SimWorld – Automatic Generation of realistic Landscape models for Real Time Simulation Environments – a Remote Sensing and GIS-Data based Processing Chain

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***Abstract*— The interdisciplinary project "SimWorld" - initiated by the German Aerospace Center (DLR) - aims to improve and to facilitate the generation of virtual landscapes for driving simulators. It integrates the expertise of different research institutes working in the field of car simulation and remote sensing technology. SimWorld will provide detailed virtual copies of the real world derived from air- and satellite-borne remote sensing data, using automated geo-scientific analysis techniques for more efficiency and greater realism for landscape models. The implementation of geo-databases and GIS technology within the simulator will allow for further simulation and testing of new technologies like e.g. radar-sensors, night vision systems as well as positioning systems such as GPS and Galileo.**

***Index Terms*— GIS, Remote Sensing, Car Simulation, Virtual Landscape**

I. Introduction

Real time simulation-environments are crucial for a time and cost effective development of new automotive technologies for replacing risky and expensive test setups. The quality of virtual models of vehicles, instruments and surrounding environment has significant impact on the range of applications where simulations can be successfully used. Due to an engineer-driven development of simulators, current vehicle-simulations provide well-elaborated, precise numerical models of the crafts themselves, the sensors involved and assistance systems to be analyzed. On the other side the representations of the virtual outside environments used as backdrops are often very limited in their spatial extent and are lacking realism. This lack of realism limits the applicability of simulators and reduces especially the credibility of perceptually oriented test series. But even the generation of basic environment models requires – despite their low realism – a time consuming, manual production process based on the information available from maps and other sources

Therefore the interdisciplinary project "SimWorld" was initiated to improve the virtual depiction of the real world and to provide easy access to realistic landscape models for numerous driving- and flight-simulators applications. SimWorld therefore integrates the competencies of several DLR institutes in the field of Remote Sensing technology and car simulation systems. The project will provide realistic representations of the real world derived from GIS and remote sensing data.

II. Background

A. *Real Driver Assistance Systems Laboratory at DLR*

Since 2001 DLR operates a Driver Assistance Systems Laboratory (FAS-Lab) encompassing a research vehicle named ViewCar as well as a full scale car simulator. The ViewCar configuration allows for studying the driver's behavior in real traffic situations and is therefore equipped with a broad range of sensors. The driving simulator extends these abilities by providing a second test environment for tests that can not be realized in reality e.g. for security reasons. The dynamic driving simulator enables researchers to evaluate a broad range of assistance systems also in critical situations transferring the results to the test vehicle and the real traffic. It generates a realistic driving feeling by three parameters: an efficient motion system ensuring a credible driving experience and a realistic environment consisting of a real car and the virtual environment model.

The motion system uses - for the first time worldwide - a hexapod system with the cabin hanging in below the upper articulations. This novel construction allows big linear movements of approximately three meters at a low installation height.

Fig. 1 – DLR Hexapod Driving Simulator

Fig. 2 – Integration of a complete Car for realistic Driving Experience

It also offers the possibility to use two degrees of freedom independently: the linear motion for representing temporary accelerations and the tilt coordination (inclination) for continuing acceleration.

Furthermore a high payload capacity of approximately 1.3 tons allows the integration of a complete car within the simulator for a maximum of realism. Via a CAN-Bus (Controller Area Network Bus) the driving behavior (e.g. acceleration, steering) is transmitted to the simulation computer and recorded in a database. Vice versa the simulation system controls the dashboard instruments such as the speed indicator. All inputs and actions made by the driver, from braking over steering to operating the radio, can be recorded and analysed. Displays and control elements can be completed or substituted according to the requirements. The realistic driving impression is completed by a surround sound system playing back the sounds of cars and environment by the implemented loudspeakers including Doppler-effects. A high-resolution projection system with 9200 to 1280 pixels finally complements the immersive simulation environment and provides a wide field projection of 240° x 40°. The rear-view and side view mirrors, fed separately by additional monitors, literally expand the driver's view to 360 degree [1]-[3].

B. Landscape Visualization

Whereas the existing simulator enables an accurate simulation of the car and car-related components, it currently provides only a basic representation of the surrounding landscape. This mismatch is rooted in the complexity of real world landscapes and the enormous effort necessary for generating a credible virtual representation thereof. Furthermore every single experiment requires new virtual landscapes to meet the specific project requirements. With regard to the, up to now, laborious generation of the virtual worlds, more complex scenarios are too time-consuming and costly. Thus fictive landscape models are often used instead of realistic landscape representations. At best basic virtual models are derived from maps or images by remodelling - placing landscape elements such as roads, houses and vegetation manually.

A few commercial software packages aim to meet the demand for fast landscape modelling for real-time applications. Tools like Visual Nature Studio, LandExplorer, Leica Virtual Explorer, Terrain Builder etc. are specialised on landscape modelling. They provide support for geo-referenced data, such as digital elevation models, satellite images, geo-referenced 3D models and GIS data. They even provide procedural textures and methods for the automatic distribution of vegetation and other landscape elements. Unfortunately these tools are not tailored to the specific requirements of car-simulators and still need a high level of expertise in geo-data processing. The import of satellite images for instance helps a lot for an overall view of a landscape, but does not help much for close-up views of the direct surrounding of the car. For close-up views, not the geo-data itself, but the encoded information must be extracted as the basis for the generation of a credible simulation: instead of satellite images draped over digital elevation models, single tussocks, bushes and trees, as well as other landmarks must be integrated into the model and then visualised. Therefore the import of geo-data surely is an essential prerequisite for landscape modelling, but the derivation of the information describing the landscape is the most crucial step towards a credible virtual copy. The information extraction must either be done manually or requires profound geo-scientific knowledge [4]-[7].

III. SimWorld

A. Modelling Reality - Data availability and integration

The aim of SimWorld is to develop a widely applicable and automated processing scheme for the generation of virtual landscape models using geo-scientific knowledge. The processing chain integrates a wide range of geo-data types, held in separate geo-data bases. The vast amount of Remote Sensing data stored in the archive of the German Remote Sensing Data Center is the key to the success of the project. As it turns out, additional data from other sources – especially data from Geographic Information Systems – will have to be integrated to fulfil the requirements of the users. For the development of the systems two test areas have been identified to test the methods and algorithms developed. The first test site is the area around Braunschweig in central Germany. The region is relatively flat and is traversed by numerous larger highways ("Autobahnen"). The second test area is located in the very southeast of Germany close to Berchtesgaden – a region characterized by smaller streets, villages and mountains.

Fig. 3 – Berchtesgaden Test Site as Virtual Landscape Model

The technologies will be tested and refined within these two regions, but should – at a later stage – also be applicable for the whole of Germany and possibly beyond.

B. Topographic Information

Information on the topography – meaning information on elevation – forms the core element of every virtual landscape. Digital Elevation Models (DEMs) provide information on the height above sea level for every coordinate and they are available from numerous sources in different resolutions and accuracies and in a variety of data formats.

A consistent elevation model of the earth has been generated based on measurements collected by the American Shuttle Radar Topography Mission (SRTM) with German and Italian contributions. The result of the mission was highly accurate topographic information using radar technology. In SimWorld SRTM X-Band data is used whenever available, offering a horizontal resolution of 25 meters. Data gaps existing in the DEM are filled based on data derived from the ERS-Satellite. The 25 Meter SRTM and ERS DEM provides a landscape basis that allows for easy recognition of typical landmarks. This data is adequate for the principal representation of the landscape, though the accuracy does not suffice to describe the vertical profile of street levels. For an exact street profile the data must be refined using available road information from Geographic Information Systems (GIS) or must be complemented with higher resolution elevation models from other satellite- or airborne sensors. For this purpose high resolution satellite images from the IKONOS-satellite were used within SimWorld to triangulate Digital Surface Models (DSM) from stereo images. Digital Surface Models (DSM) – in comparison to DEMs – provide information on surface heights including e.g. forests, buildings and other objects. This information is twofold and can be efficiently used in two ways for model generation. On one hand a pure Digital Elevation Model showing only the base height can be derived from the DSM by applying cleaning and conversion algorithms. Secondly this information can be used successfully in the further processing chain for the deduction of details about the structure of settlements or the heights of trees.

Even higher elevation accuracies in the range of decimetres finally can be achieved by using aerial data. The data used for the project originates from the High Resolution Stereo Camera (HRSC). The pushbroom camera was originally developed by DLR for the Mars Express mission of the European Space Agency (ESA). The advanced airborne successor of the Mars camera delivers not only multi-spectral aerial images but also highly precise DSMs. The high accuracy of those surface models comes along with higher costs and lower availability. The data from the camera is not available for large areas and can only be captured under perfect weather conditions. The recently launched German radar satellite TerraSAR-X and his twin-satellite Tandem-X planned for 2009 will provide weather-independent acquisition possibilities of high accuracy elevation models with a horizontal resolution of two meters. Until 2014 they will furthermore deliver a new global elevation model with a resolution of 10 Meters and thus allow for the generation of virtual models of literally every remote landscape on earth [8].

Once the elevation models suitable for the different areas in the model (close and far range) have been identified and processed, the next step includes the integration of different road levels. Based on data on road location as well as type and width the elevation has to be smoothed and adapted around the street level. This will ensure a “smooth” appearance of the later model within the direct surrounding of the car.

C. Texture information

Whereas for flight simulators satellite images in realistic colouring draped over elevation models, already deliver acceptable simulation results, in ground based driving simulators this technique can only be used for distant landscape elements. A car simulator needs much more details because of the minimal distance between the car and the landscape and the relatively low speed of the driver. As a consequence different levels of detail are required and have to be considered already when identifying the base data.

Medium and High resolution satellite data: Satellite data in natural colouring applied to an accurate elevation model can be used as background information in the simulation. For this purpose different data types like e.g. of the MODIS or Landsat class with a resolution from 250 to 30 meters and better can be directly applied. The big advantage of this type of data is, that it renders full coverage of every area and that it is readily available. As all these sensor system observe the earth far beyond the visible portion of the electromagnetical spectrum the data is perfectly suited for deriving information on land use and land cover in high resolution – a key requirement for the later placement of individual objects like buildings and vegetation in the landscape. Using this technique, the lower resolution of the data can be compensated in the medium range distance between the landscape model and the observer. For these areas, as soon as trees and houses become recognizable as three-dimensional elements, the image data is gradually replaced by 2-D or 3-D objects, using the land-cover information for a rough positioning.

Very High resolution satellite data: In the immediate vicinity of the simulator, when e.g. single trees and bushes affect the overall impression of the landscape, high resolution data will be used. The data are provided e.g. from ResourceSat or the Indian IRS-Satellite in a resolution of up to 6 meters per pixel.

Fig. 4 – Elevation caused by Street Plantation in a Digital Surface Model

Fig. 5 – Cleaned Digital Surface Model with 2D / 3D Objects

Very high resolution data in the one-meter class can be obtained from IKONOS or Quickbird and will also be used for classification and segmentation of groups of trees, single trees, houses, roads and infrastructures. Depending on the intended accuracy, aerial data capturing such as HRSC-data or aerial images will be used to identify very high resolution detail like e.g on the presence of guardrails or the differentiation of over- and underpasses.

Furthermore data of radar satellites, which operate in the microwave part of the spectrum, will be included in the analysis of the landscape. Radar pulses are very sensitive to metal structures of any kind and could prove to be a valuable source for information on bridges, traffic signs or guardrails. Apart from the radar satellite data which is available, DLR operates an airborne 3-D radar instrument. The data provided by this relatively new technique has to be evaluated for it´s information content for SimWorld [9]-[11].

D. *Geographic Information Systems (GIS)*

Geographic Information Systems allow for the storage, management and analysis of geo-related information. The information extracted from satellite data and other sources via principal-component analysis and object-oriented classification, is stored as line or polygon based GIS data in the geo-data base and can be translated in any other format necessary for the simulator engine. Furthermore additional GIS data can be implemented from external sources for a maximum of accuracy. Within the GIS, the Digital Landscape Model (DLM) represents the entirety of information represented by polygons, polylines or points connected to a database holding additional metadata to all objects. In this database attributes for each street segment can be stored, providing information about street type, street conditions, speed limits and street infrastructure.

As this information can not be derived from remote sensing data, external appropriate GIS databases will be used. As selection criterions the quality of content, the implementation, the availability, the data interface, the guaranteed future continuation and costs were analyzed. It turned out that commercial GIS datasets for navigation purposes (e.g. from Navteq and Teleatlas) fully meet the demands. Data from ministries and public authorities - despite their better spatial accuracy - do not contain additional information necessary for the planned purpose. The lack of accuracy of some data sets can be corrected by automatic object classification and matching methods using high resolution satellite images as reference for the street course. For an overall land-use information, Corine Land Cover 2000 (CLC) is used for the visualisation of distant areas, comprising 44 land use classes for Europe in a resolution of 100 meter per cell. Even though this information could be drawn directly from the remote sensing data, the usage of the CLC data set saves processing time and ensures comparable, consistent results all over Europe.

Other GIS data bases containing location and size information for e.g. street signs, utility poles or water drains partly exist at different institutions. Their availability and usability have to be evaluated.

One of the big advantages of the GIS System is the possibility of deriving new information from the GIS using analysis functions. E.g. by providing information on soil type, elevation and vegetation cover, the most probable type of trees can be calculated. Another example would be the blending of information on height above sea level and exposition in combination with current temperatures – all indicators for a risk analysis of snow and ice on the road. Using elevation data in the GIS will also allow for a view shed analysis – this will optimize model generation and object visibility in the next step [6].

E. *Natural Rules*

Apart from analysis of geographic data from satellites, airplanes or GIS systems, a rule set will be implemented within the landscape generation system. This rule set has to be identified and will be the last step in the process. The rules will give the system the final touch and will be defined on a regional basis. E.g. the appearance of buildings changes with cultural borders and houses in the north of Germany will more likely be equipped with a brick outside façade, whereas in the south there will be more wooden houses.

Other examples include the placement of vegetation. No trees will be allowed in the landscape, if the elevation exceeds 2000 meters above sea level. Coniferous or deciduous tree types will be identified and placed according to their natural distribution. Highways in Germany will always have noise protection walls, if a village or city is close by. This rule set is still in the making and will greatly contribute to the fine tuning of the models.

IV. CONCLUSIONS

A basic set of satellite and GIS data has been identified, available on European scale and suited for the derivation of the required information for the automatic generation of virtual landscape models. Most part of the needed information extraction techniques is developed and applicable and now has to be integrated in a general processing chain. In the next step metadata bases, such as a plant library with typical European ecosystems and natural rules will be defined and implemented for further enhancement of the classification results.

The demand for virtual models of cities and landscapes becomes obvious in the success of so called Virtual Globes software. Automatically generated realistic Landscape models can not only be used for driving or flight simulators but are also suitable for applications like:

- Train Simulators
- Advanced Navigation and Infotainment Systems
- in Situation Rooms for disaster management
- 3D Mapping for Traffic Management
- Management of major Events in Sports, Entertainment or Politics

The results of SimWorld will greatly facilitate the generation of realistic landscape models for use in these applications. The next challenge will be the development of interfaces to the car simulation systems – the data has to be correctly and consistently converted into formats like VRML and open drive and have to be integrated into the car simulation software. The future use of e.g. Geo-VRML and other formats enabling the use of geographic information will be evaluated.

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