Development of Exercise Designing Module for Computer Training Complex

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Abstract: The development of exercises for computer training complexes is a time-consuming process, which includes many factors that must be considered. In the training complex, it can be simplified by a special module that takes into account the characteristics of the subject area and simplifies the development of the exercise. However, at the moment such a module has not been submitted. The aim of the article was to develop an exercise designing module that takes into account the possibility of interaction between elements of the simulator and compiles the exercise scenario. The ontological model was developed for the selection of consistent elements; finite-state machine was comprised the exercise scenario. The novelty of developed module was the integration of 3D-scene creating tool and an exercise scenario designer, based on the ontology of simulator' subject area. The developed module was tested by designing an exercise scenario included in the examination program of the National Commission for Certification of Crane Operators (NCCCO).

1 INTRODUCTION

Computer training complexes (CTC) are designed to train personnel and develop the necessary skills for the effective, high-quality and safe work. An instructor is responsible for a personnel training at CTC. His tasks include personal work with the trainees, tracking their learning progress and designing a training program which consists of individual exercises. Exercises are necessary for developing professional skills. Each exercise in the CTC consists of a 3D-scene and a scenario of actions that the student must perform in order to complete the exercise successfully. When developing a 3D-scene for an exercise, it is worth considering that not all of its elements can interact with each other. For example, grab can not be used for container moving. Therefore, developing and combining all the components of an exercise is a time-consuming process. Therefore, the actual task is to develop a module, which would take into account the parameters of objects on the 3D-scene, the possibility of their interaction with each other and simplified the process of creating an exercise scenario. This module will be useful for both the instructor and the developer, as it reduces a time for exercise designing and allows to be flexibly customizing.

Some authors have described the various parts of the exercise using ontology and finite-state machine. The authors of the [1], [2] described possibilities of ontological modelling used in simulation systems, citing as an example CTC.

In the [3], [4] the authors developed a system for calculating the trajectory of the weapons shells flight, based on the ontological approach. The ontological model contained equations, parameters of elements and entire structure of system. To calculate the trajectory, it was necessary to convert the ontology into the MATSIX project for using in MATLAB.

In [5] and [6], ontology described geometric-temporal concepts of trajectory and motion. The authors presented the path as a set of key points consisted of its position and timestamp. The model was used to compile routes using data from various sensors. In [7], control points, in addition to timestamp and position, were characterized by speed and acceleration. However, these models worked with already prepared data, without defining the requirements for the exercise.

In [8], a finite-state machine of a water pump was developed. The nodes of model were the states, and links consisted conditions for transition from one state to another. However, the authors of the article have not described the process of designing a model. Hence, the problem of developing a system for designing of exercises can't be considered solved.

Therefore, the purpose of this article was to develop a module for the designing of an exercise which takes into account the possibility of interaction between the elements of the simulator and allows to compile the exercise scenario.

2 EXERCISE DESIGNING ALGORITHM

As an exercise in this article, we understood the complex of objects involved in the learning process and the scenario of the exercise.

The module was developed as a part of CTC, described in [9], which has a control system for the formation of sensorimotor skills [10]. Control system automates learning process by defining of exercises for the student, depending on his skill level. A set of necessary exercises need to be designed by the developed module.

For the exercise designing, we need to identify objects, involving in a learning process. As a result of the analysis of various teaching programs and training standards [11], typical objects were united in classes and presented in Table 1.

Table 1: Learning process parts and classes, related to them.

Part	Class
Operating machine	Crane
	Lifting device
Cargo properties	Cargo
	Quantity of cargo
	Starting place
	Destination place
Workers	Banksman
	Signaller
	Slinger
Environmental conditions	Weather conditions
	Time of day
	Speed and direction of wind

Every object in a simulator belongs to some class. When designing an exercise, a user should choose from all objects of a class a specific one.

However, it is worth noting that not all elements of the subject area can interact with each other. For example, a grab can only interact with bulk loads, and a 40-foot container cannot be connected to a hook. In order to take into account the restrictions when setting the parameters of a 3D-scene, it was necessary to develop an ontology that takes into account the components of the simulator and its relationships. The developed model was used as the basis for generating a 3D exercise scene.

The second step of the exercise designing is to set up a scenario which includes a set of control points and the conditions for their passage. In addition to the correct sequence of actions, the scenario can also contain student's erroneous actions and the response of the simulator to it.

Based on the material studied, the exercises designing algorithm was compiled. It included such steps as:

1) Selection of components involved in the exercise, based on the description of the subject area;
2) Arrangement of selected components on the 3D-scene and generation of start and end control points of cargo position;
3) If necessary, the placement of additional control points and setting conditions of their passage.

3 THE ARCHITECTURE OF THE EXERCISE DESIGNING MODULE

Figure 1 shows the architecture of module that was developed based on the exercises designing algorithm.

The Ontology of simulator is an ontology that contains data about all simulator elements, which can be used in an exercise designing and relationships between them. The choice of ontology is explained by the simplicity of organization and obtaining of necessary information. In addition, a reasoner is able to infer new logical consequences, that helps in complex queries.

The Scene manager module output is 3D-scene in a simulator. There were 3 ways to get a 3D-scene as a result: 1) Creating a new scene from basic components manually; 2) Generating new scene by setting some input parameters; 3) Loading a scene, that was saved before.

The easiest to instructor way to prepare a 3D-scene is automatically generating it or to load saved scene. In case of scene generation, module used the elements selected in the interface and information

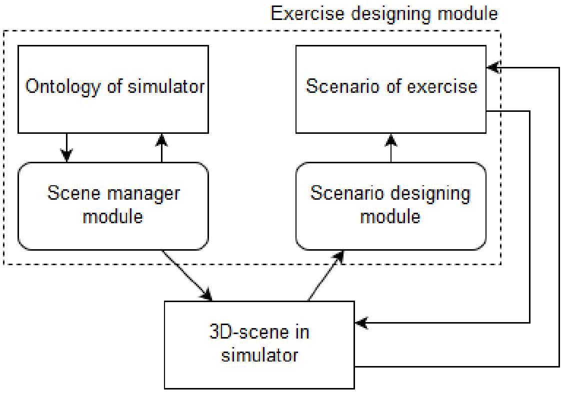

Figure 1: Architecture of an exercise designing module.

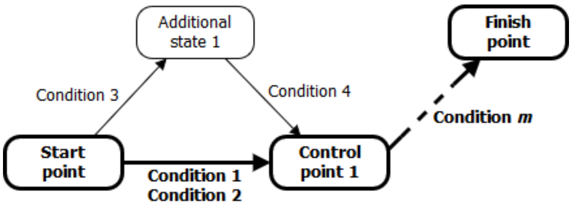

Figure 2: Example of exercise scenario scheme.

about them from the ontology and then converts it into a 3D-scene, which can be improved later by the developer or instructor. SPARQL queries were used by the interface for interaction with ontology of simulator.

The purpose of the Scenario designing module was to create a sequence of control points and set conditions for their passage. The result of the module work was a finite-state machine, represented an Exercise scenario. The nodes of the finite-state machine are control points, and the links contains conditions for the transition from one point to another.

Figure 2 shows the scheme of an exercise scenario, where bold-style blocks and arrows composed the path, which cargo should pass to finish an exercise. In addition, additional states can be configured that take into account the possible erroneous behavior of the student, examples of ones presented below:

- Out from permissible borders;
- Touched the ground;
- Cable break, etc.

Conditions can track the following parameters:

- Reaching the defined position;
- Cargo collision with a ground or other scene objects;
- Scene object position and rotation;
- Cables length and tension;
- Cargo speed and acceleration.

Scenario designing module generates start and finish only, based on position of starting and destination places, defined in Scene manager module. The other states and conditions can be added manually.

The result of the exercise design module was generated 3D-scene and a scenario for the exercise.

4 MODEL TESTING

An exercise designing module for the AnyCrane CTC [12] was developed.

To test the developed module, a full cycle of creating an examination exercise from the NCCCO certification standard [10] for tower crane operators was designed. The 3D-scene contained a crane, a cargo and poles that limit the route. At the beginning of the exercise, the cargo was at the start point; the hook and the cargo were connected by slings. The task was to move the cargo to the finish point.

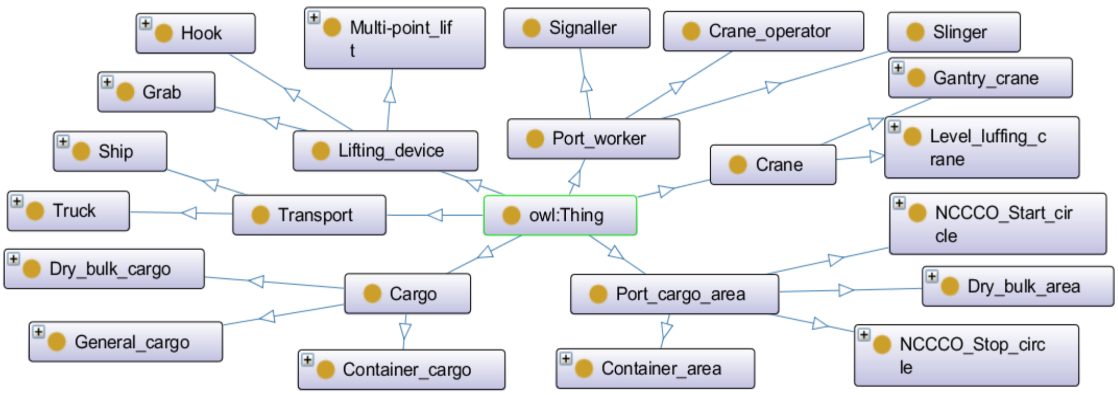

Figure 3: Class hierarchy of ontology model.

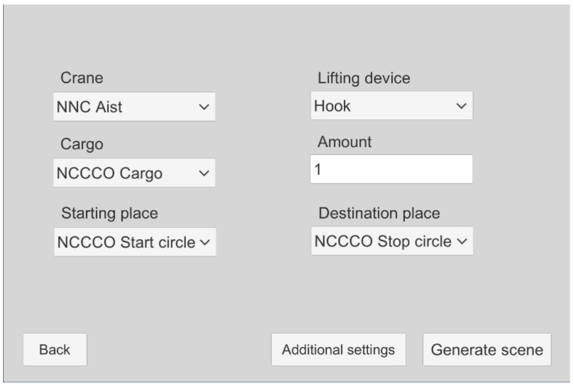

Figure 4: Scene options selection in the Scene manager module.

The sequence of the exercise is defined as follows:

1) Raise the hook with a cargo at least 10 feet above the ground to avoid obstacles and personnel.
2) Move the cargo from the start circle to the end circle.
3) Once the cargo has reached the end circle, place it in such a way that the cargo contacts the ground inside the circle and remains there.
4) When the cargo is contacted the ground surface inside the finish circle, cargo is not allowed to rise above the ground.
5) The examiner will give a stop signal when the cargo is under control.

In accordance with the subject area of the CTC, an ontology was developed. It includes a structural model of classes, instances of simulator objects with its parameters, and relationships between ontology objects. Figure 3 shows the 2-level class hierarchy of the ontology model.

For example, a query can retrieve a connection device, which can be used if a user has selected CMM Aist crane and brick pallet as a cargo. The SPARQL query, which was sent to the ontological model is presented below.

```
SELECT ?LiftDev
WHERE
{
:CMM_Aist :canBeConnectedWith
?LiftDev .

?LiftDev :canTransports
:Brick_pallet
}
```

The query result is:

```
:Hook
```

Figure 4 demonstrates the interface that allows user to select elements of the exercise. Every parameter can be chosen from the dropdown list, which was formed by obtaining query result. The following parameters were selected: NNC Aist, Hook, NCCCO Cargo, 1, NCCCO Start circle, NCCCO Stop circle. The scene was edited manually: poles, the start and stop circles were added.

Using the scenario development module, checkpoints and conditions for their passage were added in accordance with the sequence of the exercise. The first control point is placed above the starting position in accordance with step 1. Intermediate points were set at the corners of the route. The last point was determined automatically, in the stop circle.

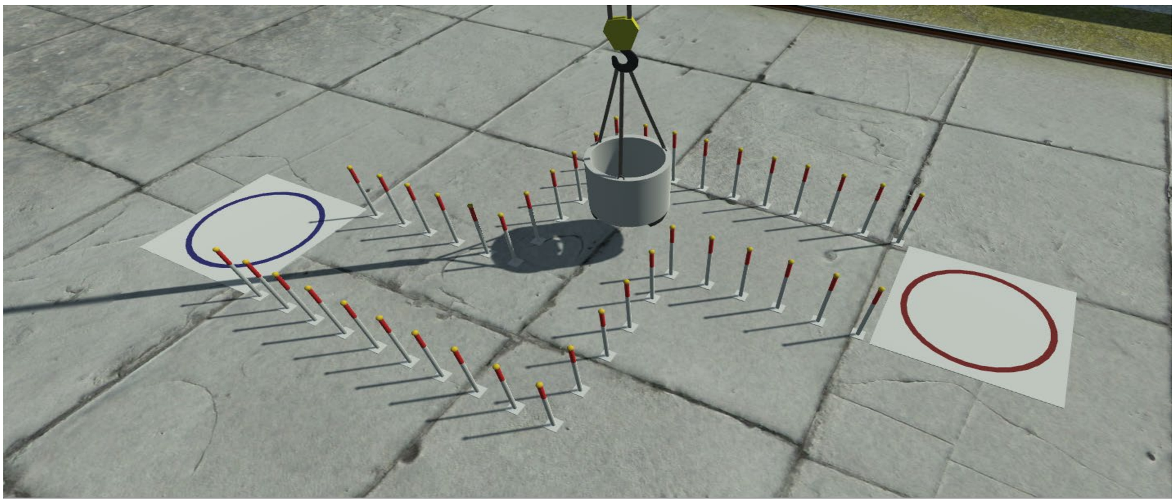

Figure 5: Exercise performing process in the 3D-scene of AnyCrane CTC.

Then the main exercise scenario was compiled by defining conditions for passing each control point. The main scenario of the exercise was extended with additional branches, taking into account the touch of the poles and the ground surface.

Figure 5 shows the exercise process. A banksman can be placed on the 3D-scene. It will signal the target position and conditions for passing the point.

5 CONCLUSIONS

As a result of the work, the original technique and the software module for the exercise designing were developed. Also, the module was integrated into the AnyCrane TSC. The module was tested by building an examination scenario for the “crane operator” NCCCO qualification.

The novelty of the developed system was the integration of 3D-scene creating tools and an exercise scenario designing based on the ontology of simulator’ subject area. The use of the ontological model made it possible to determine the consistent elements of the 3D-scene and compile the exercise scenario.

The module can also be used in another simulator’ subject area, such as technological process or medical operations. A subject area ontology of the CTC should be composed.

However, the developed module has limitations. The first is the inability to set different conditions for control points for different cargos. The second is the need to write additional code to register events occurring in alternative ways of the exercise scenario.

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