ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889, 2023-5.384 ResearchBib IF: 8.848 / 2023

THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-1

AUTOMATION AND ROBOTICS FIELD PLANNING, MANAGEMENT SYSTEM

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Abstrakt. The construction industry is a major economic sector, but it is plagued with inefficiencies and low productivity. Robotics and automated systems have the potential to address these shortcomings; however, the level of adoption in the construction industry is very low. This paper presents an investigation into the industry-specific factors that limit the adoption in the construction industry. A mixed research method was employed combining literature review, qualitative and quantitative data collection and analysis. Three focus groups with 28 experts and an online questionnaire were conducted. Principal component and correlation analyses were conducted to group the identified factors and find hidden correlations. The main identified challenges were grouped into four categories and ranked in order of importance: contractor-side economic factors, client-side economic factors, technical and work-culture factors, and weak business case factors.

Keywords: Automated construction, Robotics, Additive manufacturing, Exoskeletons, Autonomous vehicles, Off-site construction.

1. Introduction Construction industry in most countries amounts to 10–20% of the GNP, making it the largest economic employing sector. Construction work is laborintensive and is conducted in dangerous situations, also the work content and materials change frequently. Robots are used widely to help human workers in construction sites. This approach demonstrates a decentralized, autonomous, flexible, simple, and adaptive approach to construction. Therefore, construction robotics has been a very hot research area in the construction industry. The main goal of this paper is to convince building designers and managers to incorporate robotic systems when managing modern buildings to save manpower and improve efficiency. The objectives of this paper include, among others:

1) Studying recent applications and projects for using robots and automation in the construction industry;

2) Setting opportunities and challenges facing the use of robots in the construction industry;

3) Predicting changes in construction industry resulting from robot usage, and ;

4) Setting framework for better planning and control of construction operations. The need for automating is justified first and the existing techniques, technologies and applications for robotics in construction industry are identified. Tools for selecting/assembling optimal automated and robotics system according to required tasks in construction works are then identified.

2. Automation in construction The project success from the project management's viewpoint is achieved when the project is completed with the lowest possible cost, the highest quality, no accidents, etc. In other words, success means bringing each of the project performance indicators (PPI)- such as cost, schedule, quality, safety, labor productivity, materials consumption or waste, etc. to an optimum value. Applying automation and robotics in construction is addressed from the perspective of raising building projects performance to serve the client and the environment. Robotics and automation systems in construction industry can achieve the following advantages: - Higher safety for both workers and the public through developing and deploying machines for dangerous jobs. - Uniform quality with higher accuracy than that provided by skilled worker.

- Improving work environment as conventional manual work is reduced to a minimum, so the workers are relieved from uncomfortable work positions - Eliminating complains about noise and dust concerning works such as removal, cleaning or preparation of surfaces - Increasing productivity and work efficiency with reduced costs. The past two decades have witnessed an intense/active search among researchers for suitable ways to introduce robotics into the construction field. In Japan, robotic manipulators were used as assistants to human construction workers. This approach allows the robot to be less autonomous and technically simpler, needing only limited sensing abilities. According to this approach, the human performs the vital parts of the task, and the robot is used to expand the human physical limits. Such systems, of less autonomous performance, can be more easily adapted for assistance in a variety of building tasks. As improvement of the construction process will be the task of the future, new developments cover design strategies, human machine technologies, employee safety, progress monitoring, and distributed production information. Various approaches of integrating the work of humans and robots in construction fields are introduced hereafter.

Finishing Works The following tasks related to finishing works can be achieved. - Development of a robotic system for indoor plastering while human operator completes final delicate parts of the task. - A masonry robot that pre-plans its tasks in detail. Within that project, adding a global positioning sensor corrects deviations of the robot's Tool Center Point (TCP) due to static deflection of the manipulator structure.

- Window glass mounting or panel fixing using a hybrid-type robot with pneumatic actuator and servo motor. The hybrid-type robot mechanism has a wide range of workspace and precision, and it consists of a serial and parallel part. - Welding as the robot identifies the seam to be welded and tracks the seam while welding it. - Surface finishing in tunneling, leveling and compacting concrete, tile-setting, interiorfinishing such as painting, plastering, tiling, etc. - Pre-fabrication of GRC parts manufacturing such as robotic spraying of panels, also optimization and rationalization including panels’ transportation and storage. - Simple, identical, autonomous robots assemble two-dimensional structures using prefabricated modules as building blocks. Modules are capable of some information processing, enabling them to share long range structural information and communicate it to robots. This communication allows arbitrary solid structures to be rapidly built using a few fixed, local robot behaviors. - Attaching heavy ceramic tile on walls using a designed robot which lifts or manipulates the tile, while a human worker attaches it on wall. In experiment, the proposed construction robot lifts the tile (5 kg) and moves it through the circle path. The designed sliding controller is adequate for a pneumatic cylinder control (Figure 5) . - Renewal of facades using a proposed System consisting of three components: tool head, a telescoping manned platform or another lifting unit, and a vacuum cleaner. The principal application is the removal of roughcast or other old coating by means of a brush. The vacuum "swallows" the particles loosened from the treated surface, passing them through its hoses to a receptacle. The air is then filtered, and the remaining refuse divided among designated

3. Conclusions The following conclusions are made: - Robots are increasingly involved in construction operations to maintain highly accurate actions and to reduce hazardous risks achieving improved control and safety. - Automated construction can be further developed to

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VOLUME-4, ISSUE-1

include: design, engineering, maintenance of existing and planned structures. - Many research works suggest highly autonomous robotic system for the construction performance. The "Sense-and-Act" may indeed become a reality in the development of more advanced robotic systems for construction applications. - Real-time planning is commonly employed in tasks that require the robot to contend with uncertainties and undefined environments. - Efforts should be paid to convince professionals in building management to look into the possibility of integrating robotics and building

automation together to improve the quality of services for modern intelligent buildings. - All new ideas for Automation or robotizing on the building site have to be generated by a combination of new designs, new forms and new materials that meet the requirements for building in a metropolis. However, many problems in construction engineering cannot be fully addressed through optimization and computation. - With intelligence activities such as generalization, analysis and decision-making for multi-objectives, there can be a better understanding of the construction engineering problem.

4. Evaluationfor using robots and automation

Initially, robots were developed for the manufacturing industry and were intended to perform routine task in a very familiar environment. Unlike such robots, those designated for work on construction sites must be mobile, maneuver in changing environments, and perform a different task at almost every step. Construction engineering is changed by the application of more industrial production, sustainable production, mass individualization, and intelligent building to improve constructability. Therefore, recent research indicates that robot technologies can; in fact; significantly improve quality and equipment control in several construction automation applications. The ability to automate construction would be useful particularly in settings where human presence is dangerous or problematic; for instance, robots could be initially sent to underwater or extraterrestrial environments, to create habitats to await later human travelers. Actually, there is plenty of room for improvement in all process elements concerning robotics and automation.

5. CHallengesfacing automation and robotcs in construction

The primary contribution of automation in construction is the development of a comprehensive, multidimensional analysis of costs and benefits associated with a specific robotic application. It is quite important to analyze success through the technical and economic feasibility. The technical feasibility is determined by an ergonomic evaluation of individual steps taken to accomplish the given work task, and by analysis of the requirements for robot control and process monitoring. The economic feasibility, which is perceived to be the decisive factor in the market success of the proposed robotic systems, is determined by the analysis of the costs and benefits associated with their development and field implementation. Specific technologically challenging process and characteristic of robot construction applications include: - Performance in a harsh work site environment, or undefined and sometimes hostile conditions such as: - Difficult climatic conditions - Exposure to dust - Calibration in relation to environment - Adjustment to changing surface conditions - Complexity of the working environment

In contrast, a robotic system that would operate with no need for detailed pre-planning would be less technologically demanding and may, therefore, be easily developed during early stages of robotics integration into the construction field. The "Senseand-Act" process can probably eliminate the need for high accuracy when positioning the robot at its workstation, a fact that saves

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time and leads to greater economic feasibility of the system. Some researchers attempted to increase the autonomy level of robots by enabling them to map their environments and independently navigate through them. Although construction sites are characterized by inaccurate geometries, numerous obstacles, etc. the mapping and navigation methods may be adapted to it. Such navigation methods are expected to deal with these difficulties and succeed in achieving accurate enough results. Researchers and developers of autonomous robots have attempted to solve the problem of adjusting the robot to its environment by developing automatic mapping and self-positioning methods. The robot then autonomously navigates from one workstation to another. Forsberg et al. suggested a plastering robot that uses a rotational laser beam to measure and map its surroundings (walls and openings). The mapping data was to be translated into a working plan, which would be presented to the operator for improvements. The suggested system depended on accurate navigation methods, and was supposed to bring the robot to within ±1 cm of its workstation. Beliveau described an orientation system for indoor automated guided vehicles (AGVs), using three laser transmitters accurately positioned on the floor at known points. Experiments with this system revealed that the deviation of the measured path from the desired path was ±10 cm . Shohet and Rosenfeld examined the accuracy achievable by automatic mapping of indoor construction environments. It was found that when robot positioning was precise (orientation and location errors of 0.2° and 3 cm, respectively), the achievable accuracy of indoor environment mapping was 3–5 cm. This degree of accuracy is sufficient for tasks that do not require contact with the treated element (e.g. spraying). However, tasks that involve precise placing of elements (e.g. block laying and tiling) require a mapping accuracy of 2–3 mm, as well as the utilization of well-controlled end-tools.

The types of automation and robotic technologies for construction can be grouped in four general categories (see Table 1):

(1) Off-site prefabrication systems,

(2) On-site automated and robotic systems,

(3) Drones and autonomous vehicles, and

(4) Exoskeletons. The first construction robots were developed in Japan to increase the quality of building components for modular homes .

(Category 1: Off-site prefabrication systems). The adoption of these robots was the result of the successful use of robots in the automotive manufacturing sector in Japan. Later, construction robots started appearing on construction sites, and automated construction sites systems were developed (Category 2: On-site automated and robotic systems) . The latest developments have been robots and autonomous vehicles for inspection, monitoring, maintenance, etc. (Category 3: Drones and autonomous vehicles). Lastly, exoskeletons are wearable mechanical devices that augment the capabilities of the user. Note, that exoskeletons are not strictly a robotic system, because they augment the capabilities of the worker instead of replacing it altogether. However, it was decided to include exoskeletons here because this study focuses on all hardware technologies that improve construction activities. Also, in the future, this distinction will not be as clear cut. For example, exoskeletons require a high degree of automation and a considerable potential exists on human-robot collaboration . In this sense, before construction sites are entirely devoid of human workers, it can be expected that robots, automated systems and augmented workers will work together seamlessly.

What is robot fleet management system for?

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The Fleet Management System is responsible for centralising the management of the robot fleet, allowing operators to act from several standard communication devices. In this way, the robots can be accessed from any location (office, warehouse, home…) and by any device (PDA, mobile phone, tablet, computer, …).

FMS offers a higher layer of abstraction that allows interacting with the entire fleet of robots as if it were a single system. Different access levels can be defined so that it is possible to specify typologies of users, each of which will have certain privileges to interact with the system.

In addition, a user can define missions with different levels of detail. It is possible to assign a robot to a specific mission or let the intelligent system decide which robot in the fleet will be given the mission.

Capable of coordinating fleets of robots.

Can be deployed locally / in the cloud.

Graph based orchestration .

Monitors fleet status.

Customizable.

Within robotic logistics tasks, it is essential to minimise transport times. It goes without saying that saving transport time for loads or goods saves costs. In addition to minimising transport times, there are other advantages offered by robot fleet management. For example, maximising autonomy times, priority management, quality control if it is a mobile manipulator, etc.

Modern robots are increasingly capable of performing “basic” activities such as localization, navigation, and motion planning. However, for a robot to be considered intelligent, we would like it to be able to automatically combine these capabilities in order to achieve a high-level goal. The field of automated planning (sometimes called AI planning) deals with automatically synthesizing plans that combine basic actions to achieve a high-level goal. In this article, we focus on the intersection of automated planning and robotics and discuss some of the challenges and tools available to employ automated planning in controlling robots. We review different types of planning formalisms and discuss their advantages and limitations, especially in the context of planning robot actions. We conclude with a brief guide aimed at helping roboticists choose the right planning model to endow a robot with planning capabilities.

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