Oculus Rift Planetarium Project
STFC small-project public engagement award
Third Report 19th May 2015
(This report can be read in conjunction with two earlier intermediate reports)

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Initial budget £9,150 Final expenditure £8,902.07

Project outline:

A pathfinder project designed to find/adapt/develop planetarium software to make use of the Oculus Rift VR headset, primarily aimed at stargazing tours and educational use. The project can be broken down into three key stages:

1) To achieve a comfortable/enjoyable single-user Oculus Rift planetarium experience

To keep things as simple as possible, the users location would remain at a fixed point on the Earth and be free to look around under a simulated night sky. Basic Stellarium-type functionally would also be important (eg: toggle constellation lines/art; change date/time; highlighting objects of interest).

2) To integrate group functionality

Through local connections or via the internet, users would be able to join a live hosted stargazing tour where the telemetry (eg: constellations lines on/off) for each connected simulation would be controlled by the host. The audio feed from the host would also be provided. Users would still be free to look around as they wished.

3) Luxuries (optional)

With the basic framework in place there are many improvements which can be made to make the experience more enjoyable. This includes, in no particular order: adding in a way for connected users to be made aware of where on the sky the focus of the host is directed; finding a way of zooming in on objects or making them appear larger on the sky; allowing connected users to ask questions; adding in additional sky maps such as the CMB/IR-sky; adding in memorable extras designed specifically for the group experience.

Results to date

We are now in a position to say that we have been able to achieve all of our main objectives for this project (stages 1,2) and in addition have been able to implement some other features which will enrich the experience for the user.

Locating a software developer with the necessary experience was crucial to this project but we have been fortunate in this regard. Our chosen developer, named above, is very familiar with the Stellarium source code which has enabled us to work quickly in testing and implementing some of our ideas.

With regards to stage one, the initial tests were encouraging with both frame-rate and headset response performing well though there were noticeable issues such as lag spikes and 'judder', particularly on lower spec hardware. At the time of writing both of these issues appear resolved and the field-of-view for the headset is now set correctly. In order to minimise the hardware requirements there are currently no stereoscopic effects implemented, in fact the same image is presented to each eye. As everything of note is at infinity in Stellarium this was felt to be an acceptable compromise - the image of the terrain is not ideal underfoot but looks fine toward the horizon. The headset allows the user complete freedom to look around but at present the height above ground level is fixed in the simulation and thus will not react to changes in user height or position. For future work it may be worth implementing a fully rendered 3D environment though it remains to be seen if this is necessary.

Within the simulation the starfield looks very good though there are usually some residual chromatic effects and they lose focus towards the edge of the field of view. These problems are not enough to ruin the experience though they may become a priority for future work. We have also been able to make many of the Stellarium features perform as expected such as adding in constellation names/lines/art, changing location/times, displaying orbits/grids and removing the atmosphere/ground. The view with no atmosphere/ground has to be seen to be believed!

With regards to stage two, the developer made excellent progress. It is now possible to use Stellarium's plug-in system to initiate a stargazing 'server' or connect to an existing one by typing in the IP address of the host. This is designed to work over the internet as well as a local area network. When connected, a client simulation will receive all of the telemetry from the host, in effect they have ceded control. They are still free to look around as they wish but all of the Stellarium settings mentioned in the previous paragraph are controlled by host. The host would remain in 2D mode for the duration of the talk.

We have made no attempt to integrate audio functionality at this stage. There are a number of freely available third-party voice packages (*Ventrilo* is one example) which can be set up to provide the audio from the presenter on the host machine. Users would simply connect to the audio stream prior to connecting Stellarium. This now puts us in the position of being able to offer guided stargazing talks over the internet. For future work we would want to find a way of providing a more two-way experience by allowing connected users to ask questions or perhaps letting the host see a list of the connected clients along with their current field-of-view.

In achieving our primary objectives for stage one and two it became apparent that for a hosted talk we would need at least one of our optional extras listed in stage three, that of making connected clients aware of what the host is looking at, ie. to find a way of directing people around the sky. We have been able to achieve this aim by providing extra functionality so that when the host selects a target, it is also selected for the connected clients which adds a targeting reticle over the object. In

addition, if the connected user is looking elsewhere in the sky at the time, an arrow is provided at the edge of their field of view which directs them to the object in question.

A second problem to overcome is that in normal Stellarium it is possible to zoom in on objects of interest. This is not so simple in a group-VR environment as any changes to the field of view may induce motion-sickness. Also, people may be looking elsewhere on the sky which would add further discomfort. Rather than zoom we decided it was best to simply make the objects larger on the sky. At the time of writing we have not yet added this functionality for deep sky objects but we have been able to add a novel way of seeing the planets up close. For this, we are able to replace the Moon object in Stellarium with any of the planets, with the added option of increasing the scaling to make the smaller planets readily visible. This adds a unique way of viewing the planets of the solar system (the phases of the Moon are replicated on the planet object) and also allows an easy size comparison with other solar system bodies. We wish to add a similar feature for deep-sky objects but in these cases it would be simplest to overlay with a scaled up image.

Feedback from testing

We have had two opportunities for some early testing. At a public event during the Edinburgh Science Festival we had an opportunity to allow members of the public to test a very early build using only a single headset and an incorrect field-of-view. The feedback was very positive across a wide range of ages. Below are some responses:

"Really educational, a very different way to see the Galaxy. Great to have someone talking you through it whilst using it."

"As a teacher, would love to share this with a class . Very easy to immerse yourself in the experience...excellent!!"

"Give these people more money. This is important for education, for inspiring people to be curious about the universe - particularly in a world where so many people living in cities never or rarely see the stars, and for being awesome. I didn't spot any issues that you didn't seem to be aware of, although it did make me feel slightly motion sick. "

"Fantastic. Loved the talk and the enthusiasm was infectious. My three boys and I learned a lot. Thanks!"

"I wear glasses, the headset is not as comfortable with glasses on. In addition there is high chromatic aberration. Otherwise this is a very good idea and will help people get a good star gazing experience and is worth developing."

The full survey summary with all responses can be found here: https://docs.google.com/forms/d/1Ya8uxjT9qC7JMFAqcvUkAcixoN72amlcPg3brKB8vIQ/viewanalytics?usp=form_confirm

Of the potential issues which have been highlighted in testing, the most common are the chromatic/focus issues discussed above, problems with wearing glasses with the headset (Oculus actually supply different lenses for improving the experience of people with glasses which we didn't have access to during the test day) and rarely, feeling slightly motion sick. The Oculus headset also has a calibration step (measures pupil separation) to reduce these issues but for testing purposes we were using the default configuration. The motion sickness issue is less of a problem for us than true 3D VR-games as we have a fixed viewing point. The things which currently risk inducing motion sickness in order of importance are: frame-rate problems; speeding up the simulation too much;

changing the location during a session and in rare cases, removal of the ground.

A recent test session involved the first ever demonstration of two linked headsets for the benefit of Royal Observatory staff. By and large the responses have been excellent and allowed us to begin the process of refining how a guided tour should be conducted whilst bearing in mind the issues discussed above. The stability of the latest branch is much improved though there are some minor issues which will require correction. The main issue facing us at this stage is how to reduce the focus/chromatic problems still further. Given that the new headset launch in early 2016 will likely render increased work in this area moot, we are currently of the opinion that this should wait until such time as we see how the commercial release of the headset performs. These issues may become much less of a problem as the resolution of the display increases. It should also be noted that stars, by their nature of being white, point-source objects, are most likely to highlight the limitations of the optical setup in this style of headset.

On the whole, the project is in a very good place and our next aim will be to begin testing how it performs over the internet in addition to getting more feedback from individual users.

Future work

The money for software development work has almost been exhausted so we are now focusing on fixing minor issues and improving the quality of the experience. Very soon we will release our branch to the Stellarium developer community as we are keen to get feedback from them on the project and whether or not they wish to integrate some/all of these features into the main public-release branch. It is also our hope to begin small-scale testing of hosted VR-stargazing tours from the Royal Observatory. This could be considered beta testing at present and may flag up additional issues which will require further attention. We have yet to decide on the exact form these beta tests will take but it will likely involve a web presence where keen users can download the branch and follow instructions for joining any hosted talks.

In the longer term we would very much like to continue looking into sources for additional funding, both to maintain the current branch and to implement other desired features when possible. The new retail version of the Oculus Rift is expected to hit shelves in the the first quarter of 2016. This is an upgrade on our development kit headsets and it is likely that further tweaks and adjustments will be required to ensure that the branch remains stable. For now the technical details of the new headset have not been released. We would also like other makes of VR-headset to be able to make use of the branch which could be simple or complex to implement depending on how similar to the Oculus these headsets are. One final option would be to prototype a portable 'demo kit' which would allow us to easily transport the hardware required to run a 4-person group stargazing demonstration. The ability to easily showcase the work with this project may prove invaluable.

Formal cross-check against proposal goals

1) Obtain 3 Oculus Rift software development kits and the hardware needed to run them.

DONE. Headsets purchased as expected. Custom-designed PC purchased for testing. Hardware also tested

2a) Get Stellarium to run on a single virtual reality headset. DONE.

2b) Test and refine the experience to make sure it is comfortable/intuitive to use.

DONE. See notes in reports 1 and 2.

3a) Get all 3 headsets running simultaneously, with independent freedom for each user.

DONE.

3b) Assess load on hardware and check for stability issues.

DONE. This was a considerable part of the work of the contracted developer, and led to us simplifying some of the interface. The result is that our Stellarium branch can run on much lower spec hardware than will be the case for most gaming experiences

4a) Build in synchronization protocols to allow the speaker to pull focus across all linked simulations, eg. to attract attention to a certain planet or constellation.

DONE. Our system works as a master-slave set up, for an arbitrary number of slaves. Each slave simply has to connect to the master copy. Each slave runs their own version of Stellarium, with configuration controlled by simple messages from the master copy. We also added a pointer and reticle to the software to show users where to look.

4b) Stress testing to ensure robustness.

DONE but to a limited degree so far. Tests of real scalability will need a follow-on project.

5a) Begin small-scale testing with members of the public visiting the observatory.

DONE. Demo'ed the system at a Science Festival event, and also to ROE staff in an all-day drop-in event.

5b) Based on user feedback, address any issues/concerns raised.

DONE. Early informal feedback from a small number of users was crucial to take decisions on system design. At the Science Festival and ROE events we collected feedback.

6) Write summary report and conclusions. If all outcomes successful, arrange for software code to be uploaded to open- access repository, produce road-map for next stage of the project, meet with groups who may have an interest in the project. If some outcomes not achieved, produce detailed report on the problems encountered and solutions attempted to aid in any future work.

DONE. Three reports written and plans made for beginning public events. The reports are available at http://www.roe.ac.uk/~al/oculus-temp.htm