

Methodology for automated assembly and delivery of products using mivar expert systems

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Abstract. The paper presents an analysis of the task of automating assembly using robots with mivar decision-making systems. The question of the relevance of solving this problem is considered. The trend of robot development and their application in various sectors is also examined: from delivering parcels to customers to industrial warehouses. The use of mivar expert systems allows solving a large number of tasks for planning robot actions. Moreover, solving planning tasks allows to move towards a fully autonomous delivery transport system. The subject area and existing analogs are analyzed. The algorithm for implementing this task is described. In the end, a conclusion is given and the feasibility of this system is evaluated. This work describes part of the architecture of a web application, which is a cloud constructor of mivar expert systems. The created expert systems can have any subject area embedded in them by the architect. The main principles in development were: convenience, maintainability, scalability. Parameters necessary for the operation of expert systems were defined for further object representation: thing, property, relation. Based on the calculated parameters, expert systems make a decision about further actions. This work is intended for engineers involved in the development of autonomous robotic systems related to the delivery of goods.

1 Introduction

Currently, artificial intelligence is developing at a rapid pace, and advanced AI developments are capable of competing with established methods. The business sector is actively interested in automating the processes involved in the production of products. The development of automation opens up large-scale prospects for the wide decision-making system and use of artificial intelligence in such areas as development, production, and many others. An example of use is the massive creation of decision-making systems (DMS) for autonomous robots.

The development of mivar technologies of logical artificial intelligence has been going on for quite some time. They have proven themselves well in solving tasks in the format of production networks because they allow finding a solution with linear computational

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complexity [1]. Mivar technologies are actively used to create expert systems in the following areas: management of educational programs at the university [2], detailed description of knowledge in a scientific discipline [3], detection of bank check fraud [4], intelligent plant care systems [5], decision-making on the safety of thermolabile blood components [6], optimization of the process of preparing fresh frozen plasma for transfusion [7], diagnosis of diabetes [8], artificial intelligence in medicine [9], mechanical engineering [10] and many other areas. When creating hybrid artificial intelligence (AI) systems, mivar technologies have also found their place. They can be implemented in a wide variety of activities: creating a brief overview of judicial practice [11], detecting energy theft in smart grids using explainable attention maps [12], using metagraphs to represent data sets [13] to overcome limitations [14] and improve existing knowledge bases [15], for tasks of analysis and classification [16] of equivalent logical operations [17], solving first-order logical equations with exhaustive search for solutions [18].

The approach of hybrid AI with the application of mivar technologies includes neural network methods. Neural networks can be used for sentiment analysis based on text and audio data [19], for processing media information [20] and its optimal encoding [21], for working with satellite images [22] and with text queries [23]. In addition, hybrid AI can be used in the development of polymer microstructures [24] and composites [25], in modeling heat exchangers [26], as well as in the formation of intelligent technological units [27]. The use of mivar technologies in conjunction with a neural network approach can simplify the process of data analysis from LiDAR for the task of finding trees and estimating their diameter [28] and for measuring active gases affecting the climate for carbon landfills [29]. Mivar technologies can cope not only with decision-making but also with intelligent analysis of pulsed EPR for recognizing 3D objects by an optical location system [30]. The most promising area of application of the mivar approach and hybrid AI is the development of robotics [31] and navigation systems of robotic complexes [32], as well as the creation of intelligent vehicle control systems [33]. One of the complex tasks in this area is pathfinding [34] with planning the shortest route for a robotic complex [35]. Especially many conditions need to be taken into account when moving autonomous transport on public roads [36].

Building a product or structure is a labor-intensive process that takes a large amount of time, but involves a large number of similar operations, so the use of robots, due to their performance, accuracy and durability, has significant advantages. In addition, workers on the factory floor or construction site are exposed to hazards, unlike robots, which are ready to work under any conditions and are less likely to make mistakes when assembling a structure or product. As part of this work, we specified the logic used to realize the logical reasoning required by autonomous robots when operating, using the KESMI software product. With this tool, we can build real-time algorithms for planning robot actions. It would also be worth noting that artificial intelligence itself is divided into types: weak, strong, industrial, etc. As examples of spheres, in which it is necessary to use decision-making system for autonomous robot we can imagine for example: direction of safety on the road, industrial care of infrastructure of megacities, household furniture assembly, as it is easy to notice, the possibilities of using decision-making system for autonomous robot are unlimited. In this paper, a decision-making system is developed to automate assembly processes using robots.

2 Overview of robotic systems for automated product assembly

Analogue of the developed technology can be conveyor robots, which are customized for assembly of specific products. In contrast to most common systems, mivar technology allows to adapt the robot for the assembly of products with significant design differences,

just by changing the knowledge base and rules that are set by software or special interfaces, without affecting the hardware of the robot or making very minor changes to it. A striking example in the area of assembly and parts production is the BMW assembly line. BMW uses robotic systems with computer vision to assemble car parts. This allows for faster assembly and greater precision, which is particularly important for the production of high-quality cars. Parts on the production line pass through a series of robotic stations that are equipped with cameras and other sensors for recognition and assembly.

Also, one of the most famous and close analogues are the robots of the American company Boston Dynamics. The robots of this company analyze the environment and make decisions based on machine learning algorithms that allow them to "learn" and "adapt" to changing environmental parameters that affect the method and purpose of fulfilling the set goal. What makes these robots special is their ability to make independent decisions based on the information they receive from their sensors. For example, Boston Dynamics' SpotMini robot shows its ability to make real-time decisions as it moves towards a designated point. It uses its cameras and sensors to detect obstacles in its path, and performs maneuvers to dodge them. Similar technologies have been implemented in the manufacturing processes of many leading companies, including ABB, FANUC and many others.

The use of automated systems in product assembly tasks allows for high assembly accuracy, as robots can perform operations with greater speed and accuracy than humans. In addition, the use of robots and computer vision can reduce waste and reassembly, which in turn reduces production costs. Unfortunately, the vast majority of robots are designed to perform single-type operations, which extremely narrows the scope of their application. The algorithm being developed is necessary to ensure that the robot assembler is not limited to several similar tasks and can be used in various subject areas without major design and software modifications.

3 Description of the methodology for automated assembly of products

As an example of an algorithm for assembly, we will consider the assembly of furniture, since the instructions for its assembly are the most accurate and informative. The main steps of the algorithm are shown in Figure 1. An assembly instruction in pdf format is taken as input. By processing the pdf file, an image with sequential assembly steps is extracted. Next, individual objects are extracted from the images, which are the assembly parts as well as the fasteners that will be used to join the parts. In the next step, the images are converted into an XML file using optical character recognition methods, as well as natural language processing methods such as named entity recognition (NER), entity extraction (EE), and relationship extraction. The resulting XML file contains a set of parameters that represent all parts, fasteners, and rules describing the order in which they are connected. All these parameters are fed as input to the KESMI, which composes the algorithm that the robot will use to assemble the product. The robot uses computer vision methods, in particular Siamese neural network models, to determine the parts to be assembled. Also, a set of files of models, parts and fasteners used in the assembly can be given as input data. An alternative algorithm is also possible: using image comparison methods based on the same Siamese neural network model, a missing object is compared with the contents of the model files until the correct one is found, freeing the operator from standardising the files.

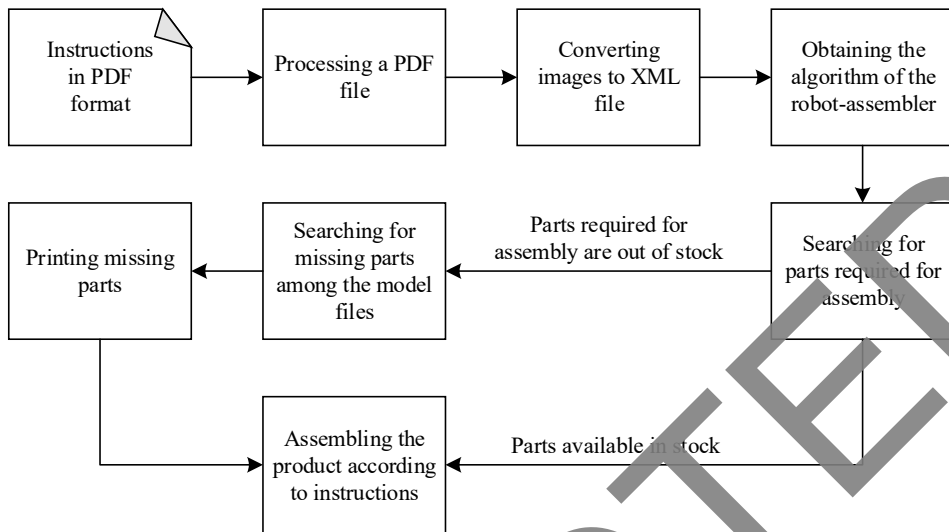


Fig. 1. Methodology for automated assembly of products

4 Review of analogs of automated product delivery systems

One of the pioneers in this industry was the Estonian company Starship Technologies. In 2016, their robot was tested by Swiss Post, and in 2017 Starship became the first delivery robot to hit the sidewalks of London. Internet commerce leaders such as Alibaba Group (China, robot "G Plus"), Amazon (robot "Scout") and Yandex (Russia, robot "Yandex.Rover") are also developing similar robots. The user can order a delivery via a mobile app and track the robot's route in real time. "Hyperlocal delivery of items by robot courier" is a joint image project of JSC Russian Post and Yandex to deliver mail items by 36 autonomous robot couriers in 30 post offices in Moscow, St. Petersburg and Innopolis.

The mass of an empty robot "Yandex.Rover" is 70 kg, its maximum speed is 8 km/h. The robot has six driving wheels. The minimum ground clearance when fully loaded is 100 mm. The Yandex.Rover robot uses Lidar technology to detect objects and determine its position in space. The algorithm combines the point cloud obtained by Lidar with a 3D map stored in memory and searches for the best match. This makes it possible to recognize obstacles and, as a result, autonomously navigate in urban environments.

Wildberries has also decided to join the optimization of delivery with the help of drone robots. It became the first Russian retailer to start test flights of unmanned drones. This initiative is designed to facilitate the delivery of goods to hard-to-reach regions of Russia. According to the retailer's press release, the range of the drones is up to 300 kilometers with a maximum load of 200 kilograms. At the same time, the company claims that it will only deliver small cargoes using drones.

5 Solving the logistics problem by means of mivar technologies

For delivery from the company's warehouses to the points of goods delivery, small cargo transport with a load capacity of up to 3 tons is usually used. Such vehicles move within the city, which allows them to use standard algorithms for driving unmanned vehicles. However, a payload capacity of 3 tons allows to deliver goods in one trip for 6 pickup points, which creates a route optimization problem for both human and robot driven

vehicles. Therefore, developments in route optimization between multiple points in urban areas can be used both as part of unmanned driving and as part of a decision support system for the driver. To solve this problem, it will be effective to use mivar technologies, as they are used to create both decision support systems and decision systems for autonomous robots.

For small-sized trucks, it will be sufficient for the points to be located in the same neighborhood, since due to the payload limitation, it is impossible to carry goods for more than 6 pickup points. This reduces the route-finding algorithm to $N \leq 6$ points located in the same neighborhood. Constructing a minimum route between these points can be easily implemented using a mivar approach. If we take into account that the points are located within the same neighborhood and the distance between them does not exceed 4 kilometers, we can neglect the peculiarities of traffic in a particular area and use the standard formula for calculating the distance between the coordinates on the map. This system can easily be scaled for many points.

In order to fully automate the process of delivery to the customer, it is necessary to implement courier delivery of goods. The results obtained by KESMI can serve as a good example. They can be summarized as an approach to automated order delivery using small autonomous robots that can serve limited areas and deliver orders from order pickup points to final recipients. Since small robots move on sidewalks, it can be argued that decision-making for multiple deliveries consists of finding the minimum distance to the nearest address to make the delivery. Therefore, in the case of small delivery robots, as in the case of cargo unmanned transportation, we can apply the same algorithm for finding minimum distances described above. As a result of KESMI, a graph with a problem-solving algorithm reflecting the logical output of decision making by an autonomous robot.

6 Possibilities for further development of the delivery system

In addition to simply controlling small autonomous robots, a system can be developed that utilizes a product table containing information about orders, delivery addresses, priorities, and other details. The logic-computing techniques used in the mivar approach allow for the creation of decision-making systems and the extension of an existing system to incorporate this data to optimize robot routes, taking into account factors such as proximity of delivery points, number of orders, priorities, and other constraints. The ability to reuse rules in mivar space allows for a general autonomous delivery system using different types of robots, but this requires additional research and analysis of the various factors described below.

First, determining the optimal number of robots. One important research aspect is to determine the optimal number of robots needed to serve a given neighborhood. This may include analyzing the volume of orders, expected delivery times, population density, and other factors. Second, consideration of neighborhood characteristics and user needs. End users and neighborhood characteristics can influence the design of an autonomous delivery system. Studies can be conducted to analyze user needs and preferences, neighborhood infrastructure features such as road network, obstacles, and other factors. Third, scaling and optimization of the system. When designing an overall autonomous delivery system, it is also important to consider scaling and optimizing the system for real-world conditions. This will create an efficient and scalable autonomous delivery system that can handle the increasing volume of orders and user requirements.

7 Web service architecture for a product assembly and delivery system

The structure of the “Cloud KESMI” model consists of two parts: client and server. The client part gives the user the ability to work with models: creation, editing, sending the model to the server for saving, launching, and managing models. Registered users or standalone devices can work with multiple models simultaneously, as well as a group over a single model. After the editing is completed, the user or device has the opportunity to send the model to the server for further processing. By sending requests, the client can interact with the models and receive processing results, information about the status of the launched model.

Interaction with the launched miavar model can be carried out in two ways: API using the user’s key or public key, interaction through the web client interface. The client can receive from the launched model the result of the model’s work, the decision graph, the console output, the status of the launched model. When the user stops working, the model will be saved using the version control system. “Cloud KESMI” allows you to test the operation of the model before implementing it into the system. “Cloud KESMI” is also a more secure version compared to its counterparts. This version allows you to prevent unauthorized access, ensure protection against illegal use of software and protect miavar software from reverse engineering.

8 Client part of the "Cloud KESMI" web service

The Front-End consists of two parts: a miavar model editor and an interface for managing running models. The task of the miavar model editor is to provide the user with the ability to create and edit a model. Due to the need to minimize response time and ensure data safety, the editor can work without an internet connection, with the network being used only for synchronizing the local model with the model on the server. Synchronization involves sending or receiving the latest current version of the model. A version control system is provided for this mechanism to work.

After finishing work with the model and synchronizing with the server, the client has the ability to launch the model locally. There is an interface for managing running models to perform various operations on the model. This interface provides the ability to launch the model, pause the running model, send input data to the running model, receive output data from the model, receive the model log, i.e., the algorithm for processing input data of the model, graph, receive information about the state of the running model, and receive the output graph of the model. This interface will be implemented as a web application, for this it is necessary to use such tools as: HTML, CSS, JavaScript. To optimize the development time of the front-end, we use the JavaScript library React.js.

9 Server part of the "Cloud KESMI" web service

The server part consists of the Reasoner, which processes miavar models, a version control system for miavar models, a database, and server software to link all components, an API for interaction with the launched model. The Reasoner is the logical core of the complex management system. The Reasoner uses the miavar approach. The miavar approach is based on a multidimensional space $\{V,S,O\} - (V)$ thing, (S) property, (O) relation. The term “thing” implies the name of the object, its designation. The concept of “property” means a list of properties of a given object, its characteristic features, special signs inherent in this object. The term “relation” is understood as the totality of all the relationships of a given

object with other instances of objects. After determining the coordinates along the corresponding axes, it is necessary to define the object as a set of points in the VSO space. Thus, it turns out that the object is a cloud of points in three-dimensional space, the received clouds for different objects can intersect if they use common points.

Given that the “Cloud KESMI” system provides for authorization, there is a need to determine the place to store account records. It is also necessary to determine the place to store information about the model: who is granted the right to launch and interact with the model, the date of creation of the model, the date of the last change of the model; information about the launched model; service information. For these purposes, we need a database that has high performance and the ability to cluster to ensure high system resilience. The API for interaction with the launched model provides the opportunity to integrate the mivar model into the user’s software using RestAPI. RestAPI is an architectural style of interaction of components of a distributed application on the network. Through RestAPI, the user can transmit input data to the model and receive output data from the model. To ensure controlled access to the model and the possibility, a generated unique key identifier is used. There is also the possibility of interacting with the model without a key, limiting functionality.

To connect the components of the system together, software is needed that would implement the following functions: database queries, model retrieval from model storage, preparation and launch of the model in the Reasoner, collection of statistical data, expansion of the Reasoner API for external interaction. Another function of the server software is to manage information about accounts, models, and launched models. The server software is responsible for load balancing on this data processing center.

10 Conclusion

The article analyzes the task of automating assembly-using robots with mivar decision-making systems. The question of the relevance of solving this task is considered. The subject area is analyzed and an overview of existing analogs is given, as well as the implementation algorithm is described. Based on the work done, it can be concluded that it is possible to implement the set task.

After conducting a comparative analysis with existing analogs, it can be unequivocally stated that “Cloud KESMI” allows expanding the work of KESMI, accelerating the implementation of expert systems using the mivar approach. “Cloud KESMI” facilitates the implementation of mivar technologies, as the user only needs to register in the system to have the ability to create models and launch them in the cloud. Another advantage of “Cloud KESMI” is the reduction in the likelihood of technical malfunctions and their quick elimination in case they occur, as the use of cloud technologies allows for the operational collection of statistical data and error data. Additional research in the field of logical artificial intelligence can help develop a general autonomous delivery system, which can be effectively managed and serviced taking into account the peculiarities of the environment, user needs, and technical constraints.

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