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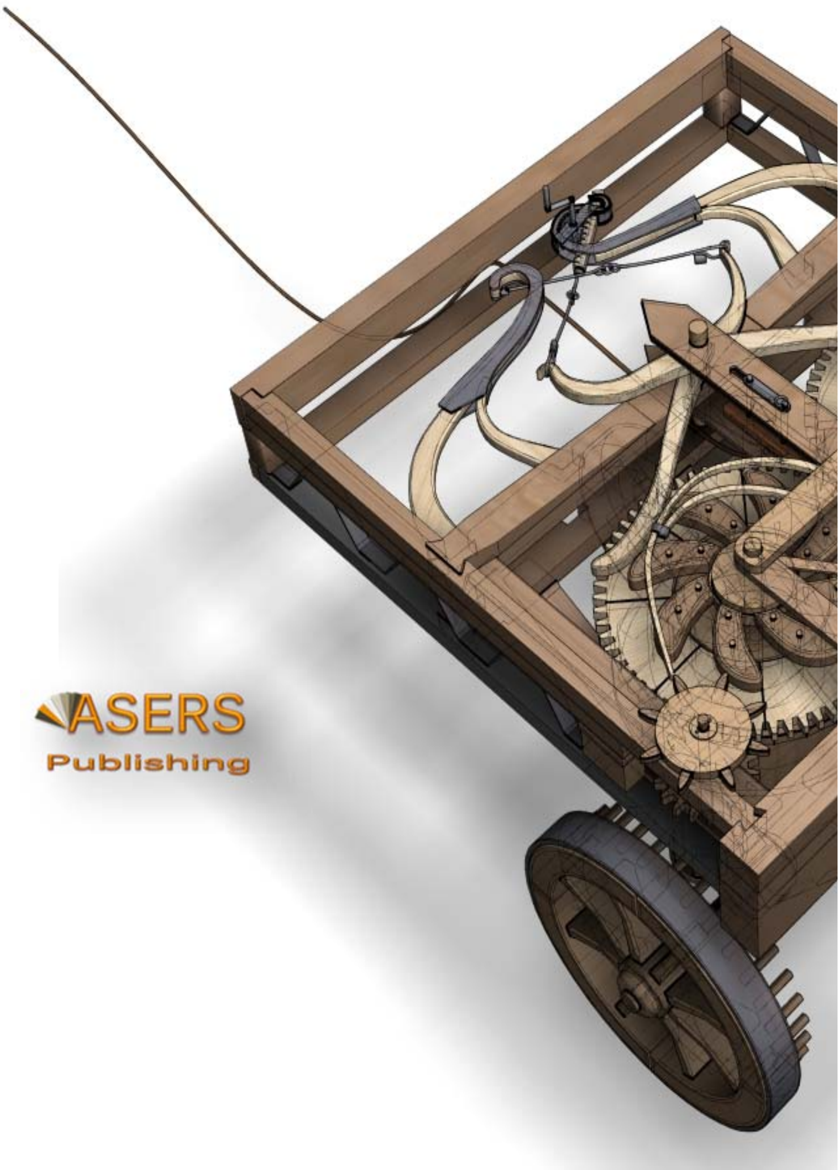

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The System of Evaluation Principles for the Economic Effects of Earth Remote Sensing Data Application for Solution of the Problems in Various Economy Branches

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Abstract

In this paper, based on an analysis of the application of Earth Remote Sensing (ERS) technologies in various sectors of the economy, a system of principles for the evaluation of the economic effect caused by the application of ERS data common to all industries is considered. For this purpose, the experience of the development of informatization of various industries in terms of integration technologies is analyzed.

Keywords: Earth Remote Sensing; technologies; evaluation principles; economic effect.

JEL Classification: O32; M15; L59; O19; Q16.

Introduction

In recent years, Earth Remote Sensing (ERS) has been organically integrated into the information space of developed countries, becoming one of the most significant tools for the solution of many pressing problems in the field of economy, defense, science, education, ecology, etc. This is evidenced by the annual increase of up to 20% in the world of information services based on ERS. The ERS technology concentrates the most sophisticated means of very many sectors of the national economy – spacecraft (SC), ground control software (GCS) for ERS, unmanned aerial vehicles (UAVs), optical-electronic video and radio surveillance equipment; however, the greatest impulse to ERS was given by digital technology. On its basis, fundamentally new means of filming, spatial information processing with the expansion of the nomenclature, geography, and scope of this technology appear. As a result, in less than 30 years, the number of countries with ERS space facilities has increased from seven to twenty (Nosenko, and Loshkarev 2010; Koryanov et al., 2018). Spatial information received from SC, UAVs, and GCS and processed by digital technologies began to be applied in such areas as cartography, ecology, agriculture and forestry, land development, geology, logistics, construction, oil and gas transportation systems, weather and climate, oceanology, etc. Features of the implementation of ERS in various sectors of the economy are discussed in (Sutyrina 2013). At the same time, the cost characteristics of ERS technologies are reflected in (Lobovikov, and Ivenskikh 2013, 590).

At the same time, the scientific, economic and government tasks being solved gradually become more complicated, ranging from monitoring of the situation and the state of the objects observed to complex management and forecasting tasks. With the accumulation of dynamic series of observations, the solution of the problems related to the integration of information from all ERS sources into a single scientific-technological digital platform, not only the individual tasks will be addressed, but also the complex ones of national and international significance in terms of solving climate problems, the Earth ecosystem studies and other important issues of science and economy. Against the background of a significant increase in capabilities of ERS ICTs and a decrease in their cost, an increase in the state and interstate space programs of ERS is observed. An example is the testing of the product Atfarm (Atfarm 2019) in Germany, which allows the farmers to apply nitrogen fertilizers at specific sites using the satellite data.

In Russia, ERS technologies are just beginning to be formed and applied. In (Ivchenko and Boronilov 2011; Kiselev *et al.* 2018), the problems arising from this are studied. The lack of an integrated approach to obtaining ERS data was noted, as well as the extremely problematic use of ERS data in such a situation, due to the limited availability of ERS data in the course of solution of several tasks at the regional level as a whole, taking into account the characteristics of the areas within the region. The solution to this problem was proposed in (Medennikov 2018, 69; Ereshko *et al.* 2016, 184; Ereshko and Kokuytseva 2017) in the form of establishment of a single information Internet space of the country's digital interaction, including the digital ERS platform. In (Kuznetsov *et al.* 2016, 7), it is concluded that in Russia, consistent state policy is required in terms of research and development in ERS.

From a review of extensive foreign studies using the most up-to-date mathematical methods (Akayev and Rudskoy 2016, 1), a number of important conclusions are drawn about the significance of the conditions of the impact of ICTs on the economic efficiency of public production, including ERS (Precision Farming Will Increase Yields, 2009).

In the absence of a single federal target program for ERS in the interests of all sectors of the economy and science, the blurring of individual tasks for different structures with minor financing, there is a problem of evaluation of the economic effect of the implementation of these technologies on a country. This method could somewhat reduce business caution in matters of investment in ERS. At the moment, following the interest in ERS, there are many developments in the economic literature on approaches to calculating the effect of using these technologies, but they are only fragmentary and are only in certain areas of ERS data application. Research on remote sensing can also be characterized with the almost complete absence of economic calculations for the payback of complex measures for the introduction of ERS technologies.

In this paper, based on the analysis of the application of ERS technologies in various sectors of the economy, a system of principles for evaluation of the economic effect of the application of ERS data common to all industries is considered.

1. Materials and Methods

The main feature of the digital economy is the requirement to integrate both information systems and information used to solve its problems. This happens most clearly in logistics (Tikhonov 2015; Az-zari 2016), in public services, in education, in banking, communications, in the provision of medical services, etc. This should also happen in ERS technologies, the information of which is relevant throughout the entire chain of its use, although even in developed countries there is a gap in this chain. An example is the testing of the product named Atfarm (Atfarm 2019) in Germany, which allows farmers to apply nitrogen fertilizers at specific sites using the satellite data. The developer does not assume the integration of ERS data and farmers' database. At present, the Russian ERS funds are concentrated in heterogeneous and disconnected bodies with the absence of any cooperation, which, given the relatively high cost of ERS data, poses the problem of cooperation of works and data integration as priorities in this industry. Therefore, in the studies of classification of the system of principles for evaluation of the economic effect of application of ERS data for solution of the problems in various sectors of the economy, the authors relied, on the one hand, on the analysis of the features of ERS implementation in various sectors of the economy, on the other hand, on the analysis of the problems of assessing the economic effect of application of ERS data, thirdly, on the analysis of the experience and trends in the development of informatization (digitalization) of various industries in terms of integration technologies.

2. Results

The principles for evaluation of the economic impact of ERS data application

The features of the implementation and manifestation of the effectiveness in various fields of application of ERS condition the use of various methods of economic effect evaluation with the generalized principles of the approach to these estimates. These generalized principles for economic efficiency evaluation include:

1) accounting for the time factor, the scale of implementation, costs, and achievement of targets for the planned period of existence of the entire ERS complex;

2) systematic and comprehensive assessment of the economic effect of the application of ERS data;

3) multivariate technical and organizational decisions;

4) the comparability of options on the source information;

5) accounting for uncertainties and risk situations.

Let us consider in detail these principles being closely intertwined.

The essence of the first principle is that the investor or the state, having invested in some ERS project, should receive large sum of money in a few years. Currently, there is a significant increase in the diversity and capabilities of the types of spacecrafts produced and their total number with the improvement of the technical, organizational, information and communication nature of ERS facilities. Therefore, it is required to organize such a scale of implementation of ERS complexes so that to obtain the desired results during their life cycle, which is very short due to the rapid update of the complexes. In (Medennikov *et al.* 2017, 23), mathematical modeling of the options for the development of agricultural informatization is considered. The results of experiments on the model convince the authors that with the present level of economic development of agriculture without state support, the maximum level of informatization is only 24%. At the same time, only profitable farms were taken into account the share of which, according to various estimates (In Russia the Share of Unprofitable Organizations in 2016 Decreased 2017; Nikolaev *et al*. 2014), was from 74% to 83%. This means that even among the profitable ones, 76% of farms cannot afford to acquire at least one computer and one computer program. Only with the transition to a systematic and integrated approach within the framework of the digital economy (DE) program, to a single information Internet space of the digital interaction between the agro-industrial complex and the country (Medennikov 2018, 69; Ereshko *et al*. 2016, 184) with state support, the full use and large scale of the implementation of ERS technologies in the agro-industrial complex with sufficient efficiency can be possible. Meanwhile, a small number of farms can take advantage of their benefits.

Therefore, in order to achieve significant economic effect from the introduction of ERS technologies in all areas of their application in general for the country in the coming years, it is necessary, firstly, to produce their own spacecrafts to become independent from foreign ERS facilities, secondly, to develop the level of technology based on cooperation and integration, thirdly, to expand the competence in the application of modern methods and tools, including mathematical models, the use of ERS data.

Currently, Russian ERS facilities are concentrated in heterogeneous and disconnected bodies with the absence of any cooperation. The same situation is with information systems (ISs) in many industries. For example, the analysis of various ISs in agriculture shows that the country continues the era of "task-by-task" design and development of them with the formation of their own conceptual logical models of crop production, which are ontologically incompatible. Following the task-by-task approach (also called island, patchwork informatization) and estimating the number of tasks solved in crop production in the amount of 150, the number of various technological operations – about 20, the number of regions –80, the number of cultures – 20, one can obtain potentially 4,800,000 information systems (Medennikov 2018, 69; Ereshko *et al.* 2016, 184; Chursin *et al*. 2018). This approach leads to a significant increase in the cost of ERS implementation and inefficient use of ERS data, because the use of ERS technologies requires knowledge of techniques for their thematic processing and, in most cases, attracting a large amount of additional information from the field of crop production. In (Medennikov 2018, 69; Ereshko *et al.* 2016, 184), a scientific approach to the formation of a single information Internet space of digital interaction between the agro-industrial complex and a country that includes a digital platform, is proposed, which, in turn, is the integration into a single cloud of database of primary accounting information and technological databases based on a unified system for collecting, storing and analyzing primary accounting, technological, statistical information associated with each other, as well as with a single system of classifiers, directories, and standards representing registries of almost all material, intellectual and human resources of a country based on ontological modeling of these types of information resources.

Such a digital platform will allow the development of standard information management systems (IMSs), as well as typical sites with a decrease in the cost of the digital economy by tens to hundreds of times. This platform could also serve as the basis for the integration of ERS data and management decisions based on them, including the basis for coordinating the work of all ground centers and stations created by various departments, in their coordinated functioning, and integrating ERS data sets on a single digital platform with significant multiple increase in efficiency.

This echoes the plans of (Nosenko, and Loshkarev 2010) to create a Unified Geographically Distributed Information System for the Earth Remote Sensing (UGDIS ERS) until 2025. Of course, it would be necessary to include in UGDIS ERS the information resources obtained from the UAVs and ground control software from common scientific and methodological positions.

Provision of multiple technical and organizational solutions.

The transition to a qualitatively new level of application of ERS technologies with the help of spacecrafts will provide greater economic efficiency, and consequently, the more competent and technically trained user. Modern ERS databases, geographic information systems require the equipment with a powerful interface in the composition of the required set of software and hardware (SH) for processing the entire stream of high-resolution ERS data. Processing high-resolution data requires large investments in the equipment upgrades. To solve the problems of the high cost of ERS data and other problems in this area, which often scare away potential consumers, a consistent government policy in terms of research and development in this area is required (Kuznetsov *et al.* 2016, 7). The ongoing development of ERS can occur only with continuous improvements in ERS technology.

Currently, ERS faces the same challenges that were faced in the 1990s, when the massive introduction of PCs began in the country. For example, it was clear to RDI of Cybernetics of the Agro-industrial Complex, that such a situation would require the delivery of a large number of software tools to several tens of thousands of agricultural enterprises, which would require a comprehensive, systematic approach to the problem of informatization of the agricultural sector, i.e. production, industrial technologies for their computer-aided design (ITCAD). Therefore, with the support of the State Committee for Science and Technology of the USSR, the most appropriate approach was chosen – the development of complex, typical information management systems (IMSs) at the reference sites, followed by replication of the used, tested systems to other enterprises (Ereshko *et al*. 2018, 22). At the same time, everyone was aware that IMSs would significantly influence both the management systems and the structure of agro-industrial production. One of such facilities was the agricultural complex Kuban in the Krasnodar Territory, in which there were 19 types of agro-industrial enterprises. Over the course of four years, individual software systems tested on the so-called reference objects were transferred for the implementation to approximately one thousand enterprises in the country. The development of ISs in the framework of ITCAD has allowed the increase in the economic efficiency of their development by tens to hundreds of times. The ITCAD standards allowed the formation of a list of tasks, logical database structures common to all types of agricultural enterprises. A creative team was formed from various leading industry research institutes and the RDI of Cybernetics of the Agro-industrial Complex, which, on a unified methodological basis, developed complex management systems for the enterprises based on the integration and typification of subsystems.

German agriculture is also preparing for the introduction of new technologies through a scientific approach, conducting experiments on experimental farms. Over 60% of farms of various sizes have already applied new technologies using the precision farming model. The experimental development takes place within the framework of the interdisciplinary project Preagro with the development of a crop production system taking into account the microconditions (relief and agro-chemical analysis) of each land plot based on satellite information in order to increase the economic efficiency of agricultural production. The project involves several research organizations, industrial enterprises, financial groups, and fertilizer companies. The project is financed by the Ministry of Education and Science.

In China, near Shanghai, the first experiments on the conduct of precision agriculture were initiated. The work is carried out by the specialists from the Academy of Agricultural Sciences of China; their goal is balanced plant nutrition. The plot of the experimental field with an area of 247 hectares is divided into small plots of land; the technology of precision fertilizer application is developed on them, depending on the needs of crops. Eleven types of nutrients are tested on 460 test sites. Everything is done in order to grow crops in the most economical way, which will then be compared with the usual crops in these places. It can already be stated that the yield of watermelons has increased from 14 to 27 %, and the concentration of sugar – by three times, rice collection – by 9-13%, wheat – by 18%. In two more places, located near Shanghai, the technology of precision positioning on the ground and remote data acquisition is being worked out on large fields.

Therefore, to test and select the most advanced ERS technologies, it is necessary to select several reference facilities (now called sandboxes) at the regional, district, and enterprise levels for testing most types of ERS technologies in a complex with the delivery of modern ERS software and hardware with various technological equipment and machines involved in the production (monitoring) process of industries, in order to ensure the multivariate technical and organizational decisions. The options for obtaining and using data from spacecraft, UAVs, and ground-based facilities should be worked out and selected based on a set of criteria.

The provision of the comparability of options on the source information is necessary due to the fact that the source data obtained from various means of ERS (SC, UAVs, GCS), including optical, radiometric devices, decoders, etc., used for monitoring, are required to be compatible in many ways, including ontological ones. This follows from the intersection of the source data from various ERS facilities, which should complement each other and be interpreted in the same way when solving the sectoral tasks in different farms. Thus, the tasks associated with the analysis of crop rotation and yield forecast require additional ground data for their solution, in particular, long-term statistics reflecting technological operations carried out on all fields in a time section with the doses of chemical agents introduced, in relief and agrochemical maps, etc. Thus, ERS data can help with most tasks, but their use implies knowledge and adherence to the methods of their substantial processing and, often, the extraction of additional data. Such a complex use of heterogeneous information from various sources is impossible without the development of a conceptual information model of crop production (CIMCP). The problems of updating such models are also successfully solved with the use of ERS data.

The ERS methods are of particular importance in "precision farming", which is a relatively new field of agriculture. Each section of the field is singled out as a subsystem of the general agriculture system. This subsystem is characterized by individual values of general indicators: relief, soil cover, nutrient composition, soil moisture, etc. Differential digital agro-technologies are being developed for this subsystem. ERS data for the operational management of the control of detected pests, diseases, weeds, and other factors of depression are useful and timely.

Similar ontological modeling of the subject areas of activity should be carried out in all sectors, followed by their integration with ERS data.

Accounting for uncertainties and risk situations. This principle is particularly relevant in terms of ERS for the following reasons. Firstly, in all industries, ERS technology is faced with adverse weather conditions, which are one of the main sources of risk for industry activities. Secondly, in many countries, ERS technologies are becoming commercial, in addition to their defense applications. Like any commercial project, the introduction of new technologies should take into account the factors of uncertainty and risk. Thirdly, the introduction of technology occurs through trial and error, constantly improving various ERS facilities, both technical and software ones. There are no established trends. Fourthly, such a rapid change in technologies, methods, and means of ERS application contradicts the conservatism of production processes in many industries. For example, in agriculture, only one cycle of some crop rotations takes more than 10 years. Accordingly, with the rapid change of ERS technology, it is impossible to assess the effectiveness of their use. Fifthly, as mentioned above, DE will introduce huge, qualitative changes in the digitalization of ERS, integration of information flows, etc. Many of the implications of this have yet to be realized and theoretically generalized; it is also necessary to identify ways for their subsequent implementation. Finally, the development of ERS is impossible without the cooperation of various sectors of the country and international cooperation. There is a lot to be done in this field.

3. Discussion

Currently, the world has accumulated significant research material aimed at studying the evaluation of the economic effect of ERS data application. According to international experience, ERS technologies provide many opportunities in almost all areas of human activity. This paper presents an analysis of these possibilities. However, there are also many reasons that impede the use of these technologies to the full extent of the opportunities that they offer. This is the excessive cost of equipment and services provided to the country from abroad on monopoly conditions in the absence of a domestic line of ERS facilities, ranged from spacecraft to software development. Perhaps today, the most important reason hindering the use of ERS is the lack of consistency and complexity of ERS data application, which significantly reduces its economic efficiency. The world's digitization of the economy is accompanied by widespread integration of both information resources (IRs) and information systems. Integration is provided by the standardization of the presentation of IRs, control functions, the development of uniform interfaces and protocols for interaction and data exchange between heterogeneous ISs, if necessary. ERS IRs in Russia are blurred by departments and centers of all kinds without their integration. In order to achieve positive economic efficiency of ERS technologies, a new infrastructure should be created, consisting of SC, GCS, UAVs, optical-electronic video surveillance and transmission equipment, the means for data storage and processing on a single digital platform; the technical means for installation of the sensors for positioning, collecting, storing, processing and transferring technological information, control mechanisms; new production management technologies. Moreover, all infrastructure should be integrated.

Conclusion

The generalization of the discussion results of the study, presented in Section 4, fully complies with the well-known dictum that for the realization of a scientific and technical idea, three conditions must be met: a "social order" must ripen, a necessary technical level must be available for the realization of the idea and a social-educational level of the population (future consumers) should be achieved for the perception of the idea. Since these conditions are not fully met in Russia, and there are no sufficient investments, the way out is seen in the technology that has been worked out for centuries: the elaboration of the most advanced ERS technologies on several reference objects – sandboxes – at different levels of territorial division, from enterprise to region, combined with the most types of ERS technologies, the delivery of modern ERS software and hardware in combination with a variety of technological equipment and machines of the industries involved in the production (monitoring) process, followed by massive implementation throughout the country.

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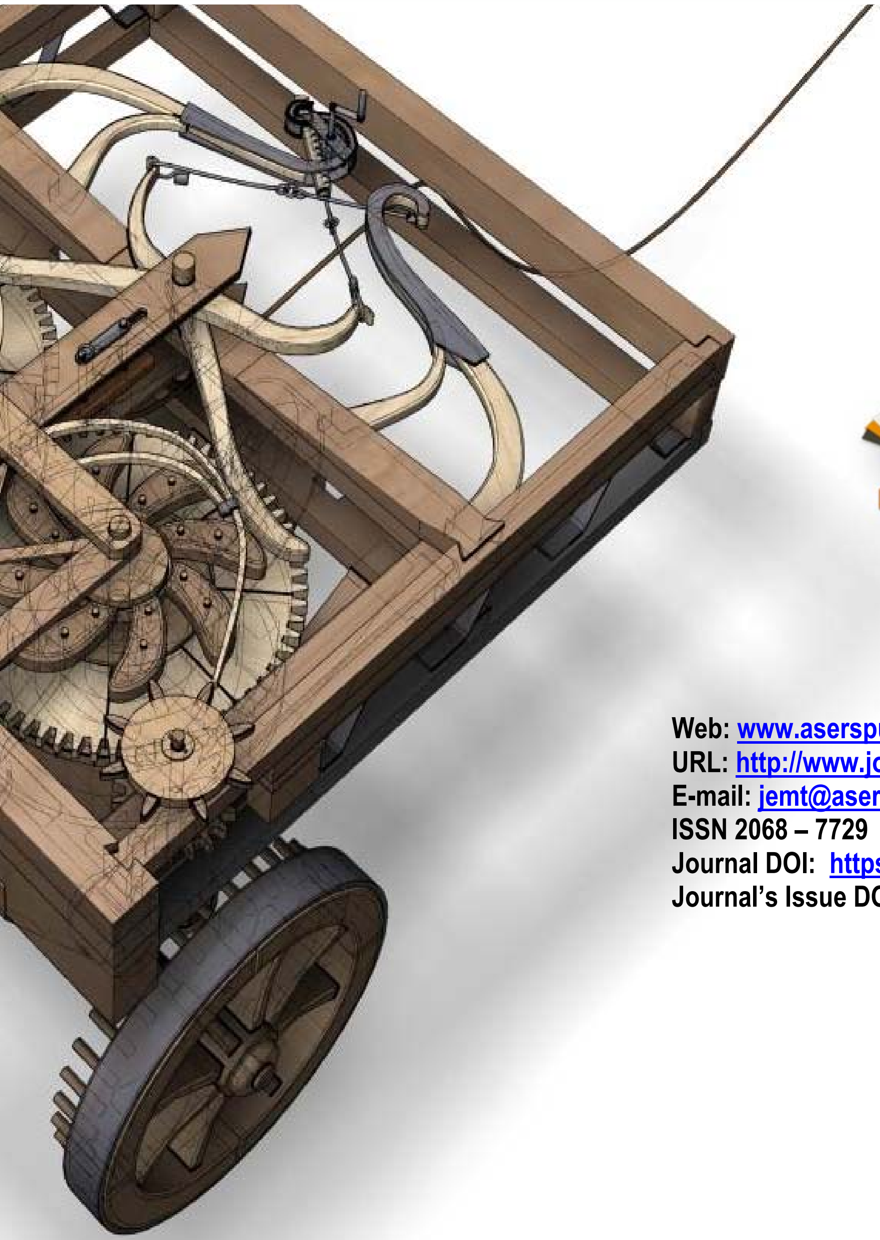

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