Virtual Telescope Project Progress Report

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Abstract

The paper describes current progress of the Virtual Telescope project development on Qt platform. The Virtual Telescope service has to allow users to get information about different sky objects, such as stars, constellations, planets, galaxies and others without using special astronomical equipment (telescopes, etc) but just by means of mobile device. In fact the service turns user's mobile device into personal telescope. Application works in three modes. In first user can get scheme of the stars, which he/she can observe in current time and location. On demand user can get different information about sky object, for example the name of constellation, planet, magnitude of stars, etc. In second mode user get scheme of star sky which corresponds area of the sky to which user is pointing by camera of mobile device. In third mode user can get real images of the sky object from the best astronomical on-ground telescopes and orbital stations.

We choose Qt as development platform because of several reasons. Nowadays there are a lot of similar mobile devices which has different operation systems. As a result we have to develop the same applications under different OS. The main reason we choose Qt is that Qt is cross-platform development tool, so we can write application once and compile it under different OS (Symbian, Maemo, Windows Mobile, etc.)

Index Terms: Virtual Telescope, Mobile Service, Stars Guide.

I. INTRODUCTION

In all times people were interested about stars and wanted to know more about world outside the Earth. But without special equipment we can see only a small percent of the stars and without supporting information it doesn't tell much. Although the mobile devices have good digital camera optics they are not be able and in foreseeable future will not be able to bring user closer to the stars. But let's search for a backdoor to overcome natural physical restrictions of the device. We cannot integrate telescope into mobile device, but by let's simulate its operation.

The paper is organized as follows. The first chapter gives common description of service. It contains use-case scenarios, requirements to service based on comparison with analogues, high-level architecture of service. The second chapter contains description of mathematical part of service. It consists of two parts: description of sky coordinates system and description of transformation of sensors data to sky coordinates system. The third chapter describes features of service development. In the end we draw present major. The paper is finalized by the acknowledgments and list of references.

II. DESCRIPTION OF THE TARGET SERVICE

A. *Use-case scenarios*

Our service has three main use-case scenarios – starpedia, stars-identifier and virtual telescope.

1) Starpedia mode – user get scheme of stars, which are available in current time and location. The main advantage is that orientation of star's scheme on the mobile device

corresponds to real orientation of device in space. By means of joystick or sensor display user can point to the internal area of sky objects and get link to the additional information about this sky object (e.g. Greek myth, etc.) This information can be locally stored or uploaded from Internet recourses. Besides, user can get main information (name, brightness, etc.) about stars by pointing on its.

Figure 1. Starpedia mode

2)   Stars-identifier mode – user get scheme of stars, which corresponds area of the sky, to which user is pointing by mobile device camera. Embedded accelerometer and magnetometer allows determining direction and angle of inclination of mobile device.

Figure 2. Star-identifier mode

3)   Virtual Telescope – user get real images of sky objects, which correspond area of the sky, to which user is pointing by mobile device camera. All real images are uploaded from Internet free databases.

More detailed description of the service you can find in our previous publications [3, 4, 5].

Figure 3. Virtual Telescope mode

B. Comparison with analogues

At the first stage of project development we searched applications for mobile devices, which realize functionality of mobile telescope. As a result we have not found any solutions that already implements basic ideas of Virtual Telescope service. The closest analogues of proposed service are Google Sky [1] и Starmap [8] for IPhone и IPod Touch.

Table 1 – comparison of Virtual Telescope with Google Sky and Starmap

	Google Sky	Starmap	Virtual Telescope
Application for mobile device	-	+	+
Access to images from orbital and on-ground	+	-	+
Approach and distancing of celestial objects	+	+	+
Providing of information about celestial objects	+	+	+
Ability to use your mobile device as a personal telescope	-	-	+
Ability to view the scheme of stars and constellations	-	+	+

As seen from Table 1, application "Virtual Telescope" combines the capabilities of the two other applications, as well as providing new ones, which are absent in the analogues.

Based on an analysis of pros and cons of the nearest competitors, we have formulated the following set of requirements for the "Virtual Telescope".

Functional requirements:

1. obtaining geographic coordinates of the user using GPS or GSM triangulation service;

    a. plus add possibility of manual input of the geographical coordinates by user;

2. in starpedia mode user gets a scheme of stars viewed at the provided geo-location;

3. orientation of the obtained images on a mobile device in-line with the orientation of the device in the space;

4. in stars-identifier mode automatic determination of the angle of inclination of mobile devices using accelerometer sensors;

5. in the stars-identifier mode providing the user with the scheme of stars that user can see in the current time;

6. the possibility of obtaining actual images of celestial objects from orbital and ground stations;

7. ability to zoom in / zoom out celestial objects;

8. ability to save the resulting circuit stars and real images of celestial objects on your mobile device.

Interface requirement:

1. Languages: English and Russian. In the development must take into account the possibility of localizing the application for other languages

Requirements for network connections:

1. Ensuring safe and reliable connections with content providers;

2. Treatment of disconnection that prevents the possibility of data losing.

Service requires that mobile device has:

1. Accelerometer, which is used to determine the angle of inclination of mobile devices;

2. Magnetometer to determine direction;

3. Internet connection for uploading of astronomical content on mobile device;

4. Optionally – GPS to determine geographical coordinates of the user.

C. High-level architecture of service

At the base of requirements we develop high-level architecture of the service.
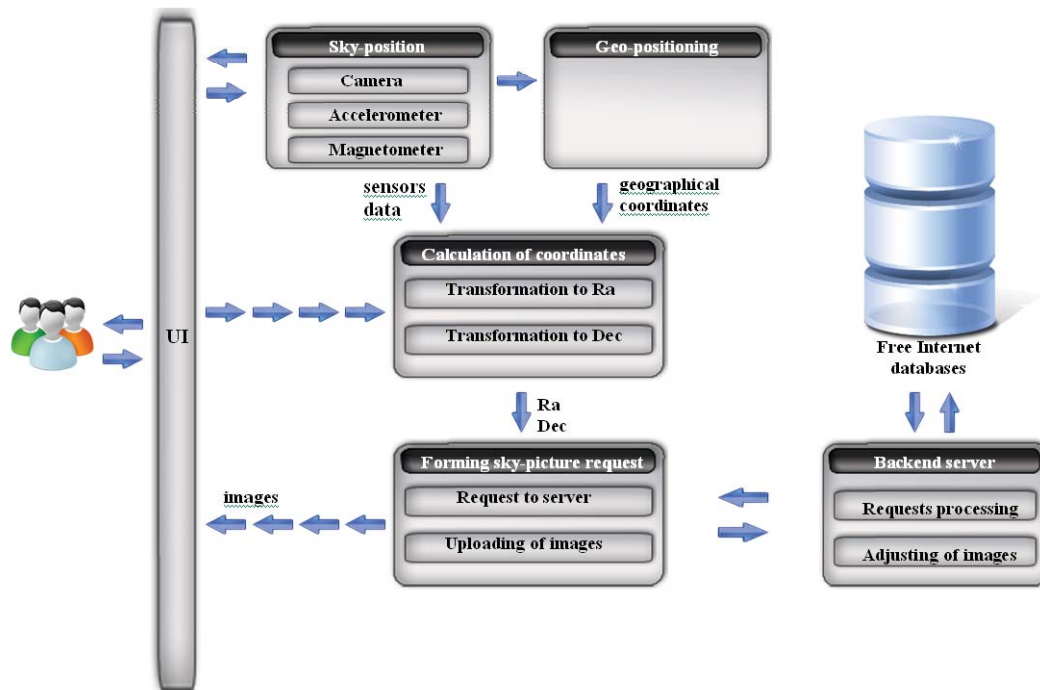

Figure 4. High-level architecture of the Virtual Telescope service

Service architecture consists of following modules:

1. **UI** - Implements cozy interface for interaction between the service and user;

2. **Sky-position module** - the module consists of two submodules – the mandatory accelerometer-based direction recognizer and optional camera module;

3. **Geo-positioning module** - this module defines user geographical coordinates by either using of GPS sensor available in many modern mobile devices, or by getting user coordinates based on coordinates of the serving base station, as even maximum radius of 50 km provides good enough accuracy for our application;

4. **Calculation of requested sky-coordinates** - the module gets date from Sky-position and GEO-positioning module and converts these raw data to the target sky coordinates in form of Ra and Dec;

5. **Forming sky-picture request query module** – the main functions of this module are:

    a. Forming of request to external server;

    b. Getting result image and preparing it for output to screen of mobile device.

6. **Backend server** – make requests of image and adjust it for output on mobile device.

III. MATHEMATICAL PART OF SERVICE

A. Description of sky coordinates system

For solving different tasks in area of astronomy different systems of sky coordinates are used. These systems differ with choosing of main plane and reference point. Within scope of this service we have decided to use the second equatorial coordinate system, because it is more convenient and often used.

Main plane in this coordinate system is plane of sky equator, where the one coordinate is polar distance p or declination δ. The other coordinate defines the hour pole of a star - direct ascension α.
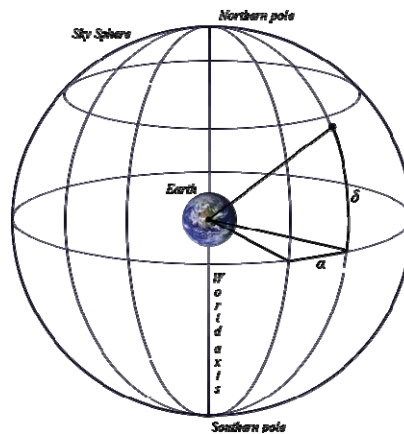

Figure 5. Second equatorial coordinates system

Direct ascension is the arch of sky equator from a point of spring equinox to the hour circle, which goes through the star or central angle (in the plane of sky equator) between direction to a point of spring equinox and plane of hour circle of the star. Direct ascensions α are calculated in the opposite side of daily rotation of sky sphere, in limits between 0° and 360° (in degrees measure) or between 0h and 24h (in hours measure). The stars that have position inside one hours circle have the identical direct ascension.

B. Mobile device sensor's data transformation to sky coordinates system

This part of paper describes mathematical transformation of sensor's data to sky coordinates system. To obtain the coordinates of a celestial object on which the user points using camera it is necessary to convert the geographic coordinates of the user in the format of Ra and Dec, so we get the coordinates of the object that user can see by looking directly upwards and then to take into account the angle of the mobile device inclination and the angle between the north and the direction where the user is pointing.

Mathematical apparatus is simple, but requires a large amount of calculations. When converting it is necessary to consider that the system is a spherical celestial coordinates system and depends on the rotation of the Earth around the Sun and around its axis.

Firstly it is necessary to convert coordinates of user location to declination δ. Calculation of δ coordinate is not a problem and can be done by using following formula:

$$\delta = n° \ nn' \ nnn'' \ N \quad or \quad \delta = -n° \ nn' \ nnn'' \ S$$

At the second step we have to calculate direct ascension (α or Ra):

$$\alpha(t) = \alpha g(t) + \lambda,$$

$$\lambda = \begin{cases} w^o \ ww' \ www'' & W \\ 360^o - w^o \ ww' \ www'' & E \end{cases}$$

where $\alpha(t)$ – angle between x-axis and longitude of user's location (it is direct ascension); t – time of measurement (current time); in fact $\alpha(t)$ is a function of time; $\alpha g(t)$ – GST (Greenwich Mean Sidereal Time or GMST); λ – user's longitude.

$\alpha_g(\Delta t) = \alpha_g(0^h) + \omega^* \ \Delta t$, where
$\alpha_g(0^h)$ – time for 0^h of certain data,
ω – speed of rotating the Earth, $\omega = 7.29211510 \times 10^{-5}$ radian/s
Δt – UTC-time
$\alpha_g(0^h) = 24110^s.54841 + 8640184^s.812866 \ T_u + 0^s.093104 \ T_u^2 - 6.2 \times 10^{-6} \ T_u^3$
$T_u = d_u/36525$, d_u – number of days since JD 2451545.0 (1 January 2000, 12h UT1)

Then we have to take into consideration angle of mobile device inclination and direction.

β – angle between direction on the north and direction on which user shown.

γ – angle between direction on which user shows and Earth plane.

Let's accept that α' and δ' – direct ascension and declination with taking into account data from compass sensor and accelerometer.

$\delta' = \arcsin(\sin \delta \sin \gamma + \cos \delta \cos \gamma \sin \beta)$ $\quad$ *new declination*

$$\alpha^+ = \arcsin \frac{\sin \beta \cos \gamma}{\cos \delta'}$$

1. $0 < \alpha \le 90^o$

$$\alpha' = \begin{cases} \alpha + \alpha^+, & 0 < \beta \le 180^o \\ \alpha - \alpha^+, & 180^0 < \beta \le 360^o, \alpha^+ \le \alpha \\ 2\pi + \alpha - \alpha^+, & 180^0 < \beta \le 360^o, \alpha^+ > \alpha \end{cases}$$

2. $90^o < \alpha \le 180^o$

$$\alpha' = \begin{cases} \alpha + \alpha^+, & 0 < \beta \le 180^o \\ \alpha - \alpha^+, & 180^0 < \beta \le 360^o \end{cases}$$

3. $180^o < \alpha \le 270^o$

$$\alpha' = \begin{cases} \alpha + \alpha^+, & 0 < \beta \le 180^o \\ \alpha - \alpha^+, & 180^0 < \beta \le 360^o \end{cases}$$

4. $270^o < \alpha \le 360^o$

$$\alpha' = \begin{cases} \alpha + \alpha^+ - 2\pi, & 0 < \beta \le 180^o, \alpha^+ > 360^o - \alpha \\ \alpha + \alpha^+, & 180^0 < \beta \le 360^o, \alpha^+ \le 360^o - \alpha \\ \alpha - \alpha^+, & 180^0 < \beta \le 360^o \end{cases}$$

Thus we get the formulas for converting data from the sensors to the system of celestial coordinates. A more detailed proof can be found at [5].

IV. REALISATION PART OF SERVICE

This section describes realization of service which has been divided into several stages. Firstly the interface of application has been developed then we divide the process of service development into three demo applications identified by three key problems. After this demo will be completed it will be possible to combine them to the generic demo application, which will realize all requirements to service. For demo development we use Qt for Symbian.

A. Design of interface

At the figure 6-8 the prototype interface of application is presented. When application starts running user see the menu, where he can choose mode of application work and also adjust settings. If user press "Starpedia" then application starts to determine user's geographical coordinates by means of GPS or by GSM. User also can not wait coordinates definition and input his coordinates manually. After coordinates are defined application starts to upload scheme of stars available in given time and location.

Figure 6. The prototype interface of starpedia mode

At stars-identifier mode user points at the area of the sky and get corresponding scheme of stars.

Virtual Telescope mode is similar to stars-identifier mode, but user gets real images of sky objects, which are downloaded from free internet databases with astronomical content.

B. 1st demo: Obtaining coordinates of star-dots for the given sky area

This demo oriented to downloading scheme of stars by coordinates of sky object. A user input coordinates of the center of area of the star sky and get corresponding scheme of stars. For these

we use Internet astronomical catalogue database, e.g. for this demo we used database ESO HST Guide Star Catalogue [9]. We select this ESO database because it allows getting scheme of stars by simple URL-requests and also allows getting information about constellations.

An example request has the following format [11]. This web-database returns results in the following format:

```
nr   gsc_id      ra (2000) dec  mag   mu      d'   pa
 1  0083200882 10 00 14.46 +10 01 28.3 10.75 F;  3.85  68
 2  0082900746 09 59 33.12 +09 57 16.1 11.13 F;  7.16 248
 3  0083200848 09 59 24.71 +10 02 51.8 11.17 F;  9.15 288
 4  0082900060 10 00 14.29 +09 55 50.7 12.02 F;  5.45 140
```

After the requested data is obtained we parse it using special class Star, which we introduced for executing tasks related to the Virtual Telescope application content management. One of the class functions is drawing on the mobile device screen star-dots, based on the retrieved data, where based on the table data each star-dot get own size and brightness.

C. 2nd demo: Obtaining picture of stars for the given sky coordinates

Second demo is similar to first demo, but user get access to real images of interested area of the sky. For the second demo we selected SDSS telescope service database [10], which is also free, has simple interface and contains a lot of high quality images of the stars.

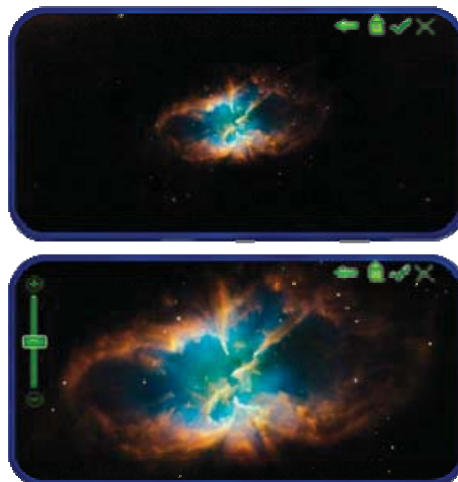Figure 7. The prototype interface of stars-identifier mode

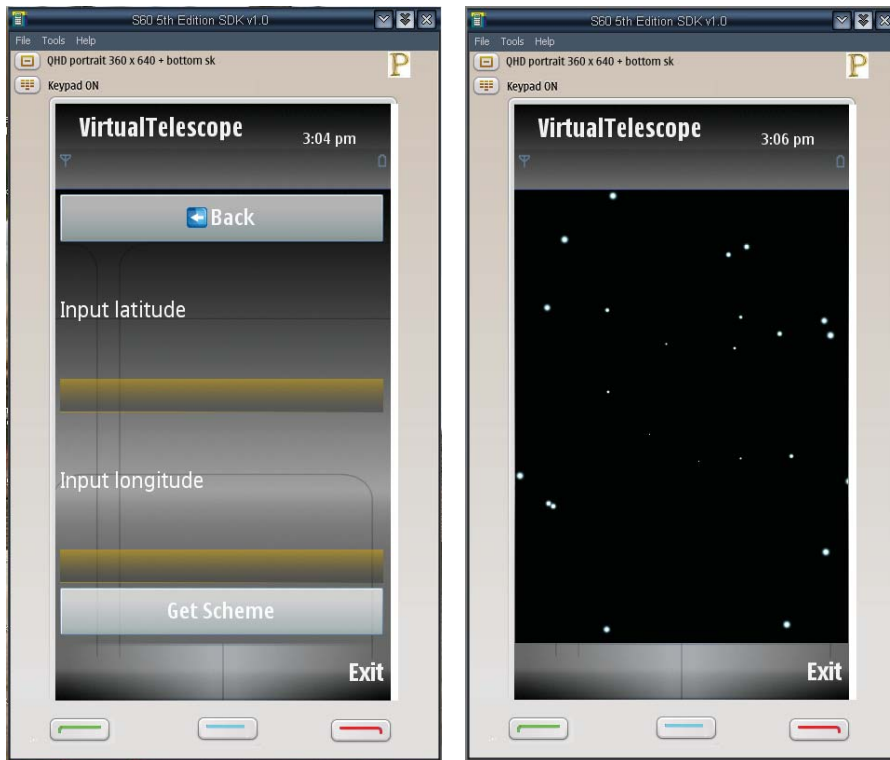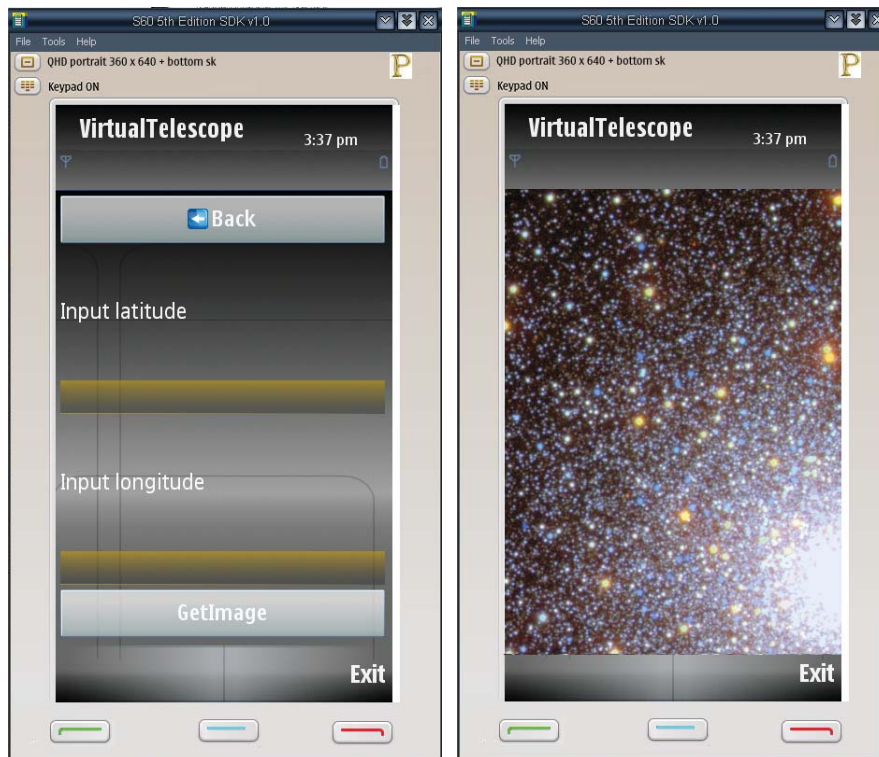Figure 8. The prototype interface of virtual telescope mode

Figure 9. First demo

Figure 10. Second demo

D. 3rd demo: Translating sensors data into the sky coordinates

The third demo gets exact direction to which user is pointing by the mobile device and translates information of the mobile device sensors into the sky coordinates. It consists of the accelerometer and compass direction recognizers. The embedded accelerometer sensor has 3 axes for down, forward and side moves. By combining data from these axes we get vector of the

device acceleration in the 3D space, but without direction, as there is no difference in gravitation if the phone is oriented to the north or south. To resolve this problem we use compass. Then the obtained raw data is converted to Ra and Dec format acceptable by the above listed star databases.

Third demo is under developing now. We use QtMobility [7] project to get access to mobile device sensor's data. For accelerometer and magnetometer we use Sensors API and for GPS we use Location API. For example, class QGeoPositionInfoSource and QGeoSatelliteInfoSource.

After all three demo will have be developed it will be possible to union this to one application.

V. CONCLUSION

The paper describes our approach and current progress of development the Virtual Telescope service. Now requirements for application, application architecture and the mathematical part of the application are developed, the first and second demos are ready and the project is in the stage of third demo is under development.

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