Virtual Telescope Services for Mobile Devices

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Abstract

Fast development of the mobile technologies allows creating new services, which help people to address different demands in all spheres of their life. Good examples of such fast growing areas are geo-positioning and navigation services. Humans were always inspired by the stars and a new class of astronomy-oriented services might be very well taken by the users. Nowadays there is a few Internet services that address this area, but having this service on the mobile device will provide user with completely new experience.

One of the most interesting for research group of services is group which address to services which combine reality and virtual reality. The paper discusses one of those services for mobile devices. The main idea of our service is to allow users to get information of different sky objects (planets, constellations and others) without special astronomical equipment but just by means of mobile device. In particular we propose the new astronomical service that turns mobile device into handheld guide of the stars sky and even to the personal telescope. The proposed service can be used in different areas of human life, e.g. from professional training of pilots and educational courses for school students that can be organized in the most comfortable and "cool" form, to just fulfilling user's curiosity about stars and space or even for fun.

The paper describes architecture for the virtual telescope group of services and defines functionality of each key module. We include description of mathematical part of service and describe main principal formulas for data transforming. As a result we propose full-functional service and this paper discuss the prototype of virtual telescope made on the WRT technology. The paper is concluded by the discussion on the potential and perspectives of the proposed services and presentation of the implementation plans. The project is done within scope of FRUCT program and it basic principles were presented at the Symbian essay completion 2009. Also we will present the progress report of this project on 6th FRUCT seminar.

Index Terms: virtual telescope, mobile service, stars guide, teaching astronomy.

I. INTRODUCTION

For centuries humans observe the stars, which created one of the longest outstanding demands - to learn more about our universe. Some Internet services are trying to address this demand, however studying the stars sky from indoors is not as useful and "cool" as if this service would be available when user is outdoors and watching the stars. This paper gives an overview of a project running within frame of FRUCT program [1], which defines the new group of services and related Symbian application for mobile device. The ultimate goal of this project is to provide functionality of the virtual telescope combined with the stars guide, linked to the corresponding books of ancient legends and other resources to maximize user experience from watch the sky, and later this service can be even extended with the virtual photography of the starts, which will maximize use of the available hardware and Internet access.

Nowadays one can find a number of different astronomic services in Internet. A well known example is Google Sky service [2]. But these services don't have versions for mobile devices. Another good example is the Starmap application [3] that is a stargazing companion for iPhone or iPod Touch. It allows users to find constellations, planets and shooting star zones. The authors claim that it is a complete hand-based planetarium for beginners and advanced astronomers, it includes information about 120,000 visible stars, 200 main stars with names, kind and spectrum and 150 galaxies and nebulae. However this application is just an encyclopedia of stars and doesn't provide user with the telescope experience, as well as other of the above listed services, i.e. database of ancient legends for the constellations, etc.

Analysis of the available prior art has shown that currently there is no solution to use mobile device for zooming and taking photos of the certain areas of stars sky. The project target is even more ambitious - how the mobile phone can emulate behavior of the telescope and deliver corresponding experience to the user. The proposed virtual telescope service is targeted in providing a number of additional services and improvements of the observation quality comparing to the classical astronomical telescope. Anyone who gazed through the eyepiece of an astronomical telescope knows that except for the Moon and planets, extra-solar astronomical objects are hard to observe. This is mainly due to low surface brightness, but also depends on the seeing, sky brightness and telescope aperture. The augmented astronomical telescope [4] proposes a system which projects images of astronomical objects (nebulae and galaxies), animations or additional information directly into the eyepiece of an astronomical telescope. As the telescope orientation is tracked continuously, the projected image is adapted in real-time to the object that is currently visible through the eyepiece. The service is deployed in public observatories and let visitors to experience the richness of deep sky objects while directly gazing at them through a telescope. This is an interesting example of how professional telescope data can be delivered to the mass users. But the proposed approach is not scalable enough to be used for mobile device based solution as we cannot allocate personal telescope for every user. Also the service control mechanism and UI are not applicable for the mobile device. Also we want to mention paper "Look beneath the surface with augmented reality" [5], which talks about mapping virtual objects to the real-time captured video.

The paper is organized as follows. The second chapter discusses idea and provides description of the proposed service. In the third chapter we discuss the implementation details of the service and especially focus on the overall service architecture, service control, organization of content delivery and the user experience. The next chapter initiates discussion around the topic of new services that open new horizons of the user experience by presenting to the user a combination of the real and virtual worlds information. And the paper is concluded by the summary of main results, presentation of the future plans, acknowledgments and the list of references.

II. DESCRIPTION OF THE SERVICE

The first service *starpedia* provides user with a scheme of stars in the sky that are observable in the given time and location. By default the service takes local time and location of the mobile device. An important feature of starpedia is orientation of the stars scheme inline with the current orientation of the mobile device, so that it would be really easy for the user to map visible stars to the constellations and stars at the scheme. By pointing by joystick to the internal area of constellation on the screen, the user gets information about its main stars and other related references, e.g. Ancient Greek myth, etc. This information can be stored locally (e.g. for the best visible constellations) or obtained from the backend service or even by direct request to corresponding Internet resource. By pointing to particular star on the scheme user gets all main facts about it, including name, brightness, distance, and so on.

The next service is *stars-identifier*. The user experience is that the user gets the starpedia page that corresponds to the area of the sky to which the device camera is pointing in the given moment of time. The motion and compass sensors should allow quite accurately define direction and angle of the camera pointing to the sky. The interesting research question is how to use camera together with orientation sensors of the mobile device for increasing accuracy of defining area of the stars sky observed by the user? One idea on how to address this question was found in the patent application "Optical see-through augmented reality modified-scale display" [6]. Without going to implementation details, which are outside of scope of this paper, the main conclusion is that implementation of such synchronization scheme would require a lot of efforts, but it should be possible for nowadays Symbian mobile devices.

The next service is *virtual telescope*. In starpedia or stars-identifier modes the user can press "zoom" and for the selected area of stars sky the service will find and download the corresponding photos from the selected content providers, e.g. NASA, RosKosmos, etc. As a result, the user gets access to the best astronomic content (photos of galaxies, planets and moons in high resolution, etc.) that will be not just nice looking pictures but the real pictures of objects that user want to see better. For example, using this service the user can study craters and surface of the Moon, see other planets and their moons and so on.

Later also commercial services can be introduced, e.g. *request for actual picture*. Most people realize that almost there are no visible changes of the stars sky during our life period, so the archive pictures and current pictures are almost the same, especially taking in account resolution of the mobile device screen. But driven by romantics and personalization reasons, many users still want to get actual pictures of the sky and ready to even pay for it if price of this service will reasonable low (within range of 1USD per picture). For example, some people have mentioned that it is very romantic and good memory if they would be able to "take" high quality actual pictures of their horoscope constellations on the first or last day of the holidays. For this service we need to build a network of astronomical telescopes with photography capability. The network can consist of various telescopes, from semi-professional telescopes in personal use and small commercial planetariums, and up to professional observatories. In the beginning the network will primary consists of semi-professional telescopes working for a share of the service income. For this telescopes we need to develop mechanics for automatic control of the telescope positioning and photography, so that the telescope owner would switch telescope into "automatic service mode" at any time when doesn't need it. The mechanics can be built based on principle of the telescope control mechanics proposed in [4]. The mobile device makes request for a picture of a given sector of the sky and along with the user coordinates send it to the closes telescope of the service network. The telescope software calculates sky zone of interest depending on the telescope and user locations and gives the corresponding positioning command to the telescope mechanics, makes photo and send it to the user. In case of multiple requests, the positioning system builds an optimal positioning chain to minimize physical movement of the telescope, but also guaranty that all requests will be served within X minutes.

III. IMPLEMENTATION

The services can be implemented as standalone applications or as extensions of the existing positioning services, e.g. Nokia Maps. The first demo of the service is targeted for nowadays available devices. The implementation work is just started and it is obvious that implementation of the above listed services will require extensive use of the device sensors, search engine for finding relevant content in Internet, and even development of the image recognition algorithm for the device camera to recognize as many star-dots as possible. In fact all needed information is available, but putting it together is a big, challenging and very interesting research and development work.

A. The Service Architecture

The services functionality is distributed between the mobile device client and backend server, and it relies on use of the public free astronomical databases available in the Internet. The high-level definition of the Virtual Telescope service architecture is illustrated by Figure 1 and below the figure we provide a list of the main service components and their functionality.

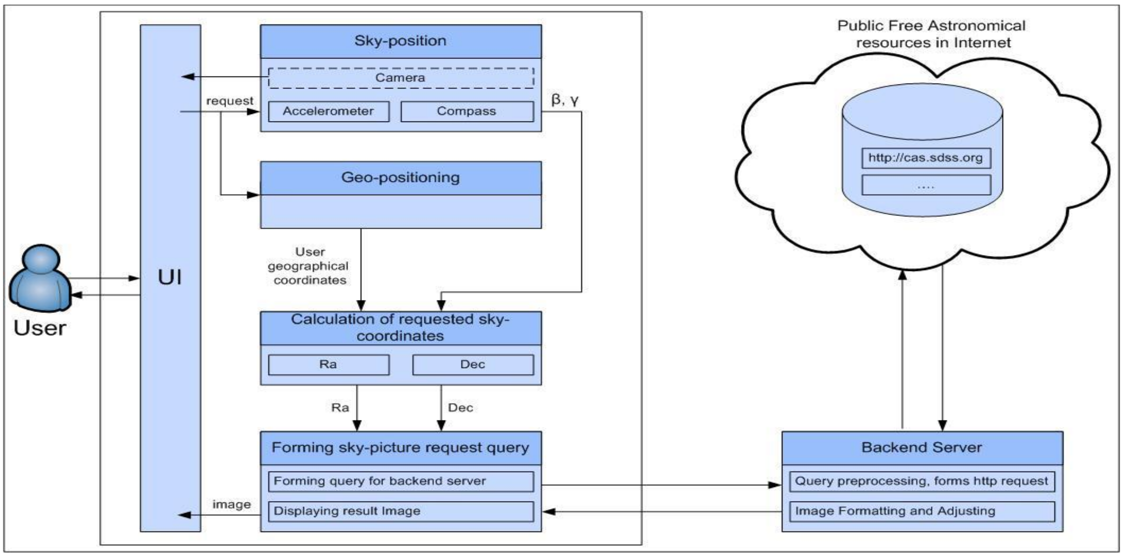

Figure 1: The Virtual Telescope service architecture for mobile devices.

1. *User Interface* (UI) provides cozy interface for user's interaction with the service and the virtual telescope experience, and implements functions for user control of the service and results representation.
2. *Sky-position* module defines area of the sky to which the user is pointing. It consists of the *accelerometer and compass* direction recognizers and optional *camera* module. 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 can use compass that is also available for a number of devices, e.g. the navigator phone (Nokia 6710, 6210, etc.).

   Camera is optional module that refines the telescope direction by recognizing maximum of the camera visible starts (doesn't work with current lens quality) and comparing it to the stars sky pattern.
3. *GEO-positioning* module defines user's geographical coordinates by using GPS sensor or from the serving base station, as even maximum radius of 50 km gives good enough accuracy for the service. The user location is obtained in following format: *n° nn' nnn" N or S* and *w° ww' www" W or E*.
4. *Calculation of requested Sky-coordinates* module gets data from the accelerometer (x, y and z coordinates) and GEO-positioning module and builds the target sky coordinates in form of Ra and Dec.
5. *Forming Sky-picture request query module*

   The main functions of this module:

- Forms a request to the backend server
- Receives the result images and prepare them for output to the user

6. *Back-end server*

In the beginning the backend server will be relatively simple module that makes requests for the images and performs adjustment of the resulting images to the mobile device. We have identified and are planning to use a number of Internet resources where astronomical data is available for free download.

B. Service Control and User Experience

When the target zone is defined, the service makes corresponding request to the backend server that makes further search of the appropriate information on web and returns stars shot as shown in Figure 2.

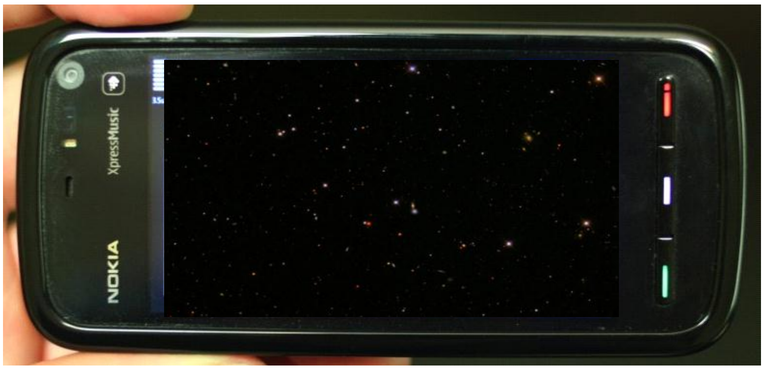

Figure 2: UI with starts sky view in the Virtual Telescope service.

In the beginning the backend server will be relatively simple module that makes requests for the images and performs adjustment of the resulting images to the mobile device. We have identified and are planning to use a number of Internet resources where astronomical data is available for free download.

IV. Mathematical definition of the service processing unit

This chapter describes how to transform data collected by the various sensors of the mobile device to get coordinates of a sky object to which user is pointing in the given time and location. This consists of the following main steps:

- definition of the output parameters from each service module;
- data transformation to the coordinates in format Ra and Dec;
- taking into consideration angle of mobile device inclination.

A. *Definition of output parameters from each service module*

From Sky-positioning module:

β – angle between direction to which the user is pointing and the north pole.

γ – angle between direction to which the user is pointing and the horizontal.

From Geo-positioning module we get user geographical coordinates. As a result, the user location is obtained in following format:

n° nn’ nnn” N or S

w° ww' www" W or E

Together this data allows defining in what point on Earth the user is located at the given moment of time and to what part of sky he/she is pointing.

B. *DATA TRANSFORMATION TO THE COORDINATES IN FORMAT RA AND DEC*

First it is necessary to convert coordinates of user location to declination δ(Dec). For simplification of the task let's assume that the Earth is ideal sphere. Calculation of δ coordinate is not a big problem and can be done using principle illustrated by Figure 2.

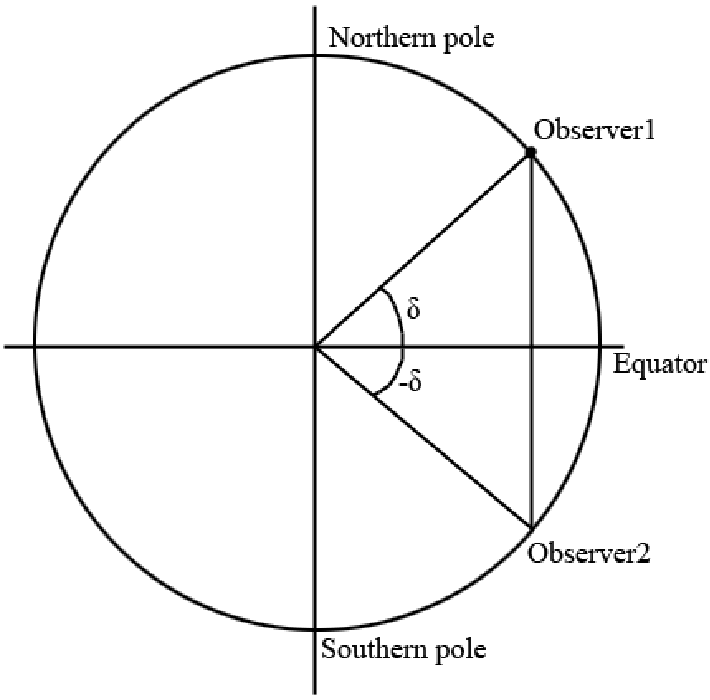

Figure 2. Definition of declination.

This picture shows a lateral cut of the Earth. For the user at the latitude δ in the north hemisphere, the declination is equal to his/her north latitude, and if user is located in the south hemisphere the declination is equal to the south latitude taken with the negative sign.

δ = n° nn' nnn" N or δ = -n° nn' nnn" S

The above illustrates calculation of the direct ascension α (Ra). Because the Earth is rotating in plane of x-y coordinates, the direct ascension is also depends on time. If we know angle between longitude and the x-axis (x-axis is directed towards the point of spring equinox) it is possible to define coordinates of direct ascension depending of the time. Let's now make the following definitions:

α(t) – angle between x-axis and longitude of user's location (it is direct ascension α or Ra);

t – time of measurement (current time), where in fact α(t) is a function of time;

$\alpha_g(t)$ – GST (Greenwich Mean Sidereal Time or GMST);

λ – the current longitude of the user.

Figure 4 illustrates Earth cut by the plane parallel to equator and going through the point in which user is located.

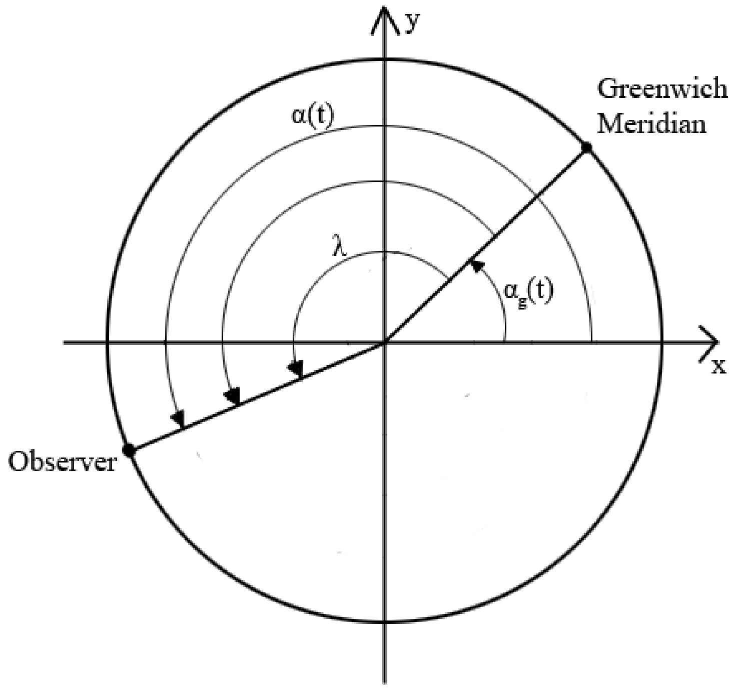

Figure 3. Definition of direct ascension.

$$\alpha(t) = \alpha g(t) + \lambda, \text{ where}$$

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

The local sidereal time is calculated based on the sum of GMST and the user longitude. Definition of function αg(t) can be found in different books, e.g. in US Naval Observatory's Astronomical Almanac [7].

$$\alpha g(\Delta t) = \alpha g(0^h) + \omega^* \Delta t, \text{ where}$$

$\alpha g(0^h)$ – 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)

Thus we get Ra and Dec coordinates of the current user location.

C. *TAKING INTO CONSIDERATION ANGLE OF MOBILE DEVICE INCLINATION*

Let's consider that δ' – new declination and α' – new direct ascension. These are the coordinates of a sky zone to which the camera of user's mobile device is pointing.

By means of some transformation of coordinates we get new declination and new direct ascension.

Depends on what direction user shows it is necessary to make transformation of angle β.

$$\angle\beta = \begin{cases} \beta, & 0^o < \beta \le 90^o \\ 180^o - \beta, & 90^o < \beta \le 180^o \\ \beta - 180^o, & 180^o < \beta \le 270^o \\ 360^o - \beta, & 270^0 < \beta \le 360^o \end{cases}$$

Based on that, Figure 4 illustrates how the result transformation can be made.

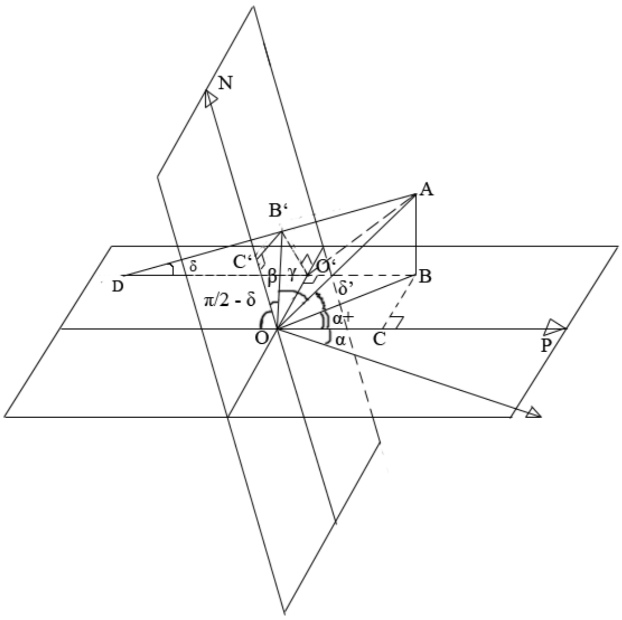

Figure 4. Transformation of coordinates

As a result we get the following formulas for calculating new declination and new direct ascension:

$$\delta' = \arcsin(\sin\delta\sin\gamma + \cos\delta\cos\gamma\sin[\beta)]$$

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

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

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

The service development work is still in wrapping up phase and a lot of research and implementation work is still to be done. For example, current definition of the service requires all-time connection to the network, as only very limited data cashing can be made for the mobile device. To reduce the corresponding expenses and allow efficient cashing we need to propose a methodology for predicting user behavior. Another research question is how to get sharper images and better stars pattern recognition based on data received from the mobile device camera.

This project will become a multiyear student activity. The service should be available for Symbian devices, which are equipped with acceleration and motion sensors, have reasonably good camera and enough local memory to store basic database. As a reference smartphone we are going to use Nokia 6210 Navigator. The first prototype implementation of the service is under development and it will be done using WRT technology [8]. In the future when devices will have better optics and allow better recognition of the star-dots and their brightness, the optional camera sky-positioning module will be implemented to allow faster and more accurate definition of the target area of the sky. If the project work will progress according to the current plan and no new major obstacles will be found, the first prototype demo of the service for Symbian devices is expected by the end of this year.

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