Integrating Robotics and Virtual Reality with Geo-Information Technology: Chances and Perspectives

Eckhard Freund, Jürgen Rossmann

Institute of Robotics Research (IRF)
University of Dortmund
{freund | rossmann}@irf.de

ABSTRACT

Recent advances in robotics and virtual reality technology have made possible the close-to-reality generation of virtual worlds with multiple agents acting almost as realistically as their real-world counterparts. In order to make these virtual worlds even more realistic, the next step surely is, not to build only artificial and closed virtual environments but rather to embrace the outdoors, i.e. to use geo-information technology to be able to build virtual worlds in a larger scale from real world data.

INTRODUCTION

By developing the capability to automatically generate 3D models from data provided by a web-mapping server and to enhance these rather static models by interactive metaphors representing features delivered by a web-feature server, we are trying to build the bridge between advanced 2D geo-information services and modern virtual reality applications. First steps to integrate robotics know-how with geo-information technology have already been taken by enhancing a forest machine simulator in the way that the virtual forest the machine is working in, may be generated on-line, based on a topographic map, as shown in Fig. 1. Of course, compared to the physical landscape, the resulting 3D world lacks considerable detail but this is mainly due to the fact that such detail cannot be derived form a simple 2D map. This is why our hopes lie with new geo-information services and approaches which make available location based properties and attributes over defined web interfaces. For example, only the possibilities to find out about the viability of paths, the structure and tree types of the forest and the size and shape of buildings would already greatly enhance the 3D representation.

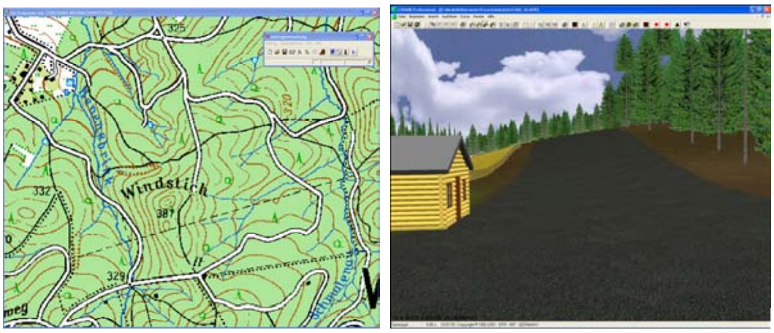

Fig. 1: Automatic generation of a 3D landscape from a topographic map

In return, the generated 3D worlds have great potentials to drive the market request for even more sophisticated geo-information. As the generated 3D worlds that are built on robotics know-how are built to be interactive, new chances and perspectives for the combination of the two technologies are revealed.

THE VIRTUAL ENTERPRISE "FOREST AND WOOD NRW"

An interesting example application, where the new ideas will be coming into play is the modeling of technical, logistic and business cases in the project "Forst and Wood NRW" where dedicated logistic and IT chains will be modeled by means of virtual prototypes in order to support the sound understanding of process related chances for improvement.

Fig. 2 shows the identified major participants in the processes related to harvesting wood in a German forest. The virtual model includes the mechanical work chain components (motor manual tree harvesting, harvesters, forwarders, wood trucks, saw mills etc.) as well as organizational entities which are involved. As the participants of this process are usually located at remote places, away from each other, it has been a very difficult task so far to optimize the logistic and IT flow for the whole application. This has resulted in yet rather isolated software applications to solve particular problems of "single players" but it has been unfeasible so far to provide an *overview of the complete process* and to be able to e.g. set up an IT chain which "closes the loop".

Fig. 2: Major participants in the process “Forest and Wood NRW”

This situation changes with the prototype of the “Virtual Enterprise Forest and Wood NRW” currently under development. This development allows to simulate the actions of the key players as well as their interaction. Thus, *in a PC cluster located in a single room, the complete virtual enterprise can be simulated.* Among other interesting questions that can be answered based on the virtual model a major application is to evaluate software packages which promise to improve the process. These programs can be tested against real world problems without having to coordinate the participants in remote locations: The people involved just meet where the PC cluster running the virtual enterprise is set up. They then work through the whole process, test the software against real world application cases and thus can immediately judge the applicability of the new software.

THE VIRTUAL ENTERPRISE BUILDS ON GEO-INFORMATION TECHNOLOGY

From a geo-information technology standpoint it is important to know that the virtual enterprise heavily builds on location information. Different participant have different “views” onto the resources, data and processes and in practice these different views are “synchronized” by means of geo-referenced location information.

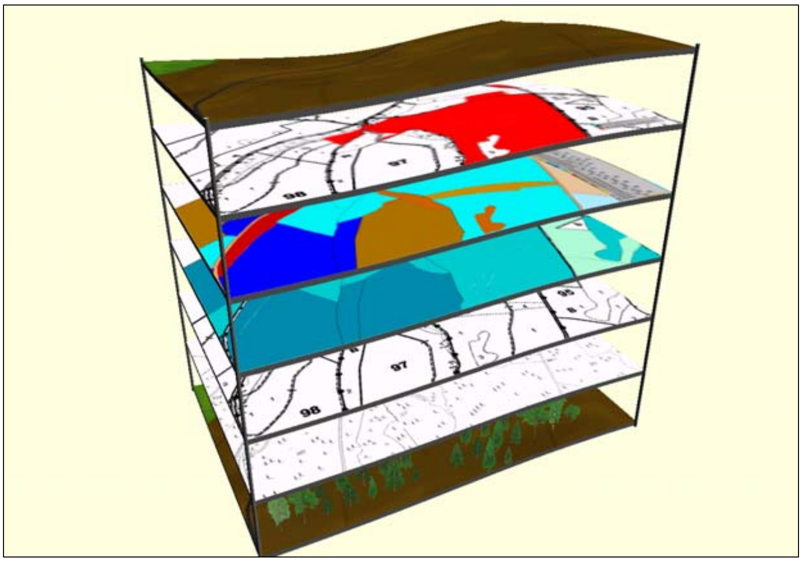

Fig. 3: Thematic maps are the basis of the virtual enterprise

Fig. 3 shows seven different views onto the same sector of a forest. Be it the “natural 3D view” at the bottom, the cadastral view, the topological view or dedicated maps related to forestry specific views, all maps can be superimposed and – by means of geo-coordinates – cross referenced in the model of the virtual enterprise to make the information accessible at different levels of abstraction.

Once the information is based on a common reference coordinate system, the information can be propagated within the process. A selection of data sets exchanged in the virtual enterprise “Forest and Wood NRW” are depicted in Fig. 4.

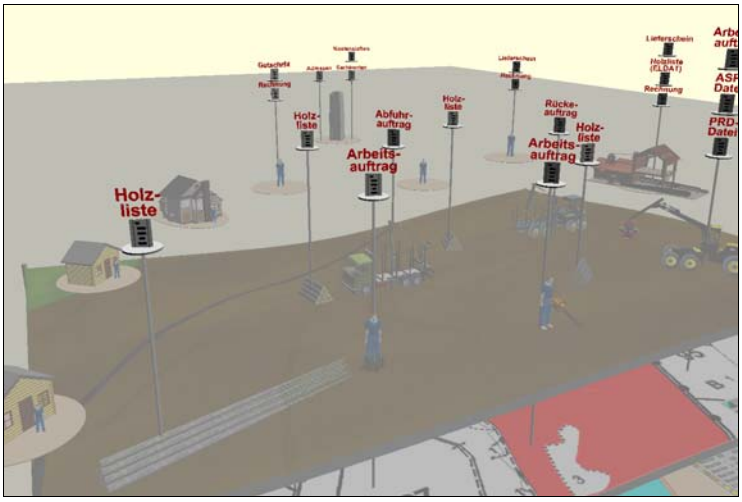

Fig. 4: Selected data sets in the virtual enterprise

In the first stage of the project, prospective software components which are suitable to play a role in the virtual as well as in the physical enterprise, have been identified and are depicted in Fig. 5.

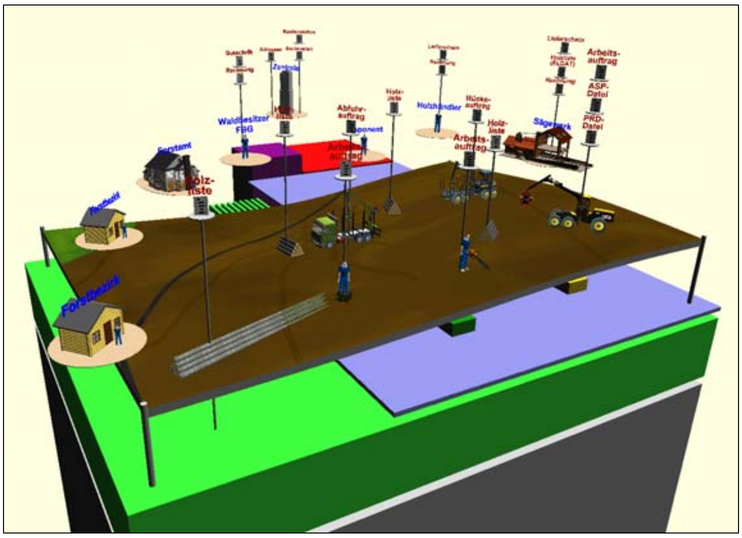

Fig. 5: Selected software components in the virtual enterprise

THE TECHNOLOGY BEHIND THE VIRTUAL ENTERPRISE

In order to realistically simulate the different chains and processes within the forest, emphasis has to be put on the underlying base technology in order to allow the simulator to grow with the users' demands. One important aspect of the realization is an intuitive user interface of the simulator in order to allow users to easily exploit the capabilities of the system. An expert in one field of the virtual enterprise should be able to successfully stimulate almost all aspects of the virtual enterprise in order to provide sensible input for the questions he is trying to solve. As the pictures above indicate, it was found that a virtual reality based user interface has the greatest chances to attract users from different fields of expertise and to serve as an incentive to support the developers to bring real world experiences into the simulator.

The machine simulators

The virtual reality development for the simulator is based on COSIMIR® VR, an industrial strength virtual reality system which provides an excellent basis for the further development.

Fig. 6: The harvester simulator based on COSIMIR® VR

Fig. 6 shows the COSIMIR-based harvester simulator which serves as a mock-up of a harvester workplace in the virtual enterprise. The driver of the virtual vehicle can operate the board computer as well as the virtual harvester itself very close to a physical machine. Thus the flow of work inside a harvester as well as its interaction within the virtual enterprise can be simulated close-to-reality. Besides being part of the virtual enterprise, the harvester simulator can also be used as an excellent training tool for harvester drivers. The leading schools in middle-Europe as well as in the USA and in Canada are already equipped with a simulator of that kind in order to intensify — and at the same time make more cost effective — their training.

Fig. 7 shows a selection of other forest machines that can be simulated by COSIMIR®. As the work chain in the forest can up to now completely — and very realistically — be simulated a lot of participants in the virtual enterprise already feel "at home" in the simulator in the way that they can work in the simulator as they would out in the forest.

Fig. 7: The harvester simulator based on COSIMIR® VR

Currently, research is also looking into the possibilities of simulating motor manual work in the forest as well.

Fig. 8: The simulation of motor manual work with COSIMIR®VR is one of the next aims

All the simulators of the workplaces in the forest have on common that they have to be easy to operate and that the representation of the virtual world has to be as close to reality as possible. With COSIMIR this can be achieved with a broad range of projection technology that is readily available for different applications and for "fat" and "slim" purses. The current high end of the projection technology is a 360° panorama projection, where the user really gets the impression of e.g. being in a forest.

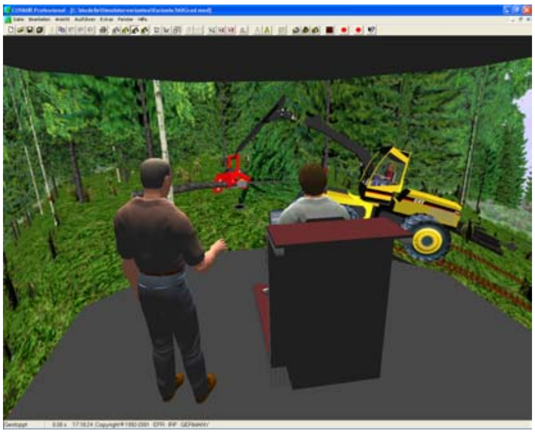

Fig. 9: Close-to-reality simulation in the COSIMIR®VR panorama projection

THE SIMULATION OF FOREST GROWTH

Another important aspect of the simulation of the virtual enterprise is the simulation of the resource the virtual enterprise is exploiting: the forest. The developed “forest-growth” simulator builds on topographic maps and in the first place generates a 3D model of the forest to simulate; thus it makes the transition from 2D to 3D by extracting information on the types and the age of the trees from other forest specific information sources which are available as location based attributes.

Fig. 10: Emergency and fire-fighting simulation based on map-data

Once this information is used to set up the 3D model, the virtual world can incorporate further information allowing to not just travel in 3D but in 4D, with the time as the fourth dimension. If the user “travels in time” in the virtual world, he can see the forest grow and its environment develop. The information on the change over time can either be extracted from maps of different times or – as in our case – can be derived from a mathematical model of the growth behaviour of a tree. Thus, again the virtual world serves as an integration node for the different technologies. The generated forest then can be used to investigate fire propagation inside a forest or even to build a fire fighting trainer. The advantage of building the simulator on geo-information is of course that the student can be trained in an environment that has been derived from a real world landscape and thus contains all the aspects that the student will meet in the field as well.

FURTHER HIGH-FLYING APPLICATIONS

Apart from exploiting geo-information for the generation of virtual worlds, virtual reality in return helps to convince users of the use of electronically available geo-information data. A very high-flying application of VR with relation to geo-information is the visualization of the SRTM mission of the Space Shuttle which provided a high resolution topographical model of large parts of our planet.

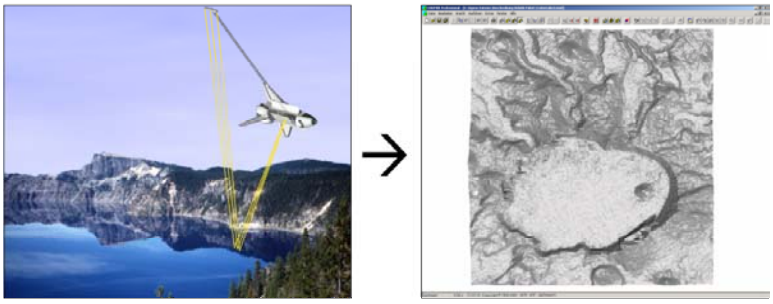

Fig. 11: Visualization of Space Shuttle data

Another high-flying application is the simulation of the International Space Station (ISS) with COSIMIR®. Built as a training tool for astronauts to familiarize themselves with the ISS, it today also serves as a tool to familiarize students with space — and geo-information technology. The figures below depict the ISS and a view onto the earth and onto the ISS from the perspective of a GPS satellite.

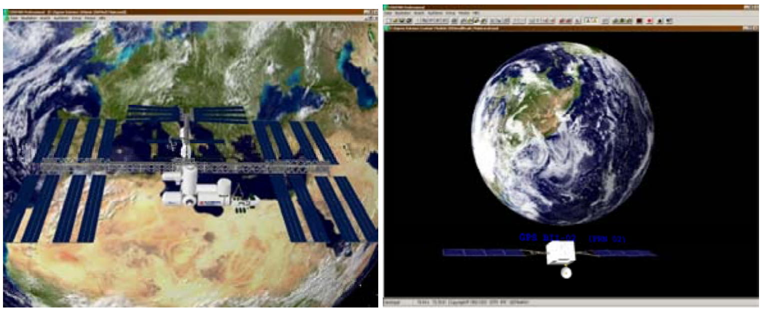

Fig. 12: A view from International Space Station and from a GPS Satellite

While Fig. 12 on the left shows the ISS in its orbit at around 400 kilometers high, the second image shows the view onto earth from the perspective of a GPS satellite at a high of approximately 21.000 km. Also on the right, the ISS is supposed to be seen! But although the ISS is almost as large as a football field, it becomes negligibly small when viewed from a GPS Satellite. This simulation helps the students very much to understand — and to appreciate — the inner workings of GPS satellites which today are to be considered as the important basis of localization and effective geo-referencing on earth.

“DOWN-TO-EARTH” APPLICATIONS

As stated in the introduction, we have just begun to understand and appreciate the value of geo-information data in virtual reality applications. Nevertheless we strongly believe that great symbiotic effects can be achieved, if these two technologies are brought together, Simply put, the major benefit for VR will be that users will immediately feel “at home” in the virtual world because they will recognize the landscape they are working in. The major benefit of the cooperation for the geo-information community could be that the data they provide can by means of VR technology more quickly and more intuitively be exploited and that the data can be enhanced by “interactivity”.

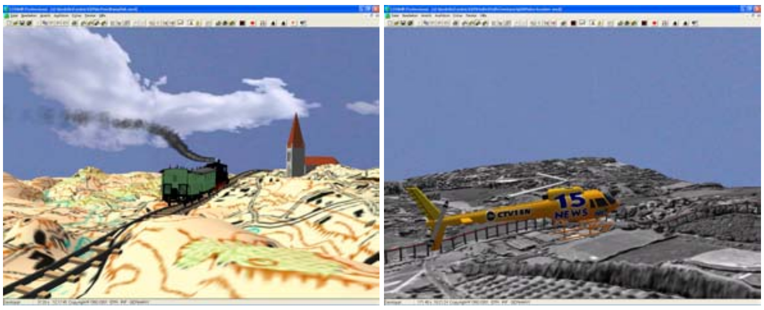

Fig. 13: Making 3D maps „interactive“ …

Fig. 13 shows two simple examples that have been realized to “enrich” the 3D representation of topographic maps. As the train rides across the landscape or as the helicopter flies over an ortho-photo enriched topography, users get a much more instructive feeling for a landscape than from state-of-the-art maps.

CONCLUSION

The availability of geographic data electronically significantly supports the generation of virtual worlds. The potential for mutual benefits in both developments is high as the applications in this paper show. The step from 2D map data to 3D geo-information can become a big leap if accompanied by new ideas for the use in new fields. As a market demand for geo-information in virtual worlds is already felt, the GI-Days may be the right plenum for the development of such new ideas and of new interdisciplinary teams to open up the new fields.

REFERENCES

Freund, E., J. Rossmann (1999): *Projective Virtual Reality: Bridging the Gap between Virtual Reality and Robotics", IEEE Trans. on Robotics and Automation*, Vol. 15, No. 3, June 1999, pp. 411-422.

Kraft, D. (2000): *Die Prozesskette Holzernte: Leistungs- und Wertschöpfungsprozess aus der Sicht eines Forstunternehmers.* Forst und Holz 55(5): 123-130.

Rossmann, J., T. Wagner (1999): *Forstmaschinenführer in der dritten Dimension*, Forst & Technik, Heft 2/99, BLV Verlag GmbH, München.