Training tool for TIRAMISU Project

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Abstract

In this paper the training tool for UGV(Unmanned Ground Vehicles) operators in TIRAMISU project is introduced. The core component of the system is implemented using VORTEX simulation. This module provides an accurate physics simulation. The main goal of this research was to prepare VORTEX models of UGVs for TIRAMISU project. New research is related with the modeling of the environment based on the laser terrestrial data. The challenge was to integrate real data with a simulation, for this purpose we investigated the methods for objects classification. Major problem is related with the representation of cloud of points in rigid body simulation, for this purpose we used the triangulation. The results are satisfactory, but major work has to be done in area of visualization, therefore future work will be related with the visual effects which improve the effectiveness of proposed training tool.

Introduction and related work

When considering educational practice, simulators of specialist equipment (the operating of which constitutes basic knowledge of every trainee) are commonly used in teaching medical personnel [1], navigators and ship crews [2], operators of machines [3], and military personnel [4]. Training courses supported by the computer simulators are relatively cheap and safe, as there is a multitude of programs to simulate equipment and its operations, while maintaining the operator's interface used in the real machine. According to Edgar Dale's cone of experiences, a simulation of a real operation enables trainees to remember almost 90% of the material being taught, and proves to be much more effective than other forms of teaching. Simulation-based teaching methods are not applicable only to computer simulations, but also to drama scenarios. Using simulators and simulations (visual models) is a practice that dates back a long time, when considering broadly-defined education. Some authors would go much further, when claiming that simulations are useful and natural, and say that young predators prepare themselves for maturity and real hunting, by "playing out a real fight", similarly to a boxer practicing with his/her sparring partner [6]. Following this definition, refraining from using simulations in teaching would deprive pupils/students of a very significant element of the education system. Considering the current phase of technological advancement, it would be fake and most likely inappropriate to exclude computer simulators from the teaching process. The fact that a trainee is much more comfortable, when learning to use highly-advanced and very expensive equipment on simulators, as compared to operating a real machine, must also be taken into account. The operator has no fear of damaging the machine, by improper handling, and furthermore, they can be "alone with the simulated machine", without third parties monitoring, which has its impact on the level of the trainee's comfort and reinforces independence.

The Methodology of Teaching Adults

Developmental psychology divides adulthood into three phases of development: early adulthood: from 20 to 30-40 years of age, middle adulthood: from 30-40 to 50-60 years of age, late adulthood: above 55-60 years of age. In the first period, i.e. early adulthood, the capability to acquire and use knowledge is at the highest level. People develop relative thinking and the ability to comprehend and balance the opposites, which greatly facilitates the understanding of others. We use our creative thinking, systematic approach to problem-solving, and the ability of rapid adaptation[7]. Middle adulthood: it is characterized by stable levels of the majority of intellectual capabilities. The vast knowledge of life and collected experiences result in great wisdom, which is understood as the capability to make accurate judgments about the issues related to important problems in life. The only thing that slows down as we grow older is the speed of processing information, which may result from the fact that we relate the problems being solved to the entire abundance of collected knowledge. Our memory will also deteriorate, if not trained enough. When teaching people at this age, one must focus on perfecting the already acquired knowledge and skills[7]. Late adulthood: it is the time of developing integration and harmony between the logical-rational and the intuitive-emotional spheres. The crystallized intelligence (social intelligence) connected with life experience remains on a stable level or even increases, but the fluid intelligence (determined by biology) responsible for the processing of information and acquiring new skills is slowly reduced. It is only with people seriously sick or near death that we observe a significant decrease in their intellectual capacity. Teachers must make note of the fact that people advanced in age are very effective students, if they can control the tempo of their own learning[7]. In conclusion, when considering the differences in learning between the young and the elderly, one can assume the following: The elderly are much less effective in processing information, but better in expert knowledge (professional knowledge), and similarly competent in less complex tasks, when compared to young learners[7]. Assuming that operators-to-be are people in their early and middle adulthood, and their abilities to acquire knowledge and learn skills are very high, all that must be provided is motivation and comfort of education when learning to operate robots. The operating of robots is much more a part of the sphere of skills, than the sphere of knowledge, and as such, it serves the purpose of learning the right habits of responding to stimuli, transmitted visually and acoustically, through monitors (view from cameras) and loudspeakers (sound from microphones and sounds of working machinery). Thus, the most important element in learning to operate robots is exercises, and it is highly recommended to use simulators (training simulators) in practical drills, at least in the initial phase of training.

Creating model of the environment based on real terrestrial data

The model of the environment is generated form 3D point clouds gathered by a laser scanning system[10]. It consists of two parts: graphical/physics model based on VORTEX engine and reasoning tool based on QSTRR(Qualitative Spatio-Temporal Representation and Reasoning) framework[8]. The models are used concurrently during the scenario execution. Graphical VORTEX model is created by turning the 3D point clouds into triangle meshes. Semantic model is generated based on the same data during a semi-automatic process that can be divided into four steps: 1) data preparation, 2) conceptualization, 3) segmentation, 4) generation of qualitative representation of the environment. During the first step the data are matched and filtered. A normal vector is calculated for each point of the 3D point clouds. The preprocessed 3D point clouds are then used for conceptualization. Each point is given a label. In current version of the tool, labels attached are: ground, building wall, vegetation and unknown. In this process we concentrate on larger, primary objects of the scene(buildings, trees etc.) Smaller objects are left as unknown for later segmentation. The three main assumptions we make about the environment are: 1) ground can be approximated by a most dense horizontal plain. This assumption has minor drawbacks, but allows for fast separation of different 3D point cloud areas, 2) building wall points have normal vectors pointing in the same direction and are mostly a vertical plain, 3) trees and large vegetation have a uniform distribution of normal vectors directions.

The detection algorithm is based on those three assumptions. First a histogram of density of points in the vertical plain is calculated. Only points whose normal vectors are also vertical are used. After that the RANSAC [9] method is used to find the most populous plain in the most densely populated cell. Points that lay in distance D to this plain are labeled as ground. The D value was chosen to be 30 cm, which is a large, but acceptable considering the scale of the objects that are being detected. Remaining data points are assigned to cells of a horizontal grid. Each cell holds point from a 2x2 m area. In each cell points are grouped by directions of their normal vectors. Points are considered to be in the same group if their normal vector don't wary by more than 12 degrees. The groups are later classified into three bins: dominating(>30% of all bin points), large(>20% of all bin points), small(<20% of all bin points). Based on this classification cells are classified to: potential building(at least one dominating group), vegetation(no dominating and large groups, at least 10 groups). The potential building cells are additionally verified by using RANSAC method to match a plain to the points in the cell. If at least 50% of points are near the found plain and their normal vectors are roughly in the same direction as the plain the cell is considered building wall. All cells that do not meet the building or vegetation constrains are labeled unknown. The last step of the classification is correction. The cell labels are corrected by analyzing their neighborhood for example: if a building is surrounded by unknown cells it is considered false positive and labeled unknown(it is unlikely that a 2x2 m building is in the scan). The third step is segmentation. Labeled point cloud is segmented into regions. Segmentation is done by and adaptation of region growing approach. The points are considered to be of the same segment if they are in 15cm distance to any point of the segment and the label of the point is the same as the label of the segment. The results of conceptualization and of the segmentation are shown in figure 1. In the last step creates a description of all detected objects. The description can then be interpreted into the QSTRR framework to create a bounding box representation of the semantic model. This model can then be used to simulate and catch events in the virtual environment.

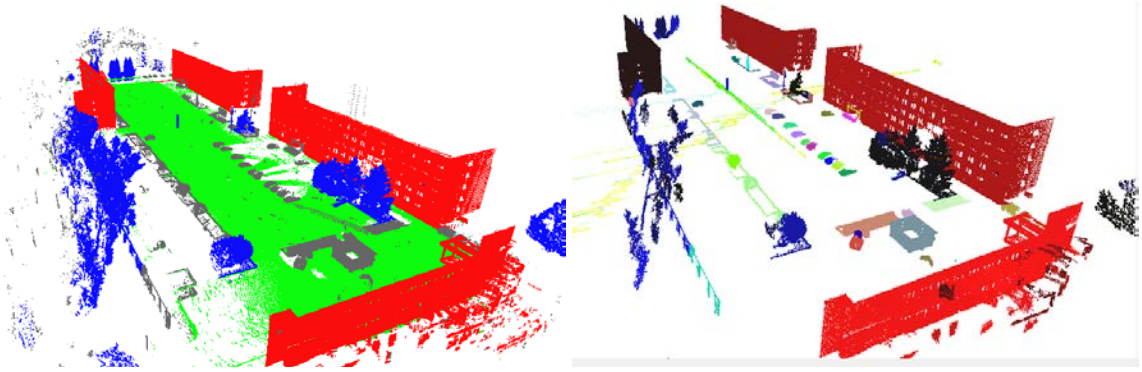

Figure 1. Left: semantic labeling: red-buildings, green-grounds, blue-vegetation. Right: segmented data.

Simulation of physics using VORTEX

For collision sensing and animation Vortex uses a simplified models consisting of basic shapes: boxes, cylinders and spheres. Combining these shapes allows to build a model covering all the space, where a graphic model of the vehicle will be loaded. Then it is necessary to set the mass and material parameters for each part. By default center of mass is set in the geometry center, but it can be adjusted, to match the actual part properties. After that, the first part of preparing the simulation is completed. The simplified model will be use in all the further calculations. For complex models it may be very time-consuming, but it is necessary to do it carefully, to achieve proper results of collision detection and dynamics calculations. The next step is getting the model ready for moving. All the parts must be connected with proper constraints. Vortex library covers a great amount of basic and complex constrains typically used in mechanisms, such as ball-and-socket constraint, hinge, prismatic, car wheel and others. All the constraints may be modified, by adding some individual limits, for example an angular limits of movement for hinge constraint. Depending on the model requirements, the constraints may be free to move or locked. The locked one may be than controlled e.g. by appropriate engine. To increase the reality, the breaking force for each constraint may be set.

Engines are the last part, that need to be added to a model in order to move it. Vortex also covers a wide range of parts typically used in vehicles like wheels, tracks etc. It allows to create an simulation which includes as sophisticated elements as the gear changing in the vehicle. At this stage the model is ready for the simulation. However for an aesthetic and reality reasons some graphics should be added. To do it we have used an Open flight (*.flt) models of the vehicles. For our purposes the very important property of .flt models is the tree structure, that corresponds to the model parts. It allows to load the graphic model to the simulation and then separate the moving parts. The simplified models of the vehicle parts are linked to their graphic representation. However all the simulation's calculations are being proceed for the simplified model, during the simulation(fig. 2). That areas, that will possibly take part in the collision detection. is why it is so important to match the model and its graphic representation very accurately.

Figure 2. CAD model of vehicle LOCOSTRA and its collision geometry model in VORTEX.

For terrain representation Vortex needs another 3D model to be loaded. Then all the forces and collision interaction between the vehicle and terrain may be calculated. We have developed a whole new system of data acquisition from the real environment. The raw data in the form of point cloud is filtered and processed to achieve a simplified triangulated shape. Then an appropriate texture is added and a model is exported to a file suitable for Vortex engine(fig. 3).

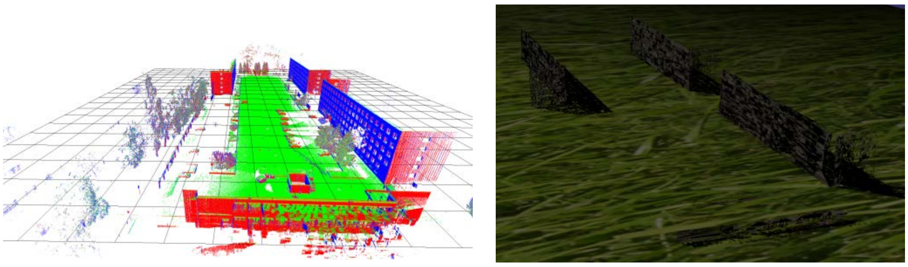

Figure 3. 3D scan input data and ready terrain model in VORTEX.

Results

In presented work we have integrated the CAD models of the vehicles with an appropriate exporter, to match the graphic representation and simulation with the exact size and shape of the vehicles. We have also developed a model of PackBot robot simulation(fig. 4). In the system we have provided the possibility to change the viewport of the camera, so that the operator could control the vehicles from different positions. First one is the view from behind and above the robot, as it could be seen by the observer walking after the teleoperated robot. Next one is the viewpoint of the supporting robot following the main vehicle. Another acts as the cameras mounted on the robot. We have also provided the possibility of adding new viewpoints to the simulation and possibility to load, directly or after conversion, third part terrain models, for example from the Trimble 3D Warehouse database.

Figure 4. PackBot and some possible camera views.

Acknowledgments

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