THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAŢI
FASCICLE V, TECHNOLOGIES IN MACHINEBUILDING,
ISSN 2668-4829 (PRINT) 2668-4888 (ONLINE)
https://doi.org/10.35219/tmb.2019.1.09

HOLONIC MULTI-AGENT SYSTEMS ALGORITHM FOR AUGMENTED REALITY INTERACTIVE ASSISTANCE

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ABSTRACT

In this paper is presented an algorithm based on the holonic multi-agent approach concerning augmented reality assistance to be applied in assembly or disassembly operations. The variation in production and fast start of production requires operators to learn assembly operations for large range of products. In order to avoid errors, operators might be trained and corrected using augmented reality application able to assist and provide important information to allow the operation according to technical required specification. The holonic multi-agent system allows solving complex calculus concerning the best choice. The proposed algorithm is easier to apply when the operator needs to be assisted in assembly operations while meeting technical specifications. By applying the proposed algorithm, the operators learn very fast the operations for assembly/disassembly.

KEYWORDS:augmented reality, holonic multi-agent, interactive assistance

1. INTRODUCTION

The AR technology is used in game industry, medical, manufacturing, education and training. There are many applications for industry: 1) assembly/ disassembly 2) maintenance, 3) design analysis 4) work safety simulation 5) medicine [1][2][3][4]. This paper focuses on the development of an application that Augmented Reality Technology might be used to inform a user with detailed information over-imposed to the real environment. Classical method to inform a user to perform operation of assembly means using a paper manual with instructions step by step. However some operations need additional information besides order of assembly and refers to force of screwing, checking conditions and the handling in order to perform a fast and without putting the user to the hazard of work accident. The basic idea is that all the information required to perform a complex engineering assembly task are displayed in a very comfortable way to the user using an AR environment. In such a manner the user would not have to refer to a printed manual with complex information very hard to show. This technology is a best way for AR guided view to aid in the assembly of multiple operations with serious amount of information concerning the operations. Such a system provides a top down view of the assembly area displayed on a screen [6][7][8]. For each step done by the user is informed with textual instructions provided with corresponding animated 3D models or even audio information. The animated 3D models show intuitive visual instructions concerning the movements for the current step performed by the user such as grabbing order of the part, force to be applied, or type of the tool to be used 9]. An augmented reality system combines the real world with the virtual world over-imposed on the real scene using animated 3D models. Scholars used even commercially available platform such as Hololens [10].

A great technical challenge is concerning the registration between the virtual and real environments as the 3d virtual model should over-impose over the 3d world with acceptable errors. The user should be informed in such a manner that the 3D models duplicate reality and there is a logical connection to the real world.

The basic idea of multiagent systems (MAS) [11] is that individual agents act by interacting between them and also with the environment in order to achieve the solution of a problem [12][13]. Multiagent systems are the suitable solution in case the complexity of the problem is high. The MAS concept means that the problem is reduced to sub-problems which can be solved by specific agents but also interact in time by different epochs. The higher complexity level of development of MAS as will provide more efficient organisations of multiagent systems is the holonic systems [13]. This is an approach based to MAS theory but means a more complex organisation of agent societies [14][15]. The difference resides in an improved methodology for recursive action of agent groups that translates in a dynamic reorganisation processing the information [16]. Holonicmultiagent system are able to reorganise during existence in order to adapt to changing environments. There are different goals to be reached by the collaborating holons as own goals but also community goals. Basically, a Holon is an entity able to coordinate, able to regroup in different configuration in respect to other holons in order to achive global goals. A holon is able to relate to a bottom organization and consequently has a self-discipline attribute. Holon concept is about be a part of a community taking into account hierarchy system but also distribution and coordination. It may act as autonomy, coordinated with other holons, and even self-distruct if necessary. The holonicsociacity is the same as many biological systems such as cells or animals societies [17][18][19][20][21].

Agent based Modelling and Simulation (ABMS) is a part of Artificial intelligent domain of study. The initial concept come back to 1940s when the first prototypical "cellular automata" was invented to simulate interaction using on-off state switches (Von Neumann 1951).

Agent based modelling refers to a dynamic processes of agent interaction that are discrete-event that occurs in time. Each interaction in time means that the model is continuously repeating and agents interact.

Aholon is primarily a container of roles and capabilities that is defined by the user taking into account the problem to be solved. The role container provides the information of the holon's roles, in what extent will have interaction with other holons. The event-based communication is the way the user define roles of the holons. Figure 3 depicts the architecture of a holon.

Several aspects must be distinguished concerning unification of the holons: one relates to the holistic nature of the entity: a holon, called a super-holon, is made up of other holons, called sub-holons or members) and deals with management of the super-holon. (ii) The second aspect is related to the problem to be solved and the work to be done. A super-holon thus contains at least two holons of a holonic organization to specify how members organize and manage the super-holon. Each member of the super holonsdescribes how members interact and coordinate their actions to accomplish the tasks and objectives of the super-holon.

MultiAgent systems are more used as such systems are considered suitable today for modelingcomplex systems with continuously changed of environment. In complex systems we need usually to use arge number of holonsto interact.

Holonic systems are used by researchers on various fields varying from production systems, military transports, medical, simulation or even medicine.

The term holon was invented by A. Koestler in 1967 defined as a self-similar structure composed of holons. Consequently, a holon can be seen, either as an autonomous "atomic" entity or as a holon organization.

2. THE PROPOSED SOLLUTION

The most important design of holonic algorithm concerns the native management of the holon society. Two main aspects need to be defined in order to implement a holon society (holarchy). The first aspect refers to the implementation of holon rules and capabilities and to the design of a general holon architecture capable of integrating the capabilities held by the role. This architecture must provide the means to manage the life cycle of roles and capabilities and to dynamically adapt to the environment. The second aspect concerns the implementation of rules of communication inside a super holon to ensure the communication between a super-holon and its members, seen as two distinct levels of abstraction. For instance, when the operation of merging, holons is giving up of their autonomy and act together with more efficient structures.

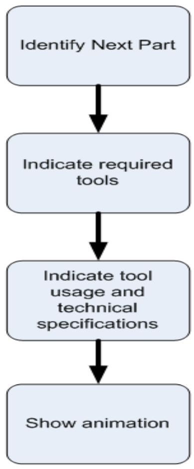

Fig. 1.*Basic steps for augmentedrealityapplication*

Fig.1 displays the basic steps for an application to use the augmented reality for assembly/disassembly operations. The system shown in Fig. 2 is an example of an augmented reality user interface using a augmented reality menu. Each step of the assembly process is displayed over de reality and the virtual menu allows the user to select different options such as animations, tools needed in the next phases, service operations (such as lubricating some parts).

The user understands where to apply force and how to disassemble the part. Proper registration of virtual content in AR needs several steps to be performed: Firstly the computer vision algorithm needs to identify exact position in 3d space the parts in order that the user manipulates a virtual 3d models.

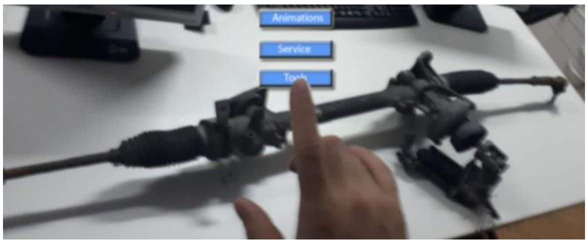

Fig. 2.*Graphical User Interface of the application*

The virtual interface using buttons, combo box controls needs to help the user in order to define operation, such as inspection, assembly/disassembly tasks while receiving haptic feedback. Suitable interactive interface needs to allow easy interaction to the user. The presence over imposed (or super-imposed) virtual information over a physical representation and this step needs necessary virtual information. Fig.3 shows the 3d model of the steering column. The 3d model which is composed of several parts is used to show animation but also to inform the user using augmented reality technology. Fig. 4 displays a detail of the 3D model.

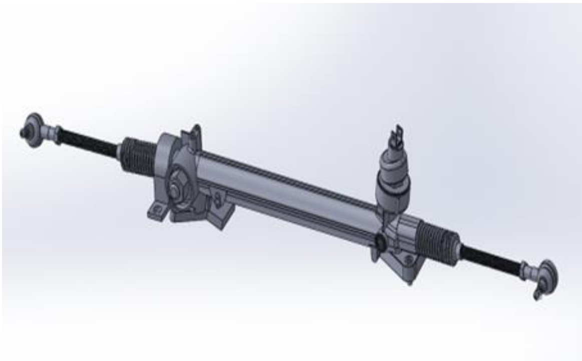

Fig. 3.*Digital 3D Model of thesteeringcolumn*

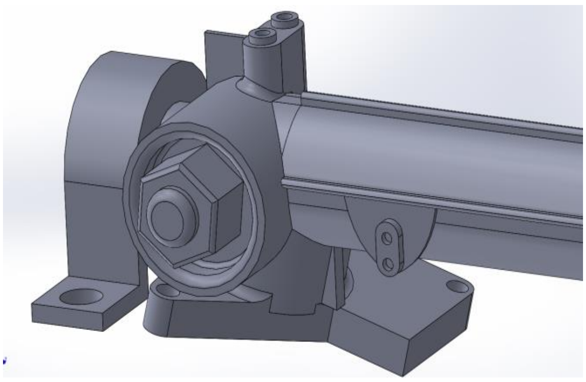

Fig. 4.*Detail of the steering wheel*

The physical assembly employed in this research is car steering column, in order to build proof-of-concept application.

Each parts is assimilated with holons, that is software entity that are process, from the point of view of operating system able to find solutions concerning the engineering task of servicing and disassembly the part. In this research each holon is a operating system that has associated 3d part as well as information to the link to other parts. The proof-of-concept aim is only to show the use of holonic approach concerning augmented reality application designed for assistance.

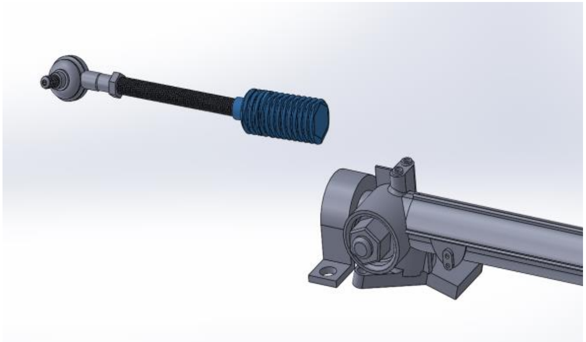

Fig. 5.*Sub-parts of the steering wheel*

The description of a typical disassembly is based on the information provided by the software system. The system takes into account the real –case scenario when there are confusions between similar parts to many producers. However the 3d model of the part are designed that cannot be placed in the right position.

With the above application scenario and typical user in mind, the cognitive walkthrough method was employed to establish use cases.

Computer vision algorithms are used to solve several subtasks: computer vision recognition of the part, indication of possible operations needed, tool identifications, and displaying the best scenario.

A full assessment of the user feedback should concern several testing with different users in order to validate the friendly user interface of the software. However, because this research is interested only in developing proof-of-concept that question is disregarded in this investigation.

When performing a disassembly operation, the software needs to identify the part or parts. The identification of part is based on contour and colour detection, as a heuristic algorithm, but also the software should identify part position. However the other case where different parts look the same and have several features which assemblies, making the recognition algorithm to false detection. However, as the system has enough time to identify, taking into account several dozens of seconds, in order to provide the result to the user, this can be overcome.

Furthermore parts recognition can be done taking into account sequential steps. This would make recognition using computer vision more efficient and produce very reliable results. Subassemblies, which are already assembled, should be identified in such a manner as the user interacts with the new situation.

Indication using animation for part manipulation aim is to make the user understand very easy how to manipulate a part. The basic task of assembly a part consists of moving the part into the scene over imposing the reality to the overall assembly.

Basic manipulation means basic operations such as movement along 2d space and also rotation.

More complex movement involve orienting the parts moving to the destination positioning the correct position.

The identification of the tools is s similar task which means computer vision algorithm to be used. The user might use a wrong tool and the system should inform about this.

Holonic approach means that the combination of the real and virtual representation is performed by the holons entity in order to represent an augmented reality. In the Fig.6 is displayed graphically the situation when a sub holon is a part of another holon.

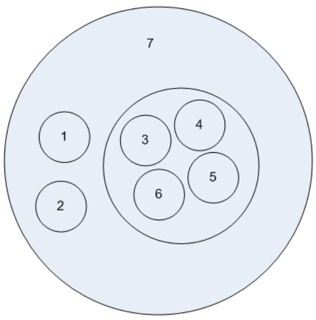

Fig. 6.*Holons parts of other holons*

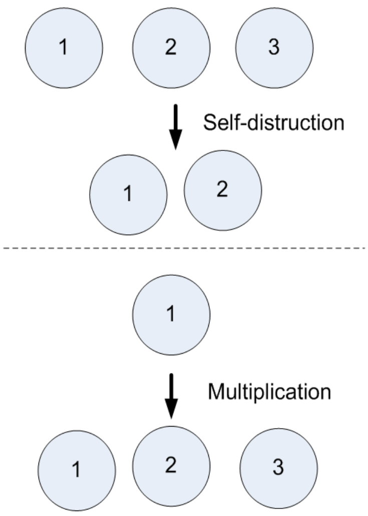

Fig. 7.*Representation of multiplication and self-distruction operations*

The holistic organization is the basis of the holon society government. A subset of members will represent all sub-holons to the upper hierarchical organisation. This management structure is highly reconfigurable in the sense that allows holons to form new sub-holons, to destroy holons or to change holons subgroups (see Fig.7). The same as workers team move to the teams where more work is needed, the holons move to new super-holons (see Fig.6 and Fig.8). All holistic roles are defined to describe the status of a member within a super-holon.

The goal of this paper is to create a proof-of-concept software component that allow easy enhancement of AR applications using holons agents. Also, we aim to turn physical objects like parts, a printer component or a washing machine component into interactive responsive animation over-imposed, virtual presenters and other synthetic visual elements. An animation framework needs to address the following major issues:

1) A high-level interactive over imposed interface is needed where virtual and physical objects are intelligent entities that are collaborating, communicating, that is living in a community called holarchy in order to achieve global goal to finish the assembly.

2) The user action is taking into account by holons in order to re-configure and adapt and also suggest solutions to the user.

This interface is able to compute automatically 3D coordinates and thus rely on holonic approach.

Artificial intelligence algorithm needs to be designed in such a manner that holons are able to communicate between in order to output reliable results. Based on the inner rule of action the holons are able to make decisions and execute actions that mean that the input, the suitable solution for disassembly is highly reliable.

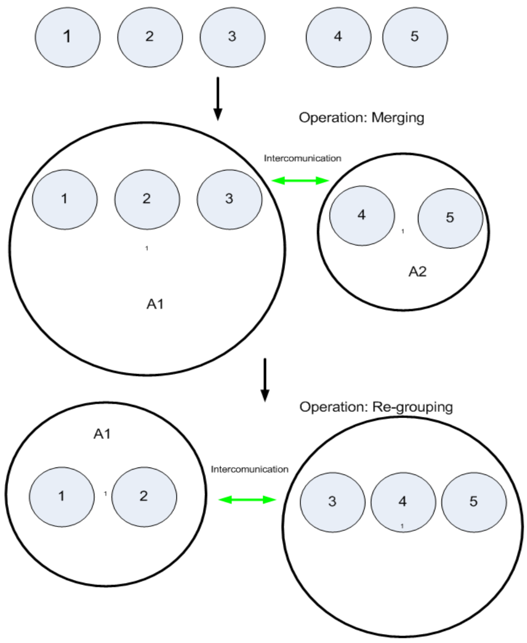

Fig. 8.*Graphical representation of operation of merging and regrouping*

Holons are embodied as operating system process associated with operations and 3d models of the assembly. In the virtual space, holons occupy also 3d space and then occupy the space, associated with a position and also can freely move using all 6 degrees of freedom. According to this approach holons are associated with a 3d model that can be observed and each holons have to not to collide in the space with other 3d model, when the user confirms is accepted scenario.

Every holon with a 3d model associated collaborate with others in order to decide what animation needs to be displayed.

A quite interesting aspect of holons is that physical objects such as a printer, washing machine have a correspondent in the virtual space of the system entities as intelligent, responsive entities that collaborate with the user.

Each holonis associated with relevant physical attributes and taking into account the environment can generate solutions interpreted by holons or subholons. Using information interchanged between holons low-level communication holons change complex information such as 3d current position.

Holons act as input and output communications devices in order to form sub-holons.

Several scenarios are simulated and compared to evaluate the self-organization procedure and rules. In the first scenario the authors disabled regrouping operation for the structural self. For second scenario, the self-destruction was disabled.. The third scenario impose that the operation of merging is disabled. We performed several simulations. The table below shows the results.

Table 1.*Comparison in case of some of holon operations are disabled*

	“Regrouping” Disabled	“Self-distruction” disabled	“Merging” disabled
Time	FAIL	+30%	+50
Errors	FAIL	+10%	+7%

As can be observed in the Table 1, disabling the structural rules of holons will translate in a low performance or even not reaching the result. In case of first case, with the regrouping disabled the algorithm fails to find solutions. For the second and third scenarios the algorithm requires more 30% and 50% more time and produce errors in positioning the virtual part in space.

This is mainly due to the main feature of the holons to concentrate in the area of solution space where is needed the most making a highly adaptable structure. Also an increasing of the time to process each solution emerges as the resources, that is holon computing, is not correctly used. In Fig.9 is shown the way the user is informed in order to proceed operations. Both augmented reality is used as well as abstract information. The experimental results for the this proof-of-concept application show the advantages of a holonic modelling in case of continuous changing conditions with a wide space of solutions.

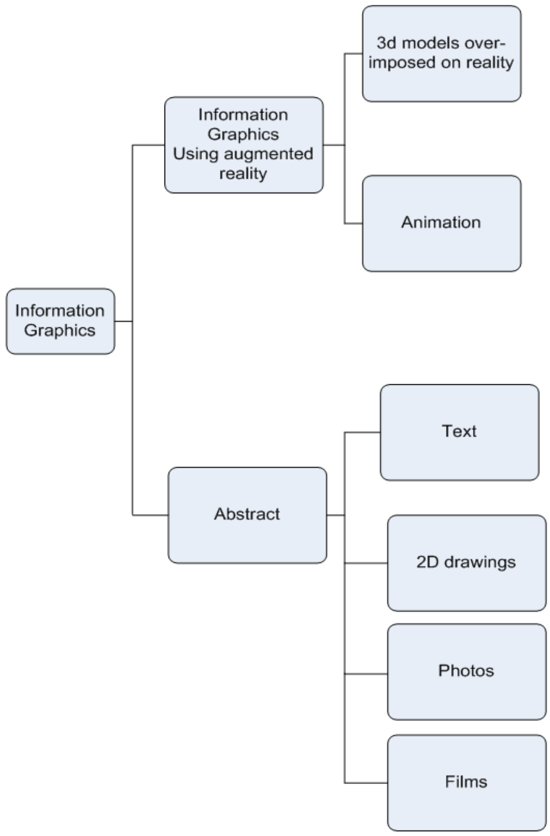

Fig. 9.*Representation of information*

3. CONCLUSIONS

This paper presented a proof-of-concept application that uses a holonic algorithm for augmented reality assistance aiming to help operators in assembly/disassembly operations.

System complexity solutions have grown in many domains showing the necessity of using artificial intelligence approaches. In this sense, holonic multi-agent allows using concepts from nature such as distribution of the autonomous entities to provide very good results.

The use of the holon approach is useful in agent based simulations, whereas different merging types support different simulation tasks (addition, average and relation merging). The experiments showed that in order to improve the proposed algorithm we need to consider adding additional operation needed for holons during the structural self-organization process.

In our future work we are developing new approaches that are considering introducing new operations and feature of holons, for self-organization of the holons. Augmented reality is a domain where artificial intelligence algorithm needs to be used.

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