Scheme of the graphical interface for simplification of the occupational accidents reconstruction through numerical simulations

Schemat graficznego interfejsu komputerowego wspomagającego proces numerycznej rekonstrukcji scen wypadków przy pracy

KLAUDIUSZ ZIEMEK *

Proposed is a concept of a new tool for supporting numerical simulations of occupational accidents. Such tool, in form of add-on for graphics software called Blender, uses MADYMO package to execute simulations. It provides fast and intuitive way of modeling accidents scenes without a need of particular knowledge in simulation physics. In the future, it will also implement an auto-search algorithm for the most possible course of event throughout any given state space. Hopefully, it will allow to recognize potential risks and create new ways of preventing injuries. This paper describes the tool, and presents early results of its possibilities.

KEYWORDS: occupational accident, numerical simulations, graphical interface

Every day, man is exposed to certain dangers that can lead to a situation that is dangerous for health and life. Different factors, for example environmental hazards, ignorance, ignorance or an ordinary case, are responsible for their occurrence. A special group of such situations are accidents during work, because it is the people who set the conditions in it and have a direct impact on possible threats [1]. By properly managing the structure of the work environment, it is possible to significantly reduce the risk of an accident and minimize any injuries suffered by its participant.

According to the data of the National Labor Inspectorate [2], the number of injured during accidents at work in 2016 exceeded 2,500, with ca. 10% of accidents having a fatal effect. An accident at work is a serious problem for both the employee and the employer, which is why it is very important to be able to analyze, assess risk and implement preventive methods for each case [3].

The multitude of environmental variables and chaotic behavior of systems of many physical bodies significantly impede the simulation of the course and analysis of the accident. You need to consider a lot of cases to be able to infer about the incident and possible changes in security. Therefore, the costs of carrying out such simulations are very high.

The solution used for a long time in the automotive industry - numerical simulations - comes with the help. The computing costs of such simulations are significantly lower than the costs of actual reconstruction, and in addition, strict control of the environmental parameters of the accident scene allows for in-depth event analysis and preliminary tests of specific protections.

An example of a tool enabling numerical reconstruction of accidents at work was created as part of one of the projects of the Central Institute for Labor Protection - National Research Institute in Warsaw. We managed to successfully analyze a few cases that actually happened [4-6]. Simulations were carried out using the MADYMO physical engine [7], for which methods for collecting accident data and an injury assessment system were developed.

Despite the significant reduction in simulation costs, a person with in-depth knowledge of the physical motor's functioning and experienced in constructing accident scenes from elements available to the engine is still needed to carry them out. In addition, analyzing the situation for many different initial parameters requires manual intervention in their value, which extends the procedure time.

As part of this article, a tool is proposed that enables simple graphical modeling of an accident scene using a graphic program that will improve the process of reconstruction and analysis of accidents at work.

Description of the tool

The proposed tool is an extension to the free graphics program Blender [8], in which the MADYMO numerical simulation package was used. The tool provides visual modeling of the accident scene and allows you to choose materials from the pool of events most often found in workplaces. Such materials will have all the parameters of reaction with the environment determined, so that the user will not have to spend time analyzing their physics. The

* Mgr Klaudiusz Ziemek (klazie@ciop.pl) – Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy

elements needed for reconstruction will be available from the intuitive interface, and fixed components will be added automatically, which will relieve the user and speed up the entire process.

After modeling the place of the event, the program will provide automatic simulation with the search for the most probable course. For each parameter it will be possible to define a range of values in which the algorithm is to look for the most accurate solution. This is the key functionality of the tool, because it will automatically find the search scenario for any defined state space. This will speed up the process of analyzing the accident and reduce the amount of human work, and at the same time the possibility of making a mistake. The accuracy of a specific iteration of the simulation will be judged on the basis of the damage suffered by the virtual manikin, compared to the description of the accident.

In addition, an initial reconstruction of the accident will be made available using a physical engine built into the Blender program, which will allow a visual evaluation of the simulation progress with the description, before the commencement of costly time simulations using the MADYMO engine.

Any changes to the model, after the simulation, will be easy and intuitive to introduce due to the manipulation directly on the visual model.
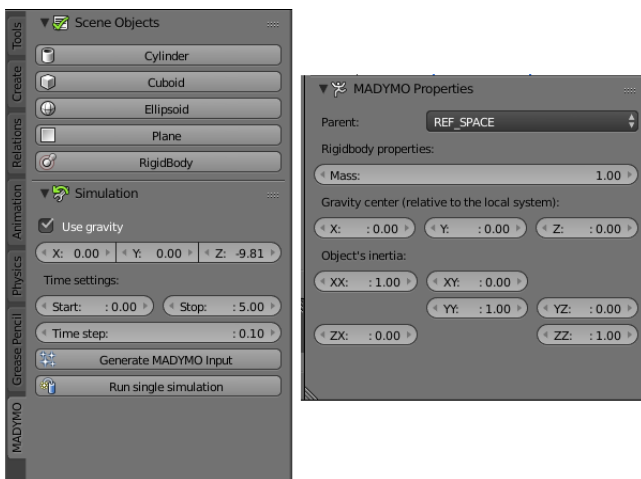

Fig. 1. Additional menu in the Blender program enabling simulation using the MADYMO package. On the left - general menu for building the stage, on the right - menu of a single object

Functional overview

During the first stage of constructing the tool, a plug-in was prepared for the Blender program, which has additional functionalities in the form of a menu in the main view and a menu for the selected object. The new interface is shown in fig. 1.

The main menu is divided into two segments: Scene Objects and simulation settings (Simulation). The objects available for building the stage are designed so that they can be moved, rotated and scaled without any limitations in any axis, but this must be done in the Blender ObjectMode mode. Such a solution gives unlimited possibilities for building a scene, and at the same time it preserves a structure that can be easily translated into geometrical elements available in the MADYMO package [9].

A brief description of the elements and their counterparts MADYMO:
• Cylinder - tube mesh with a hollow center, equivalent to the SURFACE.CYLINDER element,
• Cuboid - cuboid, is equivalent to the element SURFACE.ELLIPSOID with a high degree ($n = 10$),
• Ellipsoid - ellipsoid, equivalent to the SURFACE.ELLIPSOID element with a small degree ($n = 2$),

• Plane - plane, is equivalent to the element SURFACE.PLANE,
• RigidBody - an element with no visible grid, it is equivalent to the element BODY.RIGID, which determines the properties of the rigid body, such as: mass and inertia; it is a mobile element of simulation, to which a joint automatically specifying the number and range of degrees of freedom,
• Parent - an object on the stage to which the currently selected element is attached; for moving objects (RigidBody) one can attach further RigidBody objects or graphic objects that will move with the parent element; graphic objects connected to REF_SPACE will be treated as fixed elements of the scene,
• Use of gravity - introduces into the system a homogeneous gravitational field with a value determined by the vector (*XYZ*),
• Time settings - simulation time settings (its start, end and time step),
• Generating MADYMO Input - generates the input XML file interpreted by MADYMO in a given location,
• Running single simulation - performs simulations based on data from the previously generated file,
• RigidBody properties - mass and inertia settings of the selected RigidBody element; in addition, you can change the center of mass of the object if necessary

Modeling of the accident scene

The process of modeling the accident scene with the use of the presented tool should start with selecting only the necessary elements that could contribute to the course of the event. Due to the time-consuming nature of strict numerical calculations, each additional element on the stage will significantly extend the duration of a single simulation.

After selecting the elements to be placed in the simulation, they should be divided into two groups - stationary objects of the environment and moving objects, i.e. those that will change their position under the influence of external forces or through programmed motion. After this step, you can start creating the scene.

Modeling is best started with stationary objects, built on the basis of simple elements, available in the menu (Scene Objects). In order for an object to be considered stationary by the simulator's interpreter, its parent must be REF_SPACE.

Building movable objects should start with the "skeleton" of connected RigidBody elements. They constitute the place of joining individual moving elements and inform about their physical properties. Between them, joints are formed whose degrees of freedom and ranges can be adjusted. For each RigidBody you can attain the geometry of the object, which is also built based on simple elements from the menu.

For comparison, Fig. 2 and 3 show the scene created in the Blender environment and its visualization resulting from files generated for MADYMO.
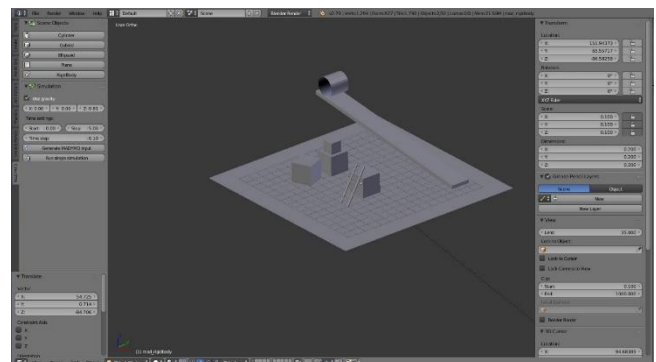

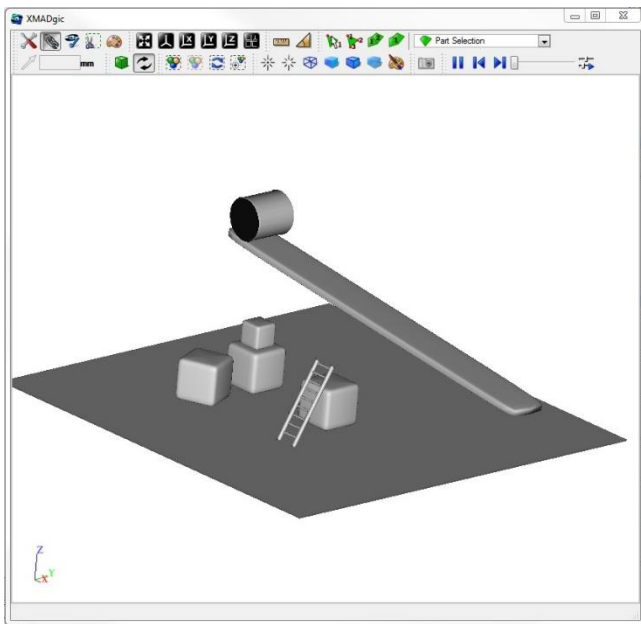Fig. 2. Example scene modeled in Blender using the proposed tool

Fig. 3. Visualization of the converted scene from fig. 2 in the XMADgic program, available in the MADYMO package

The examples shown only cover the creation of a graphical representation of the accident scene. The following will be added at further stages of the project:
- possibility to choose materials for each of the objects,
- defining the way of impact,
- animation of selected elements.

The prepared stage will be pre-analyzed using the physical engine implemented in Blender and converted with the selected accuracy using the MADYMO package.

At the last stage, you will be able to choose any of the scene parameters and determine the ranges for which the algorithm will automatically simulate and determine the course similar to the description of the accident in terms of injuries.

Conclusions

Analyzing, assessing and drawing conclusions from every work-related accident are very important factors in the increase of safety in the workplace. As experience shows, very often the cause of an accident is not obvious and its learning requires a deeper analysis.

Performing real simulations is an expensive, time-consuming and difficult process. Therefore, the use of numerical simulations is a natural step towards deepening the knowledge about the causes of dangers in the workplace.

The proposed solution goes even further. It will allow you to perform complex simulations without having to go into the physical mechanism of their operation. In addition, the tool will allow you to automatically search the system states space and find the optimal solution. In this way, the process of hazard analysis and assessment of new protections will be improved, which should significantly contribute to the improvement of working conditions.

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