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Review of Automation and Technological Progress in Construction Industry

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Abstract :*Around 16 percent of the nation's working population depends on construction for its livelihood. The Indian construction industry employs over 30 million people and creates assets worth over □ 200 billion. It contributes more than 5 per cent to the nation's GDP and 78 percent to the gross capital formation. However, the construction industry has been lagging behind other sectors in terms of productivity. The solution lies in applying automation and robotics in construction. Equally concerning has been the issues related to safety of on-site construction workers. There are several instances of safety regulations not being followed, resulting in injuries and sometimes even death. Automation can eliminate this menace to a large Extent. Finally, it is contemplated that automation will reduce expenditure compared to manual labour which might end the affordable housing problem. In this regard, a review of the available automation technologies in construction industry is of utmost importance.*

Keywords : *Automation, Robotics, Construction, Algorithms, Simulation, Challenges, Brick Laying.*

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I. Introduction

The construction sector globally has been considered as being slow in adopting new technologies, and its labor productivity has stagnated accordingly. The McKinsey Global Institute (MGI) survey revealed that measured labor productivity in the construction sector has remained flat over the last two decades compared to other industries. Adding to this challenge are common issues facing many countries such as building regulatory reform, requirements for responding to climate change and carbon emission reduction and high-profile enterprise failures. The United Nations (UN) population estimates and projections suggest that the world population will likely grow from 7.7 billion people in 2019 to around 8.5 billion in 2030 and 9.7 billion in 2050. The need for more affordable housing as well as social, transportation, and utility infrastructure has placed the industry under a societal obligation to transform. The industry has vast potential, however, for improving productivity and efficiency, thanks to the potential offered by digitalization, innovative technologies, and new construction techniques. The productivity gains by using industrial robots over the past decades have helped to open up new application areas of robotics in on-site building construction. Unlike robots for off-site construction, the complex activities happening on the site often require on-site robotics to be able to travel to and/or localize itself at the work face of a building element and directly work with human workers. As on-site building construction activities become more complex and challenging for large infrastructure and commercial building projects, robotics may offer opportunities for implementing new mechanisms of construction to deal with these complexities. It is against this backdrop that by using a systematic review methodology, this paper attempted to identify and evaluate research articles with a focus on the use of robots in the on-site building construction process.

II. GetPaperReviewed

- **InAutomation of the construction process by using a hinged robot with interchangeable nozzle**,

E.A. Grigoryan, et. al,
The following things were observed:
Problem solved: Mobility of 3D printing device.
Abstract:
Two nozzles were there
1. For capturing brick blocks fed by Conveyor & movement to desired pt.
2. mobile extruder in a timely manner dosage

Introduction: Rapid increase in labor productivity but the construction industry lags behindother areas.
Problem - Printing structures using selective layer-by-layer deposition by extrusion is low mobility & poor weather resistance. Printing of structural elements takes place in spacious & equipped rooms, which is not optimal, complex & often economically profitable.
Solution: Use of existing equipment with the need to modify it (nozzles for different types of work). However, it can increase cost of materials, as in practical application, the need for a concrete mixture of a higher & more expensive class will increase. Manipulators for large-scale printing-overview:

Extrusion 3D printer
1. print head (prints the structure)
2. Positioning system (moves head precisely along print path)
Disadvantages:
● Limited in working space (around 4-5m)(ineffective to deal with large objects).
● Design of engine belt has one axis of movement only, therefore, not convenient for working with objects of large scale
● Needs to be fast enough to realize economic printing speed. French company **XtreeE** made an industrial robot To increase working space, it uses several robots placed at different pts. at reqd. distance. It has large coverage radius.
Disadvantage:
1. Inability to work with a Solution consisting of a large filler.
2. Unable to work with solution of low class & mobility **ApisCor** implemented a new 3D printer concept. Rotary mechanism in central axis of robot base with horizontal telescopic boom.
Application: to erect simple structures outside earth for SpaceX or NASA
Disadvantage:
1. Restriction on height of structure & final location of 3D printer.
2. Difficult to move because of high weight Solution by Author: Use a specific manipulator having several nozzles capable of different types of work.
Technical characteristics:
● Model: Mitsubishi Robot RV-2AJ
● Type of robot: Articulated
● No. of joints: 5
● Payload: 2.0kg
● Repeatability: +-0.02mm/s
● Arm reachable radius: 482mm Brick with a scale of 1:10 w.r.t. size of actual brick was used. FA was presented with a Gypsum-based solution.

Stages of work:
● Algorithm creation using a special programming language
● Creating of drawing of working system
● Create a drawing of gripping brick claws
● Calculation of -
○ viscosity of liquids
○ Solution supply speed
○ extruded head movement
● Testing with mock-UPS to illustrate feasibility
● Calculation of percentage of components entering extruder feed
Control the robot using a programming language:
● MELFA BASIC IV under the computer program COSIROP was used in this study.
● Commands:
○ MOV - move command
○ OVRD - speed of manipulator as a percentage of max. Speed
○ HOPEN- & HCLOSE - Opening & closing of pneumatic grips
○ DLY - pause in seconds that the robot will make before it starts a new task
Drawing of solution supply mechanism
● The design used a system acting on the principle of crank mechanism (CM), which is designed to convert reciprocating motion into rotational motion.
● Rotation is the optimal method of feeding solution.
● Pneumatic grips are only capable of reciprocating so it is appropriate for this test.

● The work consisted in measuring the distance & dimensions of two pneumatic grips. It was then transferred to AutoCAD.

Elements of w/c mortar supply system:

1. Thermal insulator
2. A rotary screw with a specific pitch
3. The extruder nozzle
4. The direction of rotation of screw
5. The level of water solution
6. The body of the extruder

<u>Drawing of the mechanism gripping the brick</u>

● The pneumatic tong in the RV-2AJ manipulator has a pressure sensor & regulator.

● An appropriate amount of pressure is applied to lift & carry heavier objects.

<u>Calculation of percentage of components included for feeding through extruder</u>

● In 3D printing, the main role is played by properties such as static & dynamic yield strength of the cementing material.

● Cementing materials used in 3D printing consist of five groups of compounds:

○ Ordinary Portland Cement (12-16% volume share)

○ Silica fume (21-26%)

○ Sifting sand (25-30%)

○ Fly ash (33-35%)

○ Water (2-4%)

The following conclusions were made:

● In this study, a construction automation system was proposed through the use ofreplaceable nozzles for timely dosing.

● The system consists of two nozzles: a brick tong system & an extruded cement mortarsupply system.

▪ **InRobotic technologies for on-site building construction: A systematic review**,

Marwan Gharbia,et. al.

This paper provides a systematic review of 52 articles identified through the PRISMA protocol and meta-analysis. Additive manufacturing (AM), automated installation system, automated robotic assembly system, autonomous robotic assembly, and robotic bricklaying seem to be most studied. While most research discussed single construction activities related to vertical reinforced concrete (RC) elements, masonry walls, steel beams, curtain walls, gypsum boards, and floor tiles, only a few papers proposed an integrated robotized construction site.

Introduction: With increasing population, the need for more affordable housing as well as social, transportation, and utility infrastructure has placed the industry under a societal obligation to transform.

<u>Methodology:</u> The review has been undertaken in four distinct stages, including

1) identification of articles,
2) screening relevant papers,
3) applying critical appraisal, and
4) data extraction and synthesis.

The protocol for the systematic review was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Identification stage: The sources included electronic databases of Scopus, Web of Science, Institute of Electrical and Electronics Engineers (IEEE), and Engineering Village. Scopus and Web of Science were considered as the principal search systems. ScienceDirect and Google Scholar were not chosen.

The search term (robot* AND construction) was used for searching in the titles, abstracts, and keywords of articles in all four electronic databases. To ensure coverage, we also identified additional papers through manual screening and snowballing of books, conference papers, and publications in several research centers and institutions databases. The search strategy resulted in a total of 34,454 articles.

<u>Screening stage</u>: Irrelevant and duplications of documents were removed

<u>Eligibility stage</u>: Four inclusion and exclusion criteria were applied

1. those papers were excluded if their focus was not related to robotic development and application in building construction on-site.
2. papers containing first-hand research data were included, and review papers were excluded.
3. Relevance scale was used, where “1″ denotes low relevance, “2″ medium relevance, and “3″ high relevance. (all articles with contents related to real case studies of the implementation of robotic technologies in building construction or the implementation of technologies was demonstrated in a laboratory environment were rated “3″ and included in the review). Therefore, the systematic review included research articles published from

1994 to 2019. A total of 52 primary articles were included. 59.62% of the papers (31 out of 52) were published in conferences, while 19 articles (36.54%) appeared in a scientific journal, and only two articles were published in book series. There were four publications between 1994 and 2004. The period from 2005 to 2009 seemed to be a booming era for research in robotics in construction (14 articles). The number of publications relevant to this topic then decreased from 2010 to 2014 (9 articles). A steady rise in the papers has been noticed during the period from 2015 to 2019, with a total of 25 articles. Most of the papers related to the topic were published by researchers in South Korea (15 papers), followed by France, Singapore, the USA, Germany, Switzerland, and Spain (4–5 papers each).

Construction robots could be classified into three general categories based on the mechanism of controlling the robotic systems, namely, fully autonomous robot, teleoperated system, andprogrammable construction robot. The fully autonomous robot category functions in a fullyautonomous manner without human intervention, the teleoperated robotic systems includeremote control systems, and the programmable construction robot refers to those controlled bya human onboard operator.

Nearly half of the included papers (48.00%) were related to the construction of steel andconcrete structures. Papers about interior finishing and exterior envelopes came next andaccounted for 32.00% of the selected articles. Robots for masonry walls construction could befound in 15.00% of the total of 52 papers, and only two articles (5.00%) proposed a robotictechnology for pre-fabricated building assembly.

The most significant proportion of the articles point to the benefit of using robotic technology toimprove overall construction efficiency (47 articles). Two articles only considered introducing anew construction technology as a method of innovation without detailing the concrete benefits (2articles). There are a few numbers of articles (1 each) discussed how to adapt the technologyfor construction in extra-terrestrial environments, design a robot to reduce the site accident rate,and to be used for as a sustainable tool for construction.

Only three articles provided evidence to demonstrate the use of robotic technologies in masonrywall construction and prefabricated buildings assembly. Other robotic technologies in theremaining papers were split between achievable (28 articles) and challenging (21 articles)categories. Most of the articles concerning interior finishing (6 articles), exterior envelope (6articles), and steel structures (6 articles) introduced achievable technology without explainingany foreseen difficulties in implementation.

The review results showed that little research was conducted on inventing novelmaterials and creating new engineering designs for building construction, in particular theconcrete structures.

Most of the articles (90%) reported that it is challenging to apply robotic technologies for on-sitebuilding construction due to such factors as absence in design for automation, lack of research,inability to think out of the box, high cost, difficulty in a human-robot cooperative, and compliance with the building regulation.

Most articles acknowledged that robotic technologies would offer such benefits as introducinggreater efficiency into construction processes by reducing dangerous site conditions, reducingconstruction costs, and addressing labor shortages.

Analysis shows that future research needs to seek alternatives in terms ofconstruction materials and engineering design that can support advanced automation androbotization in construction.

The insights derived from this review provide a full picture of the types and categories of on-siterobots, activities they perform, and the benefits associated with implementing them inConstruction.

- **In"JA-WA" - A wall construction system using unilateral material application with a mobile robot**,

AndrzejWięckowski,

The following things were observed:

The automatic concrete laying of composite walls by utilizing a scaffolding rail assembled on site and a mobile robot that moves along the scaffolding with an injector which applies the material. The system integrates design and automatic control of the builder and insures quality control of the wall construction. JA-WA construction occurs in the "reverse" order when compared to standard methods. Wall construction begins with the outer layer, namely the sheathing element or thermal insulation. The Original features of the JA-WA system include: a lightweight, inexpensive automatic robot at the site, which relieves humans from hard physical labor; lower investment of manpower, materials and capital; and lightweight walls with good thermal insulation.

The JA-WA system represents the technology of unilateral application of materials with a mobile automated robot (Polish: JednostronnaAplikacja – WędrującymAutomatem) where the process of concrete laying at the construction site is automated when building composite walls.The order of wall construction is in reverse. First, the façade siding or thermal insulation layer constituting light unilateral formwork, is stabilized. Next, the structural part is performed. The material is jetted in layers with the "wet-on-wet" method, the automatic computer-controlled manipulator together with a mobile rail device.

The material prepared in the mixer-pump is pumped via the pipe to the application nozzle that remains in a casing which prevents dusting and losses on the one hand, and shapes the surface, on the other.
The control of the manipulator and the pump is performed by the computer. Material is laid and thickened by jetting, using the energy of the plume of high-velocity particles. Pneumatic shooting of particles was developed and patented as "Cement Gun" by Carl Ethan Akeley in 1910.

<u>List of equipments</u>

The main devices for wall construction in JA-WA include: systemic vessel, manipulator with the applicator kit, as well as a dosing-mixing unit with a pump and a material tank.

- Rail track
- Manipulator
- Applicator kit
- Foot bars
- Poles
- Expanders
- Vessel track
- Double roller
- Plate
- Affixed rotary cone cover
- Ejector cylinder
- Bumper

<u>Time limitations at material laying</u>

In JA-WA, the material is jetted in layers. For the purpose of the layers' becoming monolithic, jetting is performed according to the "wet on wet" principle, namely with meeting the condition that the material of the previous layer should be set before the commencement of material binding in the next layer. At the same time, material application in relevant time intervals allows for the use of the growing strength.

<u>Characteristic features of JA-WA include the following:</u>

• The concept of a robot "wandering" along a mobile rail device ensures precise execution of construction of a large area without the need to apply long booms and massive stabilizing structures, which are typically characterised by high material and capital intensity.
• The reverse order of the works allows for performance of a complete wall with lower outlays on labor, materials and equipment operation. Since the complete wall is performed in one technological line, it is more favorable than in standard solutions, in which first the structural layer is made, while in another cycle the thermal and protective layers are performed, causing the need to apply another external scaffolding.
• Man is favorably freed from physical labor and deals with equipment operation, with labor reduction to program launch.

▪ **InOptimal brick layout of masonry walls based on intelligent evolutionary algorithm and building information modeling**,
ChengranXu ,Jiepeng Liu , Sheng Li , Zhou Wu , Y. Frank Chen,
The following things were observed:
The manual building information modeling (BIM) technique can facilitate the modeling of bricks, but is error-prone and time-consuming. This paper presents A BIM-based framework to generate the layouts and brick take-offs automatically.the first-stage deTermines the vertical position of each course and the second and third stages obtain the horizontal positions and Sizes of bricks for odd and even courses respectively. Two types of bonds has been used in this paper English bond and stretcher bond.
Three types of algorithms has been used in the research paper
1) NFO- Neighbour Field Optimization
2) PSO- Particle Swarm Optimization
3) DE- Differential Evolution
The placement locations of bricks should be determined in the BIM model to facilitate the robotic brick laying process. The two dimensional (2D) construction drawing are generally represented by their outer boundaries, with no detailed brick layout. The number and positions of bricks were provided in the BIM model. In these studies, the computation strategies were mainly based on the top-down design rule of brickwork and certain corner bricks still needed to be resized manually. The genetic algorithm (GA) with the Bottom-Left-Fill placement rule to solve the rectangle packing problem.

<u>The proposed framework consists of three modules:</u>

(1)Data collection module – The data collection module is devised to extract the necessary data required to perform the brick layout from a BIM model. The wall information required by the data collection module comprises the position, size, and thickness of the MW, which can be determined by the structural analysis based

on the region-specific design code. An original wall model with correct outside dimension can be easily placed at the required position in a BIM model.
(2) Brick layout module – To facilitate the intelligent optimization of brick layouts, the brick layoutmodule is developed based on the logic of brickwork for each wall. The extracted information from the original BIM model for the MW can be considered as the input data used for the developed module.
(3) Data output module. -The computation results of brick layout module, the detailing design of MW can be completed in the data output module. the local coordinates of brick positions are transformed into the global coordinates including all bricks.
Problem statement
The compressive strength ranges 10-30 MPa for bricks, and 2.5-15 MPa for mortars. In a MW, full and uniform mortar joints are used to fill the space between masonry units.In China, the common brick size is 240 mm (length) x 115 mm (width) x 53 mm (height); while it is 215 mm × 102.5 mm × 65 mm in the United Kingdoms.
Conclusion
In this study, an automated BIM-based framework for detailing Design of masonry walls (MWs) is proposed to determine the optimal brick layout and obtain the brick take-offs. The proposed framework considers the brick layouts for different thicknesses of the MWs with Stretcher bond and English bond. A brick layout module is developed to integrate the necessary data required from the BIM model for determining the brick layout effectively and efficiently. A three-stage optimization model based on evolution optimization approach is proposed to find the optimal brick layout. Through the developed add-in using Autodesk Revit APIs, the BIM model of MWs is automatically updated based on the optimization results.
• The proposed three-stage optimization model can provide the Appropriate and aesthetic brick layouts in two walls.
• Compared with the PSO and DE algorithms, the NFO-based optimiZation approach saves significant amount of computation time and Uses fewer bricks and brickbats.
• The proposed BIM-based framework is fast and accurate in Completing the detailing design forcommon walls as well as the Walls with door and window openings.
However, the developed three-stage optimization models for brick Layout has the following limitations:
(1) Nominal thicknesses of mortar joints are assumed in this study, Which are difficult to obtain in practical masonry construction. Hence, in the future the optimal brick layout will be used in the Data-driven robotic brick assembly process or a masonryconStruction guidance will be provided to standardize the construcTion process and reduce the construction difficulty.
(2) The bond type of brick layout is limited to Stretcher bond and English bond in this study. Other bond patterns such as Header Bond, Flemish bond, and Monk bond deserve a further study.
(3) The brick layout optimization is only applicable to a single wall as The boundary conditions of MWs are simplified. For other Boundary conditions such as intersected walls, the optimizationModel should be further examined. Moreover, the application of The proposed optimizationmodel may be extended to fixing brick Veneers and paving floor tiles.
(4) In this study, the brick is assumed to be placed on a course not Affecting the arrangement of the bricks in other courses. Hence, a Global optimization model for brick layouts will be needed to Apply to the more general cases.

▪ **InReal-time simulation of construction workers using combined human body and hand tracking for robotic construction worker system**,
ManojKuriena,Min-Koo Kimb,MariannaKopsidaa,IoannisBrilakisa,
The following things were observed:
This paper presents a new concept that can tackle this problem in the future. The central hypothesis of this study is that it is possible to eliminate injuries if we move the human construction worker off-site and remotely link his/her motions to a Robotic Construction Worker (RCW) on-site. This combination of tracking enables the capture of changes in the orientations and articulations of the entire human body. Second, a real-time simulation system that connects a human construction worker off-site to a virtual RCW was developed to demonstrate the proposed concept in a variety of construction scenarios.
The construction industry is one of the largest industries in both developed and developing countries. Employing two million people in the UK, it is the country's biggest employing industry. In 2014–15, 35 construction workers were fatally injured and a further 65,000 suffered a major injury at work in the UK, and the fatal injury and work-related illnesses rates are over 3.5 times and 20% than the average rate across all industries. This approach aims to not only minimize the risk of MSDs and the risks associated with humans being present in a hazardous environment but also increase productivity.
Two essential systems for the RCW were developed in this study as a first steppingstone towards this ultimate goal, which are (1) combined body and hand tracking system for the efficient and natural control of the

humanoid robot and (2) simulation environment system to test and demonstrate the RCW system. First, a novel framework of combining vision-based hand tracking with body tracking was developed.
Related work
(1) wearable sensing techniques
(2) computer vision techniques
(3) robotic techniques.

<u>Wearable sensing techniques</u>
The use of on-body wearable sensors is widespread in several academic and industrial domains. Accelerometers and IMUs are one of the most popularly used sensors used to track the motions of construction workers. Such sensors can measure velocity, acceleration, orientation, and gravitational forces, and the acceleration data can be used to monitor the physiological condition of a human body.

<u>Computer vision techniques</u>
The techniques employ training and monitoring to reduce the risk of MSDs. They utilized the Microsoft Kinect to extract the worker's pose (body joint angles and spatial locations).

<u>Robotic techniques</u>
Automation with robotics is an approach that can increase productivity, reduce the risk of MSDs and minimize the risks associated with humans being present in a hazardous environment. One such robot is SAM which is a semi-automated mason robotic bricklayer. A human mason can lay about 300 to 500 bricks a day, while SAM can lay about 800 to 1200 bricks a day. theteleoperation of a robotic system with the use of Virtual Reality (VR) technology as a possibility of performing remote operation with greater safety.

<u>Conclusions</u>
In considering the larger goal of improving the health and safety of construction workers at a construction site, this study focused on tackling three major risk factors –
(1) fall from heights
(2) musculoskeletal disorders
(3) being struck by objects.
The authors proposed a novel solution called Robotic Construction Worker (RCW) system that effectively eliminates the risks faced by human construction workers. As a first step in establishing this solution, the authors developed two essential systems of the RCW –
(1) combined body and hand tracking for the efficient and natural control of the humanoid robot and
(2) a simulation environment to demonstrate, test and develop a virtual RCW.
Using a single Microsoft Kinect sensor, a novel framework of combining vision based hand tracking (FORTH Hand Tracker) with body tracking (Microsoft Kinect SDK) was developed. This was realised with coordinate mapping and a software pipeline to enable the tracking systems to run independently and simultaneously.

- **InRobotics and automated systems in construction: Understanding industry- specific challenges for adoption**,

Juan Manuel Davila Delgado, LukumonOyedele*, AnuoluwapoAjayi, LukmanAkanbi, OlugbengaAkinade, Muhammad Bilal, Hakeem Owolabi,
The following things were observed:
The construction industry is a major economic sector, but it is plagued with inefficiencies and low productivity. In construction industry Robotics and automated systems have the potential to address these shortcomings; however, the level of adoption in the construction industry is very low. The spending in construction represents between the 9%–15% of GDP in most countries Construction is a labour-intensive sector. Robotic systems and automation have proved to be very effective in other sectors for reducing labour costs while improving productivity and quality.
The conventional construction methods have reached their limits and that automation and robotics technologies have the potential to address the productivity challenges of the construction industry.
Industry-specific challenges:
(1) To identify, categorise, and rank the most important challenges that are limiting the adoption of robotics in the construction industry.
(2) To understand the expectations of stakeholders regarding the adoption of robotics in the construction industry.

<u>Robotics and automated systems in construction</u>
The types of automation and robotic technologies for construction can be grouped in four general categories:
(1) Off-site prefabrication systems
(2) On-site automated and robotic systems
(3) Drones and autonomous vehicles
(4) Exoskeletons.

Research methodology
A mixed research method was used that combines (i) literature review, (ii) qualitative data collection and analysis, and (iii) quantitative data collection and analysis. This type of mixed research methods has been proved as powerful tools to investigate complex processes and systems in other sectors.
There are various industrial challenges but out of various challenges eleven major challenges were, selected by qualitative, quantative sampling and analysis.
Robotics has the potential to provide numerous advantages to the construction industry; however, the levels of adoption are very low. This paper presented a qualitative and quantitative study of the industry-specific challenges that limit the adoption of robotics in the construction industry.
The main identified challenges were grouped in four categories in order of importance:
(1) Contractor-side economic factors
(2) Client-side economic factors
(3) Technical and work-culture factors
(4) Weak business case factors.

- **InBricklaying Robot Moving Algorithm at a Construction Site**,

A V Malakhov,
The following things were observed:
Automation of bricklaying is usually implemented using special robotic systems(Like stationary robotic systems). Stationary robotic system mean, robots like computerized machine tools, robotic arms, industrial robots, welding robots etc. Stationary robotic systems are mechanically attached to the coordinate system of a building. Such approach is connected with limited size of Building. Ex. Hadrian, It is fixed before beginning of construction and takes this position during all working time, only manipulator moves.
Mobile robot does not have a rigid connection with the coordinate system of the constructed object. Due to this, the task of positioning of the working instrument of a robot becomes more difficult. Ex. SAM100.
The robot contains the 4- degree of freedom manipulator mounted on a moveable chassis.
Manipulator takes a brick or block from a brick supplying device and moves it to its place in a wall. Blocks are laid layer by layer. Main problem for mobile bricklaying robot is creating an effective algorithm of moving at construction site.
The result of the algorithm's operation is a plan of robot movements at the construction site during laying all bricks according to a masonry plan.
The task for a bricklaying robot that should be solved by the considered algorithm is in some aspects similar to a problem of searching and an exit in a maze. This is due to the fact that a masonry plan usually has a structure similar to a typical maze, having many ways and turns divided by walls.
There are several algorithms for solving this problem like, Flood fills algorithm and a wall follower. Such algorithm cannot be applied to the considered task.
"A flood flow algorithm does not make robot that tracks the walls for laying blocks, this is only for search and exit."
"A wall follower algorithm operates only with an assumption that all walls are connected to each other, and separately situated walls are skipped, i.e. all walls are not be built."
A special algorithm should be introduced in order to take into account all the features of the considered task for a bricklaying robot.
Two Algorithms are introduced in this paper.
1) Movement during laying bricks.
2) Free movement of robot according to the map for going to one placed to another.
A bricklaying passing Algorithm (BPA) Mobile bricklaying robot is equipped with rectangular shaped manipulator's working area.
The coordinate system of a manipulator consists of axes X1, Y1, Z1, while the global coordinate system of a building includes axes X, Y, Z.
The working zone of a robot is at a certain distance from its chassis. So there is a minimal working distance d min from a chassis to wall. If we increase the distance then work done reduces, and decrease the distance to minimum then it leads to impossibility of laying closet wall. Medium distance should be kept in between chassis and wall.
General features of BPA
Robot is able to put blocks at their sites in masonry when such site can be covered by projection of a manipulator's working area.

A free movement's algorithm, The FMA should be based on algorithms allowing searching the shortest ways between a start and a final point. It should allow avoiding unexpected obstacles that can take place at a construction site.
The overall movement algorithm of a bricklaying robot Combination the BPA and the FMA gives the overall algorithm for planning movements of a mobile bricklaying robot at the construction site.
1. Preliminary calculation movements along the walls with the BPA based of a masonry plan and loading the result to the memory of a robot.
2. Determining the start point of a robot and the current position at the map.
3. Building a path to the start point with the FMA and moving to it.
4. Beginning bricklaying with moving along the trajectories calculated with the BPA.
5. If the last (highest) layer is finished, stop operation of a robot.
Development of a mobile bricklaying robot includes studying typical brickwork parameters in order to create effective algorithms of making them by automation means. From the point of view of automatics, typical walls made if bricks have some typical features. Knowing these features allows reducing the required range of robot functionality and simplify its algorithms. The found features and assumptions were used when developing a complex algorithm of moving a mobile bricklaying robot at a construction site. This algorithm is based on a combination of two separate developed algorithms, the Brickwork Passing Algorithm (BPA) that is used during the direct making a brickwork, and the Free Movements Algorithm (FMA) for optimal moving robot at a construction site without laying blocks.
The further improvements of the complex bricklaying robot moving algorithm will be made in the following directions: increasing universality, including processing more complex structures of buildings; increasing the overall efficiency, firstly by further optimization of mechanism of generation robot routes at vast and highly branched objects; increasing the performance of implementing an algorithm by using improved math, applying improved algorithms for the required tasks, including taking into account properties of used software and hardware.

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