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POPULARIZATION OF ASTRONOMY THROUGH ROBOTIC TELESCOPES AND VIRTUAL OBSERVATORIES

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Abstract. Robotic telescopes and virtual observatories have great impact on popularization of astronomy. In this paper we will present several web services and observatories that allow remote control over their equipment, which have great contribution in astronomy promotion. In addition, the first Serbian amateur robotic observatory will be presented (Night Hawk, Bačka Palanka). Finally, an economic review of this concept is done to consider its attainability to the general audience.

1. OVERVIEW

Robotic Observatory (telescope) is defined as an astronomical instrument and detection system which allows the observation without the need for physical intervention of operator. In astronomy, a telescope is considered robotic when observations can be performed without operator intervention on the equipment (even if one has to start and complete a monitoring session on it). Robotic telescopes are complex systems consisting of several subsystems. These subsystems include devices that allow: 1) control of the telescope, 2) control of the detector (usually CCD camera), 3) control of the dome (roof) of observatory, 4) control the telescopes focuser, 5) tracking of celestial objects within a few arc seconds to a few arc minutes, 6) avoiding wrapping the cord around the mount, 7) obtaining special points in the sky, 8) knowledge of the horizontal border movement of the telescope limits, 9) initial "parking" position of telescope, 10) exposure control and control of camera temperature, 11) filter control, 12) storing images and their subsequent processing using the dark frame and flat field, 13) synchronizing movement of the telescope with the sky and so on. Most robotic telescopes are small telescopes. The emergence of the Internet has enabled robotic telescopes to become accessible to a large number of users worldwide. The Internet helps to reduce costs in communicating with users. It also offers the possibility of a wider range of potential users to get to know how to control the telescope. Thanks to the Internet, robotic telescopes are becoming an important element in teaching of astronomy. The Internet also provides an opportunity for communication, data

exchange and verification of observational data obtained by many research teams worldwide. It can be concluded that the Internet in the concept of "Astronomy from the chair" is becoming an important tool for dealing with astronomy.

A virtual observatory (VO) is defined as a set of databases and software that use the Internet as a platform for astronomical research. A virtual observatory operates in a similar way like a real one, which consists of telescopes. The goal is to provide transparent access to data to users worldwide. In this way, scientists can discover, analyse and combine natural phenomena and laboratory data collected in databases. There are website groups that allow amateur astronomers to take advantage of VOs to participate in scientific research. One such example is Zooniverse.

2. VIRTUAL TELESCOPE (www.virtualtelescope.eu)

Virtual Telescope (VT) project started at 2006. It was one of the first projects related to public observations and conferences using modern information and communication technologies. The goal of this project is to provide access of professional astronomical equipment to general audience, which can use it to observe and manipulate data from their home. The equipment is used for research and for amateur astronomy. The system is configured to produce best results on photometry, but can also be used for other purposes. In addition, people without any astronomical experience can use the equipment with the help of technical staff, who are also good science communicators. VT project uses the equipment of Bellatrix observatory which is built in 1997. at Ceccano, central Italy. The observatory has two telescopes (Celestron 14" and PlaneWave 17") and CCD cameras with other components. With this equipment, deep sky objects, binary stars, star clusters, Sun, Moon, planets, asteroids and comets can be observed. The observatory is completely computerized, equipped with 3 computers for image management and editing. The software used are CCD soft, The Sky, Iris, IDL and Astrometrica. Since 2013 it is updated with TheSkyX. The area of the observatory is 14 m^2 and it has removable roof. The founder of this project is Italian astrophysicist Gianluca Masi, who is leader of the project, and the assistant is Gisella Luccone. VT project organizes the following activities: telescope control, public observations and exclusive public observations. During 6 years, 1300000 people from more than 200 countries attended activities within this project. The use of social networks greatly contributed to the success. The Facebook page of the project has more than 4300 members, and besides it, there are 2 more groups with 4900 and 890 members respectively (september 2012).

3. ZOONIVERSE (www.zooniverse.org)

Zooniverse is the largest and the most successful project intended for citizen science. Zooniverse projects are developed and maintained by Citizen Science Alliance. The project started at 2007. with the project GalaxyZoo-Hubble. Beside this one, there are 9 more projects available today: Ancient Lives, Old Weather, Ice hunters, Planet hunters, The Milky Way Project, Moon Zoo, Galaxy Zoo (understanding cosmic mergers), Galaxy Zoo (the hunt for supernovae) and Solar Starmwatch.

For each of projects listed above, a short training in the form of text or animation is available, to allow users successful start of research. They can get detailed information about the particular topic. The motif of this project is to include human factor

Figure 1: VT website

to overcome problems that technology and supercomputers are not able to perform appropriately. For example, detection of extrasolar planets orbiting around distant stars is difficult to perform. Humans are able to recognize these events as well as some unwanted phenomena in order to remove them. We will describe Planet Hunters and Galaxy Zoo - Hubble projects.

3. 1. PLANET HUNTERS (WWW.PLANETHUNTERS.ORG)

Planet Hunters is the latest projects developed within Zooniverse. Participants can get data from Kepler mission (stellar luminosities), create light curves, and analyse them. Based on light curve analysis, users should find traces of possible planet transits. If significant number of such events are reported for the same object, scientists continue to further explore it. So far, more than 4900000 cases have been studied and 34 of them are marked as candidates for extrasolar planet systems.

3. 2. GALAXY ZOO - HUBBLE (WWW.GALAXYZOO.ORG)

Galaxy Zoo - Hubble is the first project under Zooniverse project. Before starting the work, users can take opportunity to inform themselves about the project and the way how they can participate. By answering questions, they help researchers to classify galaxies. First version of this project had 2 tasks: to separate galaxies in spiral and non-spiral, and if they are spiral, to determine the direction of arms. New version has more questions (18), but the number of questions that user actually gets depends on previous answers. During 14 months, since the first version started, more than 60000000 galaxies were classified.

4. NIGHT HAWK (univerzumad.com)

Night Hawk is the first amateur observatory in Serbia which is computerised and robotised. The communication exists in both directions through the Internet. Users can remotely drive the telescope and the images are delivered from the observatory to users. In this way, users have full control as if they were on the spot in the observatory building.

The observatory is open on April 16, 2011. and is located in Bačka Palanka and belongs to AS Univerzum. It is built by Janko Mravik, amateur astronomer,

president of AS Univerzum. It is $6m^2$, 5m wide with the telescope room and working room. The building is covered by the removable and remote controllable roof. The observatory has the following equipment: Telescope (GSO 250/1250 on EQ6 sky scan mount); Main camera (CCD Astropix 1.4, mounted on the telescope); Inner camera (used for monitoring interior (room and the telescope itself)); Outer camera (used for monitoring exterior and the building); Wide-field camera ($60^\circ \times 40^\circ$ of the sky, useful for meteor observations); Meteorological station (monitor weather conditions, in the case of rain, the roof is closed automatically to protect interior); 3 computers (networked and connected to the Internet, used for observations and controlling the observatory).
During 1 year, the observatory discovered 1 variable star and recorded transits of 30 extrasolar planets. All events are confirmed by competent registries. Although it is physically located in Bačka Palanka, the fact that it contains robotised telescope and remote control via the Internet allows the observatory to be used by anyone regardless of geographical location and without need for physical presence.

5. ECONOMIC ANALYSIS

Economic analysis is based on equipment similar to Night Hawk observatory, because it can be easily found on Serbian astronomical equipment market. The goal is to determine the payback period of investment in such observatory. The assumption is that the owner already has the building which does not need further investments. Since the average salary in Serbia is about 350 €, it means that this solution is not accessible for the majority of people. If we consider that equipment for astrophotography costs 3625 € and one observational hour costs 10 €, then for 3625 € a person can book and use a total of 363 telescope hours for his observing sessions. This is especially useful for people who rarely have the opportunity to engage in astrophotography and want above all to observe night sky, which can be done without any financial compensation by attending online public observing sessions which are free (example Virtual Telescope), or using a Astronomylive site (www.astronomylive.com). If we suppose that the owner rents the telescope for 10 €/h, then payback period is given in Table 1.

Table 1: Economic analysis

hours leased per month	total hours leased in 1 year	payback period
30	360	$<$ 2 years
15	130	3 years
10	120	4 years
5	60	7 years

This calculation does not include observatory construction, equipment maintenance, taxes and other expenses, so including them will extend the payback period. Nevertheless, schools do have interest to purchase time in these observatories because this concept provides astronomical observations to the general audience, for an affordable price.