Augmented Astronomical Telescope

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Abstract: Anyone who gazed through the eyepiece of an astronomical telescope knows that except for the Moon and the planets, extra-solar astronomical objects are hard to observe. This is mainly due to their low surface brightness, but also depends on the seeing, sky brightness and telescope aperture. We propose a system which projects *images* of astronomical objects (with focus on *nebulae* and *galaxies*), *animations* or *additional information* directly into the eyepiece view of an astronomical telescope. As the telescope orientation is tracked continuously, the projected image is adapted in real-time to the object which is currently visible through the eyepiece. This way, visitors to public observatories have the possibility to experience the richness of deep sky objects while directly gazing at them through a telescope.

Keywords: Astronomy, Augmented Reality, Projection, Tracking

1 Introduction

Since its beginning mankind has always been fascinated by the starry sky. It is one of the first natural phenomena which has been investigated by humans. An observer starts by learning the constellations on the sky and their relative position, stargazing with the "naked eye". More advanced amateur astronomers make use of *binoculars* and *telescopes* with which many more objects can be observed.

Goto (motorized) telescopes become more popular these days. Many newcomers purchase one as their first telescope. These telescopes allow finding a desired object on the sky, just by selecting it from a hand controller. The user then expects for an "instant success" in the observations. This surely happens when "easy to observe", bright objects as the *Moon* or *the planets* are the targets. However, when observing faint *deep sky objects* (astronomical object which lies outside our solar system) like galaxies or nebulae, much of the initial enthusiasm is lost. These appear as fuzzy grey spots in the telescope's eyepiece and leave the observer quite unimpressed, possibly thinking about giving up his new hobby. The main reason is that the image in the eyepiece is not really similar to the well known images recorded by the Hubble Space Telescope (or some other large aperture earth-bound telescopes) which are familiar to the newcomer through astronomy websites or magazines.

We propose a system which augments the view through the eyepiece of an astronomical telescope in order to provide additional online information to the user during observation. The system overlays the currently visible object with a long exposure image of it, as a visual help. The current orientation of the telescope is permanently tracked and the currently visible sky section is computed in real time by a portable computer. There is also the possibility of blending in animations for specific objects.

In the following section we present an overview of the related work in the field of tracking and registration augmented reality applications. After giving a motivation for the use of the proposed system in Sec. 3, we provide a detailed system description in Sec. 4. We conclude and point out possible future work in Sec. 5.

2 Related Work

In the optical industry there are several patents on related applications. Beamon [Bea90] proposes a system where a stereo image is projected on two small displays situated in front of the user's eye. Ellenby et al. [EEE97] describe a basic system for augmenting real images of a scene based on the tracked orientation of the user. A technique to enhance the contrast between the projected virtual image and the visible background by first projecting a darkened mask is introduced by Melville [Mel99]. All previously mentioned patents are neither designed for night vision nor provide a comprehensive database of the visible objects.

The system developed by researchers at the Fraunhofer IGD [Str05, ZSB05] uses a *video see through* approach. This work focuses on boosting the performance of a coin-operated telescope by equipping it with a display, a standard PC, a hardware tracking device and a camera. Thus the system can be used to augment views of the attraction sites where the telescope is installed. Reeves et al. [RFS+05] depict another example of a video see through application where the visitors of an exhibition use it to gather additional information about some of the presented objects. For both applications, the optical assembly of the telescope has no real use. It is replaced by a video camera with a telephoto lens. As opposed to that, in our application the optical assembly of the telescope is of major importance, its main function of *light gathering* is kept. The hereby proposed system is an *optical see through* application thus the genuine visual impression given by the observed objects is maintained.

3 Motivation

The main motivation of our work is to increase the interest of the general public in astronomy. Visitors of public observing sessions, who look through a telescope for the first time are left often quite unimpressed by the view of a certain galaxy or nebula. They are all familiar with the colorful photographs of such objects from astronomy magazines or the Internet. The human eye has a limited capability of integrating the captured light over time thus faint deep sky objects can only be vaguely perceived. The observer does also not know when looking at a faint object how it's structure looks like. Our system gives the observer the possibility to compare online the visually perceived object with a photograph acquired using long exposure. Additional information and animations related to the object can also be blended into the eyepiece view. We mention that the proposed system is not meant to replace traditional visual deep sky observing, it is more thought as an *educational* and *visual* help for the beginner.

4 System Description

4.1 Overview

The system we propose aims at augmenting the view of the skies through an astronomical telescope. The hardware part consists of a *telescope* fitted with a goto mounting, a custom built *projection unit* and a *portable PC*. The software part consists of the customized *planetarium software* and the integrated *telescope communication module* (See Fig. 2).

The working principle of the system is the following: the telescope is pointed to the desired astronomical object by selecting it from the provided hand controller unit. The actual telescope position is constantly queried by the telescope communication module. Using the current coordinates, the planetarium software focuses directly on the corresponding sky section which is directly projected onto the telelescope's image plane by the projection module.

The planetarium software includes a database of the most interesting deep space objects, providing for each high resolution photographs, additional information and 3D animations (when available). The user can customize the exact information displayed for each object. There is also the possibility to switch between the various eyepieces i.e. magnifications during observation. Using our approach we can provide more information about the existing astronomical objects in the database than there is available in the standard telescope hand controller. The telescope used in our application is a 10" aperture, Meade LX200 GPS, Schmidt Cassegrain model (See Fig. 3), equipped with a goto mounting, but the working principle of the system can be applied to any telescope fitted with goto mounting. Fig. 1, Left shows a possible image perceived by an observer when looking through the telescope's eyepiece at the Andromeda Galaxy (M31). Fig. 1, Right presents the same sky section, after the long exposure photograph and additional information have been projected onto the telescope's image plane. The diagram in Fig. 2 highlights the components of the proposed system and their interconnections. Another important aspect of our system is to try maintaining the *dark adaptation* of the observer when projecting the additional information into the telescope's field of view. For this reason the projection module is equipped with a knob permitting permanent brightness adjustment.

Relative to tracking accuracy various elements have to be taken into consideration. When the telescope is slewing with maximum speed from it's current position to the next object to be viewed, tracking accuracy is not actually important because no observations can be made. However, during sidereal (the speed the earth rotates around it's axis) tracking of an observed object, accuracy is of major importance. The actual position indication of the telescope's

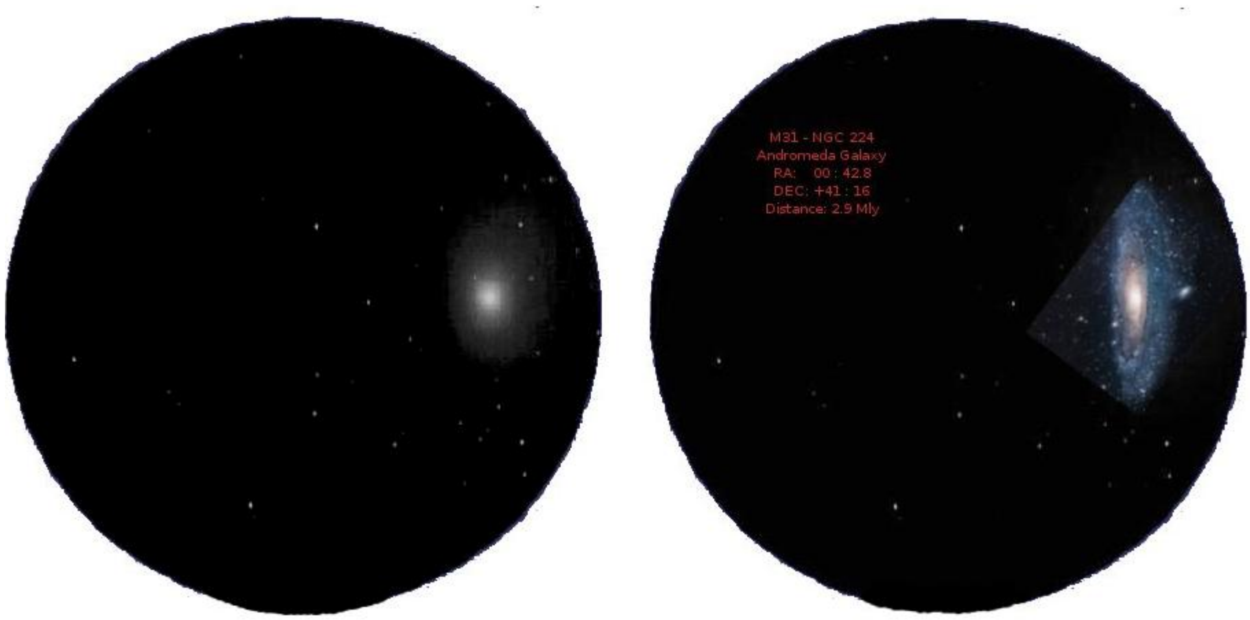

Figure 1: Left: Standard Eyepiece View. The image shows a possible view of the Andromeda Galaxy (M31) through an eyepiece, as perceived by an observer. Available From: http://members.aol.com/KDaly10475/m31.html Right: Augmented Eyepiece View. A view of the same object with the overlayed image visible and additional information blended into the upper left corner.

mounting (approximately once per second) could be precise enough, but there is also an inaccuracy in the mounting's gears. The overall accuracy can be improved by implementing a Kalman filter to cope with the imprecision of the telescope position readings. As a further improvement on accuracy there is the possibility to attach a highly sensitive CCD camera to the telescope for guiding (as shown in Fig. 2). The guiding principle consists of detecting a relatively bright star situated near the observed object, and track it's position in all the following frames provided by the camera. If the star's position changes in one of the frames, a command for a corresponding correction movement is sent to the telescope mounting.

4.2 Customized Planetarium Software

As basis for our custom planetarium software we use the open source software *Stellarium* [Ché05]. It has an easily customizable user interface and new custom objects can be simply added. There is no telescope communication support, so it was extended it by implementing the Meade Telescope Control Protocol [Mea02].

To dispose of an acceptable number of nebulae and galaxies of interest accessible, we added to the existing list the objects from the *Appendix E* of [Cla90], available also online from [Cla02]. This list includes 611 deep sky objects, which as Clark states are "the most interesting for amateur astronomers". All additional information about the objects have been downloaded from the NGC-IC project webpage [Cor05]. We set the same coordinates

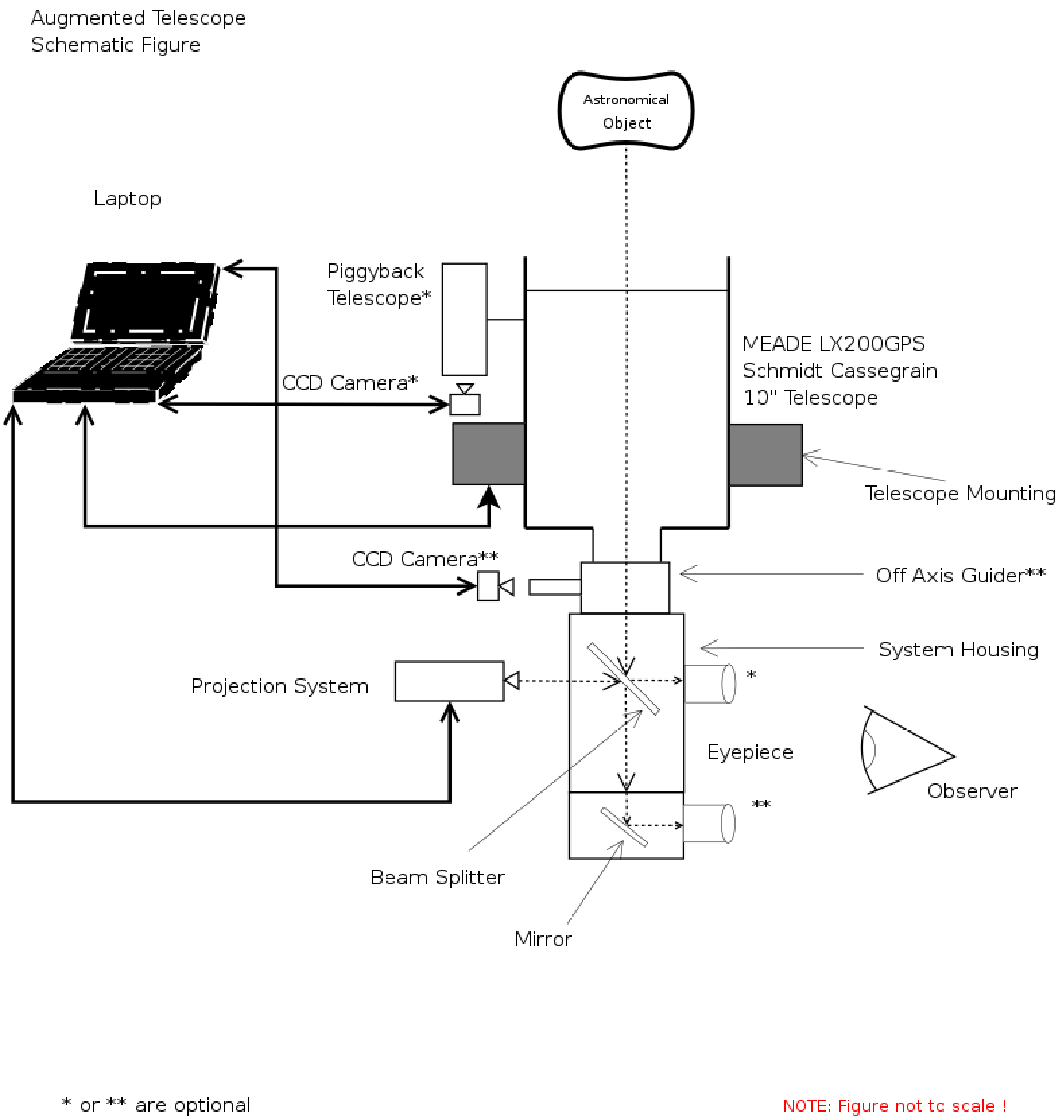

Figure 2: Schematic description of the entire system. As an option to improve the tracking accuracy, a special purpose, high sensitivity CCD camera can be added. It is mounted together with a smaller piggyback telescope or directly on the optical axis of the telescope using an off axis guider.

for the objects in our database and the corresponding objects from the telescope's hand controller, to make sure no positioning errors due to different coordinates can occur.

One of the main attributes of an astronomical telescope is that using *eyepieces* of different focal length, one can achieve various magnifications. Therefore a perquisite for the correct functioning of the system is to specify the currently used eyepiece. A snapshot from the customized planetarium software is presented in Fig. 4. On the right side the observer can select from a menu the currently used eyepiece or an animation related to the observed object

Figure 3: Left: The Meade LX200 GPS 10" Astronomical Telescope used in the application. Available From: www.sherwoods-photo.com/meade_scopes/lx200gps.htm Right: The hand controller provided with the telescope. Available From: www.meade.com/autostar/images/autostarII.gif

can be played. In the upper left corner basic information about the currently observed object is visible. The information in the lower left corner provides the currently used eyepiece and it's corresponding magnification. The long exposure photograph of the object is placed centered and with correct orientation in the frame.

4.2.1 Input Device

Nowadays almost every amateur astronomer has a portable PC available during observation. It is usually used for astro-photography means or as an optional control unit for pointing the telescope. The high luminance value of the computer's display (even if dimmable) can result in partially loosing the observer's dark adaptation. There is also much time lost by constantly switching between the PC keyboard / mouse and the telescope's hand controller. Based on the above mentioned facts, it is desirable that the user is able to control the telescope and the whole augmented reality system by the means of the already provided hand controller (See Fig. 3, Right). The control of the application's few and simple menus can easily be solved with some of the available hand controller keys.

Figure 4: Screenshot from the planetarium software used as a basis for the projection engine. In the upper left corner basic information about the observed object is displayed. On the right side the menu for specifying the used eyepiece is visible. In the lower left corner the selected eyepiece and corresponding magnification are displayed. The photograph of the object is displayed centered and with the correct orientation.

4.3 Additional Information

To help the user navigate through the sky we blend various additional information about the observed objects directly into the eyepiece view. Basic information as *position* (Right Ascension and Declination), *overall brightness*, *surface brightness* and the *name* of the observed object are overlayed. Further useful information as the object's type and classification, the page where it can be found in several widely used sky atlases, absolute magnitude or the constellation where it is found can also be customized to be directly blended in the telescope's image plane.

As a visual observing help, there is an option of blending over the observed optical image a long exposure astro-photo of the same object. Another option is to blend animations of nebulae or galaxies which have an already reconstructed 3D geometry [MKHD04]. With the proposed system, useful informations about *practically viable* magnifications for the target object can also be directly blended in the user's field of view, thus improving the visual perception of the visible object.

4.4 Projection System

There are several criteria which have been taken into account for the development and design of the projection module. It's size and weight have to be minimized, to keep the freedom of movement of the telescope and to maintain it's weight balance. The projection module also has to have the highest possible contrast ratio, so that the user is still able to discern between black and white levels when projecting at low brightness. Another important requirement is a low brightness for the black value (LCD's tend to emit light also when set to black).After researching the currently available projection technologies, we came to the conclusion that the one best fitting all these requirements is DLP (Digital Light Processing) [TI:04]. A rendering from the 3D model of the designed projection module is presented in Fig. 5.

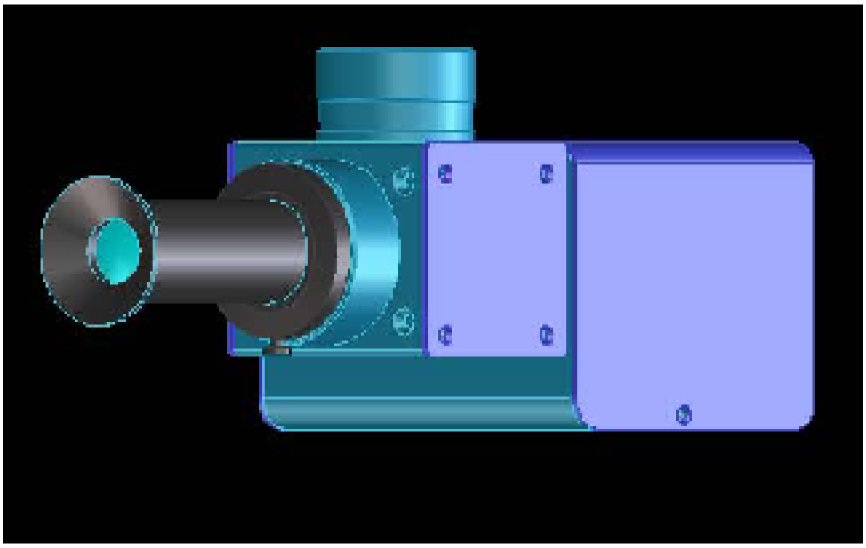

Figure 5: 3D Model of the projection system. It is directly mounted on the telescope's optical axis through the flange on the upper side. The used eyepieces are placed in the provided holder on the left side. The DLP engine and LED head are situated in the box at the right. Image used with the kind permission of OpSys Project Consulting.

The module uses a *DMD* (Digital Mirror Device) of 0,7" diagonal with XGA resolution (1024 x 768) and was developed by OpSys Project Consulting. It features a custom *projection lens* and a special, *color LED projection head*. The maximum luminance is 1,8 cd/m^2 and is dimmable down to 0,03 cd/m^2. The minimum contrast of 500 : 1 is maintained over the complete luminane range varying from the maximum value down to 0,3 cd/m^2 and decreases for lower values.

Because of the different *image ratio's* and *geometric shapes* of the eyepiece view (circle, 1:1 ratio) and the projected image (rectangle, 4:3 ratio), a compromise between the number of pixels from the projected image which are invisible and the surface from the eyepiece image with no projection coverage has to be found. We propose as a solution to the coverage problem the setup presented in Fig.6. It offers a fair tradeoff between the area from the eyepiece view with no projection coverage (small top and bottom area) and the unused pixels of the projected image (four small corner regions).

An important additional control on the unit is a potentiometer knob which allows continuous adjustment of LED brightness. This assures one can keep low luminance values during projection thus maintaining the user's dark adaptation. The unit is powered by a 12 V adapter so that it can be operated together with the telescope also from a standard car battery, when needed.

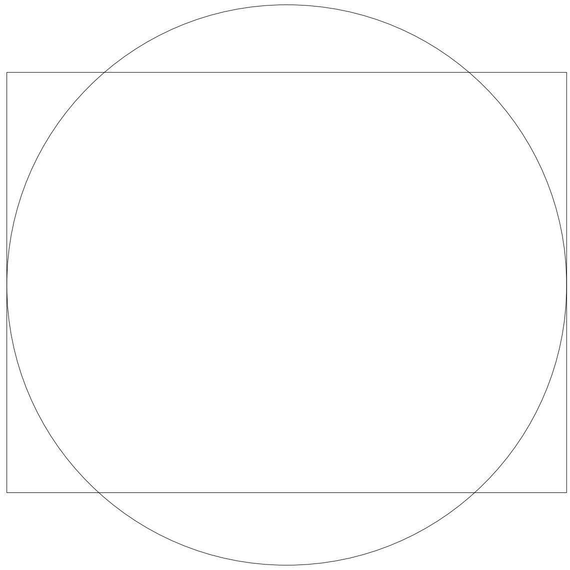

Figure 6: The proposed coverage setup.

5 Conclusions and Future Work

We have presented a system which is capable of augmenting the image visible through the eyepiece of an astronomical telescope. The user can compare the visually observed object directly with images of the same object photographed using a larger aperture telescope and long exposure time. Animations of the observed objects can also be blended directly into the eyepiece view, showing their 3D distribution or their projected evolution in time. Several additional informations regarding the observed object are also blended into the user's field of view.

In a possible future add-on, the complete mapping of the lunar surface can be added to the application, making it possible to integrate a lunar atlas such as the *Virtual Moon Atlas* [LC04]. This can make lunar observing much easier, features on the moon could be identified with ease. The number of deep sky objects available in the planetarium software can also be extended as well as the amount of available animations.

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