential for commercial feasibility.

In the present industry structure, building processes are closely tied to materials and equipment. These manufacturers are closely working with those utilizing their products to obtain efficient construction techniques. These techniques, including automated framing, are anticipated in the construction of mobilization. Proven technology that has developed over a period of many years is implemented by these manufacturers with the expertise that represents years of problem solving. Use of their equipment and expertise to study integration of robotics often avoids the repetition of redeveloping processes that have already been debugged and proven.

Despite the specialized application of robotics for mobilization construction, the concept of breaking the building into manageable envelopes of space and using state-of-the-art CAD/CAM concepts may provide a framework for the defelopment of a flexible building manufacturing system. This approach isolates the obstacle of the building magnitude. As technology becomes available providing mobility, intelligence, and other attributes necessary for on-site implementation, they can be integrated into the framework of a Flexible Building Manufacturing System. The actual building size may be the factor that determines feasibility and degree of this concept applicability at any given time.

Although this is not a solution for all types of building construction, largely due to building relative size, the application to some existing construction is already awaiting implementation. This may be seen in the recent report in the July '84 issue of 'Automation in Housing' cover story on the Japanese manufactured housing industry. The Stacked Modular System used here in the United States, for example, accomplishes approximately 85% of the building effort within a factory environment. Using available robotics technology is feasible and most likely economically attractive in this type of commercial environment. These types of systems offer great potential for robotics in construction.

The use of robotics on the construction site is a problem that presently has only isolated applications. Development of robotic integrated industrialized building systems will allow work to be done in a microcosm of on-site construction. Valuable experience in dealing with the identical issues of a Flexible Manufacturing System for Buildings may be gained. It may become evident that a generic conceptual model for Robotics in Construction based on manufacturing and assembly engineering can provide a framework for present and future systems. This type of standardization will provide foresight in application development and offer system upgrading with future technology.

In conclusion, it is evident that research and development methodology for the applications of robotics to construction consist of a logical process of analysis and synthesis. To continue to develop applications without regard to techniques in manufacturing may inhibit the potential in the construction industry. USA-CERL is happy to contribute to this effort and appreciates the opportunity to participate in this workshop conference. Hopefully, information gained here will reduce duplication of effort and help with the planning of future work.