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Visualizing planetary data by using 3D engines

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Abstract

We examined 3D gaming engines for their usefulness in visualizing large planetary image data sets. These tools allow us to include recent developments in the field of computer graphics in our scientific visualization systems and present data products interactively and in higher quality than before. We started to set up the first applications which will take use of virtual reality (VR) equipment.

1. Introduction

Two-dimensional maps are a great way to extract and combine information quickly. They also contain valuable quantitative information on the surface geometry, in particular if based on precise geometric information through orthorectification. But maps are by definition only symbolic representations. While this suits a variety of scientific needs, it does not offer an immersive environment for visual inspection. Three-dimensional models though bring the proportions and relations between the individual features on a planetary body to light and allow intuitive interactions with the data.

Visualizations of planetary data are a key element in our public outreach activities at the Institute of Planetary Research of the German Aerospace Center (DLR) in Berlin-Adlershof, Germany. We plan to refresh our setup by using modern 3D gaming engines and integrating virtual reality (VR) equipment.

2. Data

Data sets have been generated from images gathered during various planetary (e.g., Mars Express HRSC [1]), lunar (LRO, [2]), asteroid (Dawn, [3]), and comet missions (Rosetta, [4]) by applying stereo-photogrammetric methods and image mosaicking techniques. From some of these data sets triangulated and textured high-resolution 3D models were created.

We use the open source modelling and animation software *Blender* [5] to generate the triangulated meshes (Fig. 1). If necessary, models with large polygon counts are split into segments. Also, we create several levels of details (LOD) for each mesh with decreasing polygon counts. With increasing viewing distances lower resolution versions of the same model are loaded (and vice versa) which ensures a stable performance in scenes with multiple high-resolution models. The models are exported in Autodesk FBX or Alembic format for further use in 3D graphics rendering software packages.

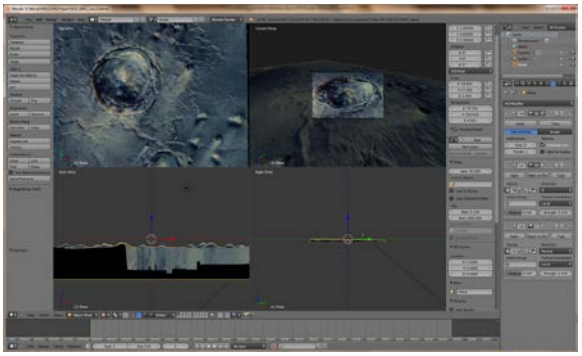

Figure 1: 3D modelling using a HRSC digital terrain and HRSC color ortho-image in Blender.

3. Application

Nowadays several 3D engines are freely available for developers (depending on the licensing terms), e.g. *Unity [6]*, *OGRE [7]* and *Lumberyard [8]*. For our needs we found *Unreal Engine 4* [9] the most promising candidate. It does not only combine a high graphics quality with a superb performance and user-friendliness, it also integrates VR hardware easily and can additionally be used to create simple

animated video sequences without the usually long render times of dedicated animation software.

We started a project to visualize the whole HRSC MC-11-E quadrangle [10] as a continuous landmass in high resolution. In preparation we sliced the digital terrain model and color image mosaic into ca. 2,000 single tiles each consisting of several LODs. The whole data set covers an area of 1,300 km x 1,800 km in an image resolution of 12.5 m per pixel (Fig. 2).

Figure 2: Mars quadrangle MC11-E in the *Unreal Engine 4 Editor*

Another project features Vesta. It allows free roaming around the asteroid as imaged by the Dawn spacecraft. There is also an integrated “Tour Mode” visiting prominent surface features and displaying additional information on-screen automatically in a loop (Fig. 3).

Figure 3: Vesta in *Unreal Engine 4*

4. Outlook

We plan to set up virtual reality systems at DLR Berlin, using *HTC Vive* VR headsets. This approach enables the user to get in a closer touch with the data which could be beneficial when used in scientific analyses where it would improve our understanding of the topography.

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Offering the Moon to the Public

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Abstract

Il Mondo della Luna is a project that puts forward a series of activities with the aim to communicate and inspire young people and the public in general to explore space and planetary science through artistic actions. The focus of the action is F. J. Haydn's Opera "Il Mondo della Luna".

1. Introduction

In a world that is constantly changing and every prevision about the new challenges of the coming years is risky, the most important ability with which we should shield young people, and those who remain young is, besides knowledge, the ability for unconventional and innovative thinking and the ability to envision, to sense, to inspire, to dare.

Especially in an era of worsening economic, political, and especially social and cultural crisis, innovation, cooperation, creativity and education are perhaps the only triggers for the evolution and progress.

According to the Anglo-Saxon approach, Art is not only seen as an artistic creation, but is integrated into the educational process by supporting the approach of other teaching subjects. In the age of Postmodern, Art/Culture/Research/Science must be combined into a harmonious, unified whole, aiming not to fragment knowledge into cognitive objects, but to the unified expression, combinational thought and multifaceted development of the child.

2. Polymnia's asprirations

The Cultural Company "Polymnia", with a significant artistic and educational work has the belief that the vision for a better world can become a reality through the spiritual development of children and their moral and mental maturity. The Cultural Company "Polymnia" has repeatedly demonstrated the essential role of Education, where the goal is to build knowledge while enhancing Imagination and Creativity, virtues that only indirectly can be cultivated.

For this reason **"**Polymnia**"** has developed, via its human resources, educational programs of Science, Culture and Art, in order to stimulate abstract but valuable mental processes. Planetary and space science has often been in the focus of such activities, entertaining a long lasting collaboration with the Hellenic Physical Society in a series of events nationwide, entitled Science and Art. These encompass innovative ideas as divers as a **"**scientific opera**"** for children, series of comics inspired by scientific themes where the art of design reveals difficult scientific notions, theater plays inspired by the exciting lives of scientists, etc.

3. Il Mondo della Luna

With the aim of making space science attractive, understandable and accessible, we inspired a series of activities focusing on the performance of F. J. Haydn's Opera: Il Mondo della Luna.

In our presentation we will try to describe these actions as well as the aim of the whole effort to include creativity, critical thinking, real science simulation, imagination, personal empowerment and decoding skills of multimodal messages, in a world that demands the cultivation of multiple literacies.

We believe that this series of activities is intimately linked to constructivism learning, combinatorial knowledge, inquiry-based learning and fostering imagination, in an original and entertaining way.

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WOLF REXUS Experiment

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Abstract

WObbling controL system for Free falling unit (WOLF) project is closely related to an experiment called SPIDER[1] (Small Payloads for Investigation of Disturbances in Electrojet by Rockets), which was developed under the Swedish National Balloon and Rocket Programme. SPIDER carried a payload of ten Free Flying Units (FFU) which were released from the main rocket at 65 km. The FFU's deployed spherical probes on wire booms to measure turbulence in the auroral electrojet between 95 km and 115 km.Those FFUs experienced a wobble motion, likely induced during the FFU ejection from the rocket. The wobbling motion of the probes may compromise the measurements on the spinning payloads with flexible booms, as the position of the probes cannot be assumed radial. In the worst cases, wobbling can compromise the dynamics of the free flyers. The WOLF REXUS experiment sets out to address this issue, aiming to demonstrate a dynamical system to suppress the wobbling, and ensure flat spin motion on disc-shaped FFUs. The experiment also addresses the questions of the FFU ejection effect on the main rocket attitude dynamics, and develops a more robust recovery and localization system to be used on FFUs of this class. The WOLF experiment was selected for flight onboard RX24 sounding rocket, realized in the framework of the REXUS/BEXUS programme[2]. This contribution describes the setup of the WOLF experiment, and presents the progress up to the Integration Progress Review level.

1. Introduction

Since aircraft and balloons are limited to altitudes of typically less than 40 km and orbital spacecraft have a minimum altitude of well above 100 km, the only viable solution to access the middle atmosphere is the use of sounding rockets. Ejectables probes from sounding rockets can be used to make multi-point in-situ measurements. This has been demonstrated, for example, in the successful flight of RAIN on REXUS 11 in November 2012, MUSCAT experiment launched on REXUS 13 in May 2013, or SCRAP[3] launched on REXUS 17 in March 2015. Other REXUS teams as ISAAC[4] or SLED[5] opened the way of SPIDER experiment (Small Payloads for Investigation of Disturbances in Electrojet by Rockets), which was developed under the Swedish National Balloon and Rocket Programme. All the projects mentioned above are designed by students, professors and researchers from KTH Royal Institute of Technology, Sweden.

The outcome of the SPIDER design is a system that measures electromagnetic fields in the ionosphere and characterize plasma's main properties. The main goal of the project is to use multiple Small Payloads for Investigation of Disturbances in Electrojet by Rockets (SPIDER) to probe the multi-scale structure of electrostatic turbulence in the ionospheric E region. The novelty of the experiment lies in the fact that auroral electrojet and pre-breakup auroral arc are studied in situ simultaneously on multiple scales. The auroral electrojet is a current of remarkable strength and persistence that flows between 90 and 130 km height in the ionosphere. It is considered to be the cause of the onset of charge density irregularities. This affects and disturbs propagation of radio waves, as terrestrial TV signals, satellite communication and navigation signals. The presence of the irregularities excited by Farley-Buneman instability is the foundation of the coherent scatter radar operation.

Ten units, called FFUs (Free-Falling Units), cylindrical-shaped with 240 mm in diameter and 94 mm in height are used for the innovative multi-point measurements. Each of them are equipped with eight spherical probes which are deployed by means of wire booms through some holes in the boom deployment unit (BDU) hull and they measure currents and electric fields. The four longer probes are dedicated to electric field measurements, whilst the other four, 1 meter shorter, are biased to provide measures of the plasma trans-characteristic.

2 Experiment Objectives

The primary technical objective of the experiment is:
OBJ 1. To design, build and validate an in-flight wobbling control system for reducing wobble of spinning free-flying units.
Secondary technical objectives are:
OBJ 2. To demonstrate a thin wire boom deployment achieving radial booms
OBJ 3. To acquire high time resolution and high accuracy data on the rocket rotational motion to characterize the ejection process.
OBJ 4. To develop and build a more robust recovery system than the one used in the SPIDER experiment and previous KTH REXUS experiments with large FFUs (such as SCRAP and SLED).

3 Experiment Concept

The experiment consists of one Rocket Mounted Unit (RMU) and two Free Falling Units (FFUs). Each FFU is sub-divided in three other units:

1. Bottom Unit (BU)
2. Boom Deployment Unit (BDU)
3. Common Unit (CU)

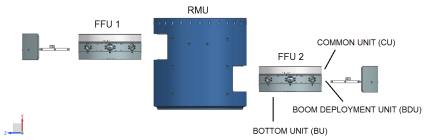

Figure 1: FFUs ejected from RMU.

The two FFUs will be ejected from the RMU, Figure 1 by means of a spring-based ejection system. The FFUs, after ejection from the rocket should spin around the spinning axis (Z axis, Figure 2). The ejection must occur before rocket de-spin such that FFUs retain their spin when they are ejected. The wobble control system will be accomodated in BU and it will damp the lateral angular rates until the FFUs will achieve a flat spin. The centrifugal force created by the spinning of the FFUs will deploy the booms out from BDU.
The purpose of the BDU is to deploy the booms that

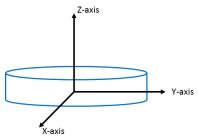

Figure 2: FFU axes.

measure the currents and the electric fields. The CUs record the general flight data for each FFU throughout the experiment. These raw GPS data, acceleration, angular rate, and atmospheric pressure will help to reconstruct the flight trajectories. The CU also houses the recovery system. At approximately 5 km altitude, as determined by the pressure sensor, the parachute is deployed and the FFU's GPS location is transmitted via radio beacon and satellite modem. The bright orange parachute along with 24 hour long location transmission will aid recovery. As all data will be stored on the FFUs, recovery is necessary for any analysis of the experiment.

4. Summary and Conclusions

Following the main objective of the WOLF experiment, we are developing and currently prototyping a reaction wheel-based control system, effectively functioning as active nutation damper. One reaction wheel is used to reduce the undesirable lateral rates. Once validated in REXUS flight, the concept and the design developed during WOLF experiment can be used for other application which require a flat spin of the free falling units.

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The Moons of Jupiter / Journey to the Stars

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Abstract

The Moons of Jupiter/Journey to the Stars is an oral talk and performance, which describes a creative project uniting science and theatre arts. In the service of offering science education outside the classroom this presentation explores the use of theatre as a vehicle for inspiring interest in science.

In The Moons of Jupiter playwright Jessica Litwak uses planetary science and Greek mythology to engage the audience in an imaginative journey, which both provokes thought and embodies scientific knowledge within the plot and through the character. It focuses attention on climate change and the global water shortage, using planetary science as a vehicle to sensitize people on these issues. The Moons of Jupiter teaches us about the history of science, the future of planetary travel and the courage and necessity of always looking toward the unknown. It's also (like all good plays) about love.

The Moons of Jupiter by Jessica Litwak, has set out to collaborate with another inspirational project, Journey to the Stars by astronomer Eleni Chatzichristou, involving a large-range of stakeholders: public, schools, artistic entities, state officials, tourism professionals. The Moons of Jupiter/Journey to the Stars is a complex, multidisciplinary, multidimensional project, a true collaboration between the arts and sciences, linking astronomy with theater both represented in Greek antiquity by the muses, the inspirational goddesses considered to be the source of knowledge.

This innovative project is aimed to inspire people to develop a genuine interest in the works of nature (our planet's fragile environment but also our place within the cosmos) and humanity, to develop affinity for the arts, and to appreciate the culture of our ancestors and of people around the world.

This presentation explores the educational and social value of the project, which encourages outreach and dialogue with the society. It is our intention that it becomes a starting point to further promote space science through artistic events and to, inversely, encourage artistic performances to accompany science dissemination activities.

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King on the MoonVillage and King on Mars: Exploring Space – Creating Space

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Abstract

It will sure take a while, but it's going to happen one day: the colonization of the Moon and Mars. Space agencies, scientists, international companies and architects; they already make plans to build a new society outside of the Earth. These developments place the notion of 'public space' and the limits thereof in a challenging context. (Im)possibilities seem endless.

Main goal of the practice ‘King on the Moon’ and ‘King on Mars’ is the search for new areas to discover and to develop. You examine issues and generate solutions to explore and take possession of new public/private spaces.

1. King of Moon & Mars Practice

In this practice you will be dealing with different (political) ideas about power, gender, colonization and technological progress. You will have to rethink you position and responsibility as a creative entrepreneur as scientific, philosophical or creative ideas are at stake in a still unexplored area. What if humans can take possession of an unlimited new public space? How much 'freedom' offers that space? Who owns what, who is in charge?

King on the Moon and King on Mars are autonomous practices; therefore, it is essential to define your own individual position within the field of design and art in public space. What role do you choose for yourself and why. This will include your personal artistic vision, intuition and emotions but also social ideals or political liking to be part of a (autonomous) visual statement.

2. Assignment

- research and develop a plan for taking possession of a new (un)claimed or alien area in the public space, consider the moon as starting point

- position yourself in this future developments bases on your own discipline

- the outcome can be anything; a 3D model, a performance or protest, a poem or music or...

- write a research document

3. King of Moon & Mars: Results

We shall present a summary of King of Moon & Mars individual projects, visual results and products.

Acknowledgements

We thank the students of King of Moon/ King of Mars programmes, ESA ESTEC, WdKA and colleagues that supported the practice.

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Space is the Place – MoonVillage ArtScience Residency

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Abstract

Space and Moon-Mars Exploration Through Art offers you a MoonVillage Artscience workshop dream ticket to ESTEC the technical heart of ESA, the European Space Agency.

MoonVillage Artscience Workshop

Located in Noordwijk (25 kilometres from the Hague), the European Space Research and Technology Centre (ESTEC) is the incubator of the European space effort – where most ESA projects are born and where they are guided through the various phases of development.

Depending on the profile of your project, you can receive guidance from space scientists and engineers, access a wealth of data collected during various space missions, and invent your own way of fostering a collaboration with ESTEC. Since the earliest scientific preparations for extraterrestrial travel at the beginning of the 20th century, the exploration of outer space has become a quintessential framework of the human condition and its creative manifestations. Although the artistic pursuit of space science is still in its infancy, an accelerated evolution is currently underway.

Keywords: Moon Village, Mars Journey, harsh habitats, sensory deprivation and psychological effects of space travel, overview effect, microgravity, immersive environments, origins of life, climate and space weather, astrobiology, nanotechnology, robotics, remote and machine sensing, Solar System, humans as extraterrestrial villagers

Objective: exploring the potential of art in relation to (outer) space; Examination: presentations, and attendance.; Opportunities: participation to workshop , definition of follow up artscience and space projects

Assignments

Individual Assignment : 1) research and develop a plan for taking possession of a new (un)claimed or alien area in the public space, consider the moon as starting point; 2) position yourself in this future developments bases on your own discipline;3) the outcome can be anything; a 3D model, a performance or protest, a poem or music or..; 4) write a research document.

Collective Assignment : 1) Habitat and simulation: How do go from a lunar habitat to a moon city? How to live inside? How could we simulate ? How to operate as an astronaut and/or as a robot? 2) Long term and global view group: Minimal base (10 people) and how to test it, and how you branch to the long term view (social, urban planning, etc.).;3) Campaign group: Content to engage the audience and stakeholders. PR campaign, arguments, performances, etc.; 4) Experiments group: Tools/concept/instrument on a real lander in 2020 (a technology precursor).

Results

We shall present highlights of results.

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We thank the students participants: Teun, leandros, Nele, Veerle, Liva, Mabel, Alexander Z, Loes, Suna, Stefano, Sabina, Jorge, Catherine, Jesus.

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