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METEOR OBSERVATIONAL DATA VISUALISATION IN THE EQUATORIAL COORDINATE SYSTEM USING INFORMATION TECHNOLOGY

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ABSTRACT. As a result of dynamic evolution of IT industry and astronomical research in the XXI century, which have resulted in obtaining large and complex data sets known as Big Data (e.g. data from the European Space Agency missions, such as GAIA mission, etc.), as well as due to rapid development of computer technologies, astronomy and computer science have become closely linked to each other. In the XXI century, Information technology has become an essential part of understanding the world around. This paper presents a solution to the problem of meteor data representation in the second equatorial coordinate (RA-Dec) system using Information Technology. Such a visualisation solution is needed to analyse the results of experiments based on the radar observations conducted in 1972-1978 (stage 1 – the data obtained in 1972 comprise 10,247 meteor orbits), which have been accumulated and stored in the Meteor Database of the Kharkiv National University of Radio Electronics (KNURE). A sample set of data with their characteristics and details about their delivery has been presented by (Kashcheyev & Tkachuk, 1980). An electronic calculator application was developed by employing the model of data visualisation in the form of celestial hemispheres using the object-oriented programming language C#.

Keywords: meteors, meteor map, data visualisation, databases, object-oriented programming, C#.

1. Introduction

It is thanks to Information Technology (IT) that scientific and technological capabilities have progressed so markedly in the XXI century (Butler 2012, etc.). The term “Information Technology” in its modern sense dates back to 1958. Information technology (IT) is the application of computers to store, study, retrieve, transmit and manipulate data for multiple various purposes to the advantage of users. This definition encompasses information processing techniques, as well as application of statistical and mathematical methods to decision-making and simulation of higher-order thinking using computer programmes. Information Technology, including internet-based technologies, is considered to be a subset of Information and Communications Technology (ICT). IT is designed to reduce the labour intensity of processes related to the utilisation of information resources. The current fourth phase of IT development is called electronic; it began in 1940. During this stage a gradual transition from procedural to object-oriented programming takes place (Graham 2004). Procedural programming is based on the concept of separating data from the code for their processing; this paradigm did not match the real world that consists of different objects which can be characterised simultaneously by their attributes (data) and behaviour (operations). Logical combination of data and procedures to perform operations on these data is the key concept of the object-oriented programming paradigm, which enabled to overcome the challenges of the procedural programming.

Meanwhile, mankind has entered the epoch of Big Data. For this reason, both the computer science and computer technology had to face fundamentally new challenges. Advances in astronomy over recent 20 years have contributed significantly in delivering a huge amount of data, and the flow of information is only expected to grow with promising new observations (Brescia *et al.*, 2016). In this regard, the Global Astrometric Interferometer for Astrophysics (Gaia) mission of the European Space Agency (ESA), as well as the Large Synoptic Survey Telescope (LSST) and Square Kilometre Array (SKA) projects are worth particular attention. The goals of these projects are very ambitious; for instance, the LSST project is aimed to address profound scientific questions related to four research areas, such as probing dark energy and dark matter, taking an inventory of the Solar System, exploring the optical transient sky, and mapping the Milky Way.

Data centres (databases) and the Virtual Observatory are also important sources of Big Data in modern science (Brescia et al., 2016). A new trend of IT-mediated reasoning from data to the core of the subject has been emerging. There are also some new trends in the field of research methods, such as search for homogeneity in diversity and search for truth in the Information Technology itself as a manifestation of predicates of the Universe. Although these trends are quite typical for the process of learning the whole range of sciences, astronomy proves to be a specific area of knowledge for a variety of reasons, conditions and circumstances. And all above-mentioned trends have been already detected, updated and even recorded in the proceedings of the International Astronomical Union (IAU) scientific convention under No 325. All these issues were discussed by the astronomers and IT experts during the afore-mentioned symposium called Astronomical Informatics held on 19-25 October, 2016, in Sorrento, Italy (Brescia et al., 2016). Among other topical issues, the participants of the symposium discussion stressed the need to combine the efforts of astronomers and programming experts in the field of data visualisation and transformation into analysis tools.

2. The study aim and objectives. Meteor data and processing technology. Results and discussion.

This study was aimed to develop convenient research tools to analyse the data obtained during meteor observations and presented as meteor data sets or databases with the function of meteor map visualisation in the second equatorial coordinate system.

To achieve the study objectives, the following tasks needed to be accomplished:

- taking specific sample sets of data from the KNYRE Meteor Database;
- creating an algorithm of links between the data available and the second equatorial coordinate system factoring in the relevant observation epoch;
- development of the software application "Astronomer's Reference Book – Calculator – Meteor Map" with the meteor map visualisation programmed in C#;
- testing and implementation of the software application "Astronomers' Reference Book" in the study of distribution of meteor radiants in the second equatorial coordinate system for meteoroids in prograde and retrograde orbits selected from the KNURE database.

It was expected that the task accomplishment would result in the practical IT implementation in astronomical meteor surveys through development of convenient virtual calculator with the meteor map visualisation option.

The study is focused on the examination of meteor data. The scope of the study covers the properties of meteor data adopted from special samples saved in the KNURE database.

The study was conducted using information technology, such as specific techniques and features of the object-oriented programming language C#.

A software product was created using integrated development environment Microsoft Visual Studio 2013, Windows Forms, .NET Framework 4.5 and programming language C#.

The novelty of the study is associated with independent development of specific IT tool "Astronomer's Reference Book – Calculator – Meteor Map", which can be used to analyse the specified meteor data and represent the results of their interpretation. This scientific paper also serves as the report on the results of the project "Astronomer's Reference Book" carried out by the students specialising in software engineering upon completion of the course within the academic discipline "Object-Oriented Programming" in the KNURE Department of Software Engineering.

2.1. Meteor data. Specific characteristics

In astronomy, meteor observational data, which are related to the celestial sphere and an observer in its centre, are specific. As seen from space, a terrestrial observer, whose position appears to coincide with the centre of the Earth, is able to record the true positions of the observed real physical objects; however, in meteoric astronomy, there is an imaginary point on the celestial sphere, called 'meteor radiant', which is the point of apparent intersection of the celestial sphere with the meteor path in the Earth's atmosphere when traced back. The position of this radiant is also related with the meteoroid, which is burning up in the atmosphere, at the instant of its burnout. Starting from the moment of observation of the meteor trail in the atmosphere at altitudes of 70-120 km, it is only the past tense that we can use to describe this meteoroid as an inhabitant of the Solar System; and its orbit in the Solar System could have been considered as ended if it was not for the assumption about the stochastic nature of meteors.

It is assumed that with a certain level of probability there might be at least one more real object which continues its motion in the Solar System along the same orbit as the burnt meteoroid did. There are also real physical meteor swarms comprised of meteoroids which travel around the Sun along similar orbits; and when observing periodic meteor showers from the Earth, it is because of these meteor swarms that a group of meteors in the atmosphere appear to emerge from one and the same radiant on the celestial sphere. Meteors which are not assigned to any of the known meteor streams are called sporadic. It is sporadic meteors that are discussed in this paper. Despite the afore-mentioned difference in determination of positions of meteor radiants and other celestial objects (such as stars, asteroids, comets, etc.), the night sky model (star map or chart) plays a significant role in meteoric astronomy; and this important analogy holds true for meteors with regard to their magnitudes. Hence, meteors with their radiants are assigned magnitudes in the same way as stars, i.e. when the meteor radiants are known, we say that meteors have magnitude "+N^m" or "-N^m"; and when meteor limiting magnitudes are recorded (in special cases), we say that meteors have magnitudes not higher than (or below) a certain value.

To describe a meteoroid as a Solar System object, its heliocentric orbit should be calculated, i.e. it is necessary to determine five orbital elements, namely semi-major axis a, eccentricity e, inclination i, argument of perihelion ω, and the longitude of the ascending node Ω. In some cases, other orbital parameters can be used: for instance, perihelion q and aphelion q' distances. The sixth orbital parameter – time t – defines the meteoroid position in its orbit. The time and date of meteor observation, meteor radiant position and velocity should be determined in order to calculate meteoroid's orbit in the Solar System. In this study, we used the guaranteed-accuracy algorithm for determination of meteor orbits which had been employed in radar observations in Kharkiv (Kolomiyets 2015).

2.1.2. Meteor data provided by the Kharkiv National University of Radio Electronics

Meteoric astronomy as a part of general line of meteor research in KNURE started developing in 1971. There is an electronic KNURE Meteor Database comprised of about 250,000 meteor orbits, which was created on the basis of radar observations of faint meteors with magnitudes below $+12^{m}$ carried out in 1972-1978 at the observation station in Balakliya. A sample data set with specified characteristics of meteor data and details about their delivery has been presented by (Kashcheyev & Tkachuk 1980). The KNURE Meteor Database is an electronic database with a statistically significant set of high-quality observational data; it serves as an IT tool and was used in the KNURE research activities many a time. It was required to refine the KNURE Meteor Database through development of specific functions to adjust the calculator to the standard epoch and to visualise the meteor map data. In this study, we adopted special sample sets of data from the KNURE Meteor Database in STATISTICA format. In order to test the software application "Astronomer's Reference Book – Calculator – Meteor Map", we used 10,247 meteor orbits obtained in 1972, as well as sample sets of prograde and retrograde meteor orbits.

2.2. Astronomical algorithm to create a calculator and meteor map

When creating the algorithm employed to develop the software application for meteor data processing, we used MAC recommendations for astrometric mathematical tools and techniques for data interpretation and analysis given in (Zharov, 2006).

2.2.1. The second equatorial coordinate system

In astronomical observations, the positions of celestial objects are defined by their coordinates on the celestial sphere. A coordinate system withthe origin lying at the centre of the Earth while its fundamental plane is a projection of the Earth's equator onto the celestial sphere is referred to as equatorial. In this study, we used the second equatorial coordinate system, for which δ is declination and α is right ascension. Declination δ varies from -90° to +90° relative to the equator towards the poles. Right ascension α of a celestial object is an angle between the two great circles, one of which passes through the celestial poles and the target object while the other one passes through the celestial poles and the vernal equinoctial point at which the ecliptic intersects the celestial equator. Right ascension α is measured in the direction opposite to the daily rotation of the celestial sphere (from 0 to 360°). An object's position $(\alpha,\delta)^0$ in the second equatorial (RA-Dec) system is not correlated to the daily rotation of the celestial sphere and changes slowly; that is important for plotting star maps and charts. It is equatorial coordinates $(\alpha,\delta)^0$ which are used in the software application "Meteor Map".

2.2.2. Calculating lunisolar precession

Lunisolar perturbations of the Earth's orbit result in a complex change in the Earth's rotation axis orientation in space. The axis slowly traces out a cone being constantly inclined to the orbital plane at an angle of 66.5^{o}. Such a motion is called precession; its period is about 26,000 years. Due to precession, the relative positions of the celestial poles continuously change. Positions of celestial objects change with time due to this lunisolar precession of the Earth's axis of rotation; hence, the adjustment to the standard epoch is needed. That is why the star maps should be regularly updated. Modern night sky maps date back to early 2000s (Equinox 2000). An annual shift of the mean pole position on the celestial sphere is about 50.3". There is a similar shift of the positions of equinoctial points as they move towards the apparent motion of the Sun. All the above has been taken into account when developing the application "Calculator"; nevertheless, the adjustments are still within the limits of accuracy.

2.2.3. Visualisation model

We used a conventional data-encoding scheme to create a 2D visualisation model ("Meteor Map") based on the projection of the physical model of the celestial sphere in the form of the globe with a constant radius onto the plane. The equatorial coordinate grid is illustrated by the beams radiating out from the centre and coaxial circles. Numbers in the margin of the map represent the right ascension (from 0 to 360°). The beam corresponding to the right ascension origin passes through the vernal equinoctial point. Fig. 1 depicts the distribution of a number of meteoroids in prograde and retrograde orbits for a sample set of orbital elements with aphelions within the range of 0.8-3.0 AU and eccentricities of 0.5-1.0. In other words, we have tested the application to visualise the space between the Earth and Ceres which orbits the Sun at a mean distance of 2.8 AU.

3. Conclusion

We have developed, tested and employed the software application "Astronomer's Reference Book – Calculator – Meteor Map" which enables to download meteor observational data and adjust meteor individual characteristics, such as unique numbers, orbital elements, time and date of observations, etc. It is feasible to create new lists of surveys, as well as to add, delete or adjust observational data. For this application, we have developed special functions, which enable to adjust the meteor data to the standard epoch, visualise meteor maps and save them in jpg format.

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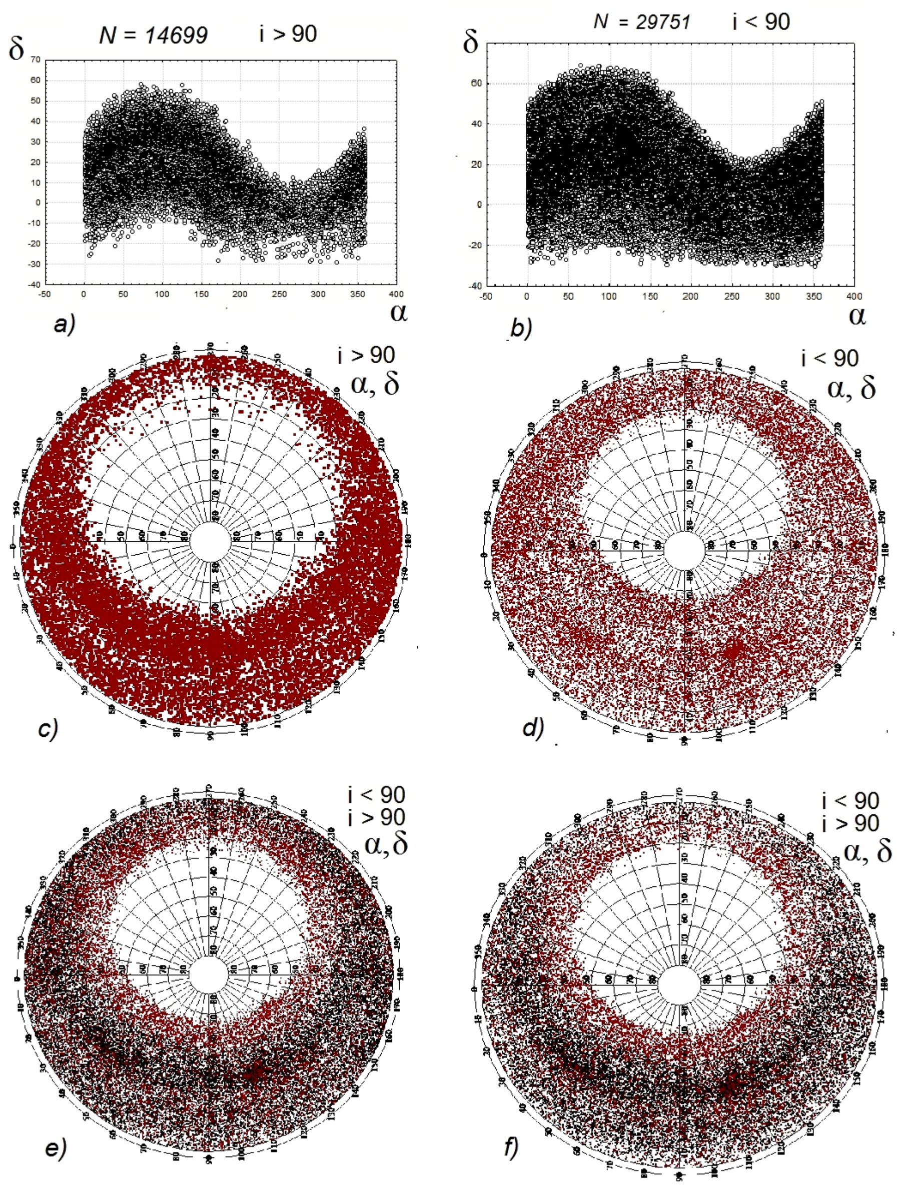

Figure 1: meteor data visualisation. The distribution of N meteoroids which orbit in the prograde $i < 90^0$ or retrograde sense $i > 90^0$ for a specific sample set of orbital elements $0.5 < e < 1$, $0.8 < q' < 3.0$ in the second equatorial (RA-Dec) system $(\alpha, \delta)^0$: a) $i > 90^0$ and b) $i < 90^0$ in the graphs plotted using STATISTICA software application; c) $i > 90^0$ and d) $i < 90^0$ in the meteor maps. Simultaneous distribution of prograde and retrograde orbits (marked with cerise and black conventional symbols, respectively) is presented on the maps: e) $-90^0 < \delta < 90^0$ (entire sphere) and f) $0^0 < \delta < 90^0$ (the Northern hemisphere).

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