Applicability of a Serious Game Framework for Construction Logistics

Gábor Bohács(✉) and Bálint Bertalan

Budapest University of Technology and Economics, Műegyetem Rakpart 3, Budapest 1111, Hungary
gabor.bohacs@logisztika.bme.hu

Abstract. Intelligence and complexity are increasingly demanded requirements during decision-making. In our former research a software framework has been developed, which enables implementation of process planning in a serious game environment. This method has an advantage in terms of increasing complexity and knowledge retention. Current paper first surveys most important features of serious gaming and points out a lack of the applications directly in planning. In the further part basics of out serious game concept is presented. The method's applicability for construction logistic planning processes is presented via an example. This relates to a complex process of concrete construction, involving the sites, he concrete batching plant and he raw material supply.

Keywords: serios games · construction logistics · process planning

1 Introduction

With the increase in the complexity of the industrial processes decision-making should also keep up with it. Besides, processing timeframe of the high amount of information, is decreasing. Agility is also increasingly demanded caused by the rapidly changing global economic, environmental background, and ever-increasing market competition. Exceptional conditions are emerging more frequently, Covid pandemic, chip shortage, lack of workforce and supply chain interruptions are only some of the problems which may require quick process replanning.

But currently there are a lot of possibilities as well. Use of the Internet is a widespread daily practice, and increased connectedness among humans, machines and information systems is also established using the principle of Industry 4.0 [1]. Additionally, application possibility of artificial intelligence is exponentially spreading.

In the world of challenges and possibilities, appropriate participation of humans in the processes, particularly in the decision-making is essential. Keeping the human in the loop of process planning and control is inevitable to understand and improve systems using artificial intelligence which also trains the humans capability.

Computer-based serious games are particularly useful in this aspect, because these are capable of integrate human intelligence with machine algorithms. Our paper first surveys

J. Fottner et al. (Eds.): CLEaR 2023, LNCE 390, pp. 33–39, 2024.
https://doi.org/10.1007/978-3-031-44021-2_4

background of serious games. Following, we present a novel serious-game software framework and validate it via an example.

Current research is part of our project INEXT, which is supported by the National Research, Development and Innovation Fund of Hungary under grant no. ED_18–22018-0006.

2 Literature Background

Serios games are interpreted in the scientific community in various ways. A comprehensive survey can be found in [2]. A common opinion is that serios games are the ones combining the entertaining way with the practical content. In other words, serious games are "games that do not have entertainment, enjoyment, or fun as their primary purpose" [3]. This is however sometimes hard to decide if a game is serious or not. Therefore, the context of playing is decisive. If it is related to work or educational purpose, a game is classified as serious. But some point out that there is also a great hype behind it, and they have the opinion that it is only a marketing technique [4]. Serious games are generally classified using the G/P/S model [5]. Here "G" stands for "Gameplay" which can be two kinds. "Game-based" games have well defined goals to achieve, so in each game a winning or losing situation can be evaluated. "Play-based" games don't have stated goals, the player can propose its own ones. The later one can be used for studying a situation or a system. "P" means "Purpose" in the model, which can be message-broadcasting, training or data exchange. The last classification criteria stands for "Scope", which describes the group of possible users. This can be for example healthcare, corporate, education, politics, science.

Our intention is to create a platform for the support of planning processes in various industrial areas. Using the above classification model, it is a play-based / data exchange / industry type game.

One possible application area is planning of construction logistics processes. These combine handling of several problem areas (see [6]). Synchronization of on-site and supply logistics has an overall importance. During this, establishment of the supply chains and stocks are necessary, together with the provision of the handling equipment. of the material. Application of diverse handling technologies like cranes, mobile loaders, baggers require proper allocation of the workforce in order to achieve schedule adherence. Construction processes are mostly implemented in large scale and/or complex environment, therefore special infrastructural elements, and layout specifics play an important role. To successfully implement material flows and services, information system needs to be established as well. The described complexity can only be realized by the collaboration of various experts. In order to fine tune the processes in advance, simulation models and serious games can be applied.

Gamification in construction logistics has already implementations. In [7] a construction logistics focused game was proposed, which serves educational purposes. This is however different from our approach, as it is implemented using physical tools rather than software, and it requires competition among the players. As we intend to use our results in process planning, we prefer collaborative characteristics. Through the interaction of various experts during the gameplay, optimized process results can be achieved.

Use of simulation modelling in construction logistics is also researched. Authors in [8] analyses the operations of an on-site batch plant and the concrete supply process using a simulation-based model. The objective of the model's application is the determination of the concrete truck fleet size that fits best the actual tasks.

In latest research, serious games are expanding from the original areas of training and education. In paper [9] a serious game to compare the manual performance of human decision and he use of algorithms is presented. The game also allows humans to create their own automated planning rules, which can also be compared with the implemented algorithms.

In construction processes collaborative planning is an increasing issue. In [10] the author presents a collaborative production planning environment with BIM system. Here live and concurrent collaboration between the participants is proposed. The proposed serious game is different, as it gives priority over multilateral discussions to a more controlled iteration process, where each player has equal priority and necessary time to reach the decisions. We would like to emphasize that neither collaboration planning nor serios game approach has priority, these apply simply different approaches.

Thus, we could not find any references in which serious game is used directly for logistics planning rather than indirectly.

3 Description of the Elaborated Framework

Computer-based planning and scheduling of logistics processes is generally done in two main steps. First process information from various experts and databases are collected, and afterwards, computer planning tools, mainly simulation software are applied in order to predict key indicators. This information is than feedback to the experts for further iterations if necessary. During this classical approach, the experts are not directly observing the evolving process, therefore important details can be missed. I serious games, the participants remain attendant during the whole process. This would however require full time attendance from the experts therefore a reasonable new approach is needed.

In our research, a concept is elaborated in which advantages of the serious games are combined with the benefits of software tools' application and artificial intelligence. It is actually a special serious game, in which some players are substituted by AI or reach their decisions using software tool. As the concept's intended main application is logistics planning, a flowchart structure can be drawn, which consists of the planning steps and aspects. Figure 1 depicts an example for this. Here the logistic planning tasks are ordered in a linear structure. Each step obtains input from the previous step and gives output for the next one. In the planning steps 1, 2 and 3 output is generated using only expert knowledge. Step 3 is completely automated, using a standalone interface software which is able to communicate with the serious game, and runs AI algorithms on demand. This can be useful if data is available which can be learned by e.g. a neural network. As an example for that, assume, that we have recorded data on the loading times of trucks with different unit load amount and different number of forklifts. By learning this data, the neural network can predict future scenarios. In step 4 a human participant generates the output, using a software, e.g. computer simulation.

The actual planning task is defined by a flowchart. Elements of the this are simply activities by the players. We decided for this simple structure over application of process description languages such as UML, EPC and BPMN, because these already have an extensive ruleset, which would limit the flexibility required in our serios game. During the research a software framework has been developed which is capable of flowchart creation and editing.

The serious game has been implemented via WebAssembly and Blazor and containerized by Docker. The first two allowed that both the frontend and the backend could be implemented in C# with a common codebase for the parts that could be shared between the two components, and the last one allowed easier storage and hosting. In the platform the user can register to the serious game with an email, username and password triplet and then use either the email or the username with the password to log in.

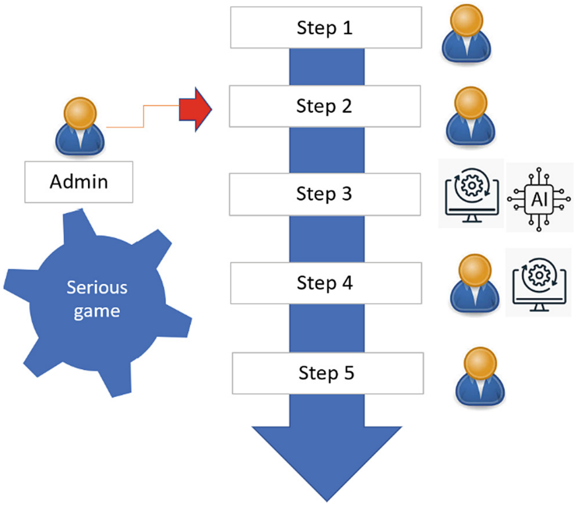

Fig. 1. Depiction of the proposed serious game's basics

After that, the user receives a JSON token which can be used in every message in order to authenticate the user and allow access to the platform.

Flowchart creation is done by the game administrator, who defines for each step following information:

– a name and description of the task,
– participant or software interface assignment for the execution of the actual task,
– input data specification from previous steps,
– output data for next players

Afterwards, connections between consecutive tasks are drawn. After the game has been created in a flowchart form, it is released by the administrator. This serious game doesn't require the participants to be physically in the same place and time. If a certain player has an actual task, because previous players have finished their tasks, a notification has been sent out about the actual required activity. This eliminates common disadvantage of group meetings and brainstorming, where the involvement of the participants fluctuates according to their expertise. That leads inevitable to utilization gaps and ineffective planning process. A further problem may arise if somebody forgets or miscalculates something. In this case result of the meeting is invalid and can only be corrected via numerous emails or another meeting. In the proposed framework responsibility of the participants can be established, as the players' outputs are recorded. If someone gives an unrealistic output, it can turn out in later phases, and can be sent back to the process step where to problem may have occurred.

So, the participants work on the planning process steps only when their task is actual. The processing of the task is carried out in the serious game framework: the player first reads the obtained input, makes the processing using necessary calculations and software, finally generates an output in the serious game framework. The player can add keywords and comments on the specifics of the decision. That not only helps the other players understanding why the output was made that way, but makes up a good basis to reuse the information and learn from it.

Planning tasks are normally iterative. The concepted serious game-based framework is also capable of handling these situations. The players are allowed to send back the received information to the previous phase for amendment and resend. The cause for this are situations in which the actual task cannot be solved, because of for example capacity limits. The game ends if all the tasks are processed successfully.

4 Application of the Framework via an Example

In order to give more insight on the functioning of the concept an example from construction logistics is presented. Main goal is to play through a concrete production and installation process, starting from the supply of ready-mixed concrete batching plants (RMC) to the concreting a the sites. This involves technological and logistic transport tasks as well. The overall process structure is presented in Fig. 2., depicting the already defined tasks and their relation in the serious game model.

Next details of the structure will be described. Playing this serious game require following player roles, and related tasks:

There is a "Network coordinator", who is only responsible in task "Order assignment" during which he aggregates the site demands and divides them to both RMC plants. This role can be implemented using a machine algorithm as well, if the only requirement is to secure smooth, evenly distributed workload, or match RMC plants and closest construction sites.

The "Weather assistant" interacts into the game at two points. First, at the start of process, during the "Weather forecast" task a time series of data is supplied for the "Site managers". These include for each day of the planning period, degree of suitability for concreting from the weather aspect. Second, he will act in the "Weather impact calculation" task, during which he possibly reduces the degree of implemented concreting at the sites, which may be caused by weather.

The "Constructional equipment manager" has also a reducing effect. He acts solely in the "Constructional equipment impact" task. Depending on the concreting intensity, he can make reductions on the implemented concreting, because of expected maintenance

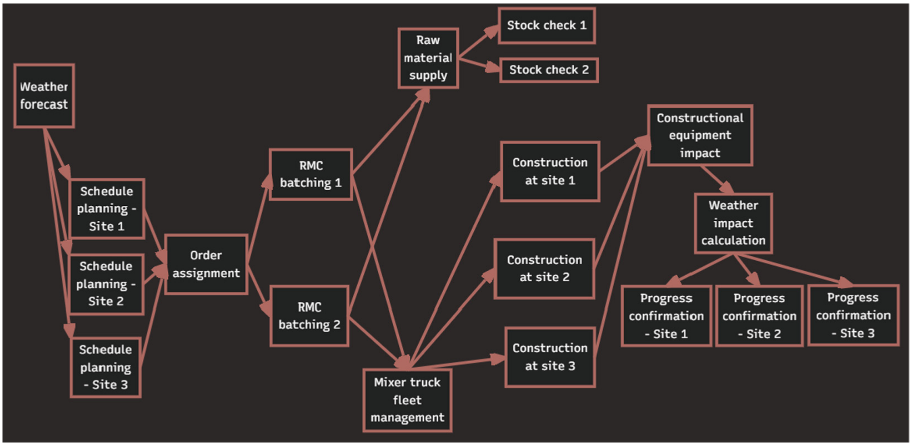

Fig. 2. The example serious game model.

and malfunctions. This task is also possible to be processed by AI, if there are relevant data from previous construction sites.

The "Mixer truck fleet manager" acts only once during the process ("Mixer truck fleet management"). His task is organization of the concrete transports among the RMC plants and construction sites.

The "Raw material supplier" obtains material orders from the RMC plants for cement and for the various aggregates, in the "Raw material supply" process. Output of this task is a list of confirmed delivery dates.

There are also three "Site manager" roles in the game. They process several tasks. First, they set-up an appropriate schedule ("Schedule planning …") for the sites using the weather forecast, and additional information on the construction project requirements. They also manage processes at the sites ("Construction at site…"), where they obtain deliveries and outputs time series of the concreting times. This is further checked from weather and equipment availability aspects by other players. Finally during "Progress confirmation …" tasks they check whether the reduced amount is acceptable or not.

Two "RMC batching plant manager" roles are also included. They process "RMC batching…" tasks, where the outputs are the necessary raw material supplies and concrete transport demands. Prediction of the RMC plant processes can be largely helped, if a process simulation model exists for the plant. This role has also a "Stock check …" process, which serves as a confirmation of raw material supplies.

Lack of a global objective function for the whole system is an important feature. All the players try to achieve their own optimal operation. If these are contradicting, certain process inputs can be rejected by the consecutive processes. If there is still no solution after several iterations the gameplay fails, and the contradictions must be handled by higher level managers outside the game. The serious game however supplies also in these cases valuable information.

5 Summary and Further Research

The presented serious game-based framework has been developed for intralogistics purposes. Later we realized that it can be used in further areas as well.

Later we will develop this framework further. In that phase using AI algorithms we will be capable of analyze the previously played serious games, and search for patterns, which can be reused. Besides, we will use it for bidirectional learning between humans and machines. Machine intelligence will be able to understand the information but by humans during gameplay. We will also focus on the application of explainable Ais, which makes possible for humans to understand how the AI component solved a certain task. As a result, this collaborating, human-machine systems will enable increased capability of understanding and handling more complex systems.

References

1. Monostori, L., et al.: Cyber-physical systems in manufacturing. CIRP Ann. **65**(2), 621–641 (2016)
2. Laamarti, F., Eid, M., El Saddik, A.: An overview of serious games. Int. J. Comput. Games Technol. **2014**, 1–15 (2014). https://doi.org/10.1155/2014/358152
3. Pereira, G., et al.: Serious games for personal and social learning & ethics: status and trends. Procedia Comput. Sci. **15**, 53–65 (2012). https://doi.org/10.1016/j.procs.2012.10.058
4. Ritterfeld, U., Cody, M., Vorderer, P. (Eds.) Serious Games (2009). https://doi.org/10.4324/9780203891650
5. Djaouti, D., Alvarez, J., Jessel, J.-P.: Classifying serious games. In: Handbook of Research on Improving Learning and Motivation through Educational Games, pp. 118–136 (n.d.). https://doi.org/10.4018/978-1-60960-495-0.ch006
6. Fadiya, O., Georgakis, P., Chinyio, E., Nwagboso, C.: Decision-making framework for selecting ICT-based construction logistics systems. J. Eng. Des. Technol. **13**(2), 260–281 (2015). https://doi.org/10.1108/jedt-07-2011-0047
7. Bergström, K., Billger, M., Fredriksson, A., Janné, M.: The MIMIC construction logistics game: facilitating group discussion and understanding of construction logistics through gameplay. In: IOP Conference Series: Earth and Environmental Science, vol. 588(5), p. 052014 (2020). https://doi.org/10.1088/1755-1315/588/5/052014
8. Panas, A., Pantouvakis, J.-P.: Simulation-based concrete truck-mixers fleet size determination for on-site batch plant operation. Procedia. Soc. Behav. Sci. **74**, 459–467 (2013). https://doi.org/10.1016/j.sbspro.2013.03.050
9. Mes, M., van Heeswijk, W.: Comparison of manual and automated decision-making with a logistics serious game. In: Lalla-Ruiz, E., Mes, M., Voß, S. (eds.) ICCL 2020. LNCS, vol. 12433, pp. 698–714. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-59747-4_45
10. Tallgren, M.V.: Collaborative production planning with BIM - Design, development and evaluation of a Virtual Production Planning system (2021). https://doi.org/10.13140/RG.2.2.10001.56166