Methodology for choosing navigation receivers capable of increasing the efficiency of metrological support for space infrastructure

A V Fomina1, 2, A M Batkovski1y and V A Sudakov3

1 Central Research Institute of Economy, Management Systems and Information «Electronics», Moscow, Russia
2 MGIMO, Moscow, Russia
3 Plekhanov Russian University of Economics, Moscow, Russia

E-mail: fomina_a@instel.ru

Abstract. Using the space infrastructure as an example, a multi-criteria selection tool for navigation receivers was developed on the basis of scientifically substantiated fuzzy preference method. This task is an integral part of the bigger fundamental scientific problem aimed at improving the use of information provided by spacecraft to solve the most important problems of socio-economic development of Russia. Today, a large number of suppliers of these products are presented in the market. Given the interdisciplinarity, multivarience and complexity of the study of the problem under consideration, it is decomposed to a rational choice of navigation receivers of signals from global navigation satellite systems that allow working with GPS, GLONASS, as well as with sophisticated GALILEO and BeiDou systems. This is a multi-criteria challenge, the solution of which must be found in a complex information environment. Therefore, the selection of a specific supplier and model is a non-trivial task. The methodology of the study is based on the theory that the issues of state security, sanctions risks, consumer qualities and economic criteria are a part of an equation.

1. Introduction

In this article, the problem of choosing navigation receivers is considered for samples of complex innovative technology: unmanned aerial vehicles, robotic mechanisms, geological exploration systems. The preferences of the decision maker, on the basis of which the choice of the navigation receiver is made, is often fuzzy [1]. Expert judgment on the technical characteristics of complex products can also be fuzzy. Therefore, to solve this problem, the “soft computing” apparatus and the method of fuzzy preference areas are used [2].

A number of criteria are used to solve the problem [3]. Technical criteria:

- offline positioning accuracy,
- positioning accuracy in RTK mode,
- number of channels for tracking,
- number of channels to capture,
- supported navigation systems,
- cold start time,
• warm start time,
• hot start time,
• accuracy of determination of orientation angles,
• accuracy of determination of speed,
• tracking sensitivity,
• sensitivity upon detection,
• sensitivity at cold start,
• minimum working temperature,
• maximum working temperature,
• maximum humidity,
• frequency of issuing the decision,
• electricity consumption,
• length,
• width,
• height,
• weight.

The following economic criteria are also considered:

• the price of devices and equipment is the investment of the customer or their contractors in hardware;
• the level of customer service - is determined by the quality of providing end users with assistance and support for equipment and services based on global navigation satellite systems;
• cost of additional services - associated with the periodic costs necessary to use differential correction and satellite signal corrections;
• flexibility of service fees - this is the ability to choose commercial services for certain time periods.

The relevance of this task is due to the logic of the development of innovatively active industries [4].

2. Methods for choosing navigation receivers

We introduce the following notation:

- $i$ is the number of the criterion ($i = 1..n$),
- $U_i$ - scale of the $i$-th criterion, consisting of $q_i$ fuzzy gradations,

$$U_i = \{g_{i1}, g_{i2}, \ldots, g_{iq_i}\},$$  \hspace{1cm} (1)

where $g_{ij}$ is the fuzzy gradation of the criterion scale, $\mu_{ij}(x)$ is the function that determines for the $i$-th criterion the fuzzy membership of the value $x$ of the $j$-th gradation.

Combinations of gradation values of all criteria break the criteria space into regions. The set of all such regions is the Cartesian product of the sets $U_i$:

$$Y = \{g_{11}, g_{12}, \ldots, g_{1q_1}\} \times \{g_{21}, g_{22}, \ldots, g_{2q_2}\} \times \ldots \times \{g_{n1}, g_{n2}, \ldots, g_{nq_n}\}$$  \hspace{1cm} (2)

The Capacity of this set:

$$Q = |Y| = \prod_{i=1}^{n} q_i$$  \hspace{1cm} (3)

For the case of gradations represented by «clear» numbers, determining the level of preference on
scales with a high degree of detail is a rather time-consuming procedure for a decision maker. However, fuzzy gradations are required much less, since they can cover quite large areas of the criteria space with different levels of membership [5].

Let the decision maker set preferences in a subset of the set \( Y \):

- \( k = 1..K \) is the number of the preference area for which the decision maker has set his preferences (the number of such areas is \( K \leq Q \));
- \( p_k \) is the fuzzy preference level of the \( k \)-th region;
- \( \rho_k(y) \) - the membership function of the rank of the navigation receiver \( y \) for the preference level \( p_k \).

\[ M_k = (j_1, j_2, ..., j_n) \] is the vector of gradation numbers for the \( k \)-th fuzzy preference region (\( |M_k| = n \));

Multicriteria analysis was performed for a number of navigation receivers on the commercial market [6]:

- NV08C-RTK-A is a high-precision multisystem navigation receiver. It provides navigation with an accuracy of several centimeters. Phase measurements of GPS, GLONASS, and in the future BeiDou and GALILEO are used to determine orientation angles. NV08C-RTK-A can be used as part of innovative navigation equipment, providing low power consumption, high accuracy and performance.
- NV08C-RTK-M is a dual-frequency, high-precision multisystem navigation receiver. It uses phase measurements of L1 / L2 signals of GLONASS, GPS systems and provides navigation with centimeter accuracy. NV08C-RTK-M is designed for use as part of mobile navigation equipment that provides low power consumption, compact dimensions, high navigation accuracy and the required performance.
- The ComNav K700 is a high-performance receiver for global navigation satellite systems. It can be successfully used to solve the positioning problem in applications such as cartographic work, GIS, monitoring the deformation of buildings and structures, real-time monitoring of moving objects and other applications where decimeter accuracy is required. It has wide functionality and low cost.
- ComNav K708 is ComNav’s flagship product. The receiver supports working with all satellite systems at all frequencies, which allows users to be confident in the effectiveness of K708 in the distant future.
- SinoGNSS K728 is a dual-antenna dual-frequency board for global navigation satellite systems that allows you to determine high-precision coordinates and course. Accepts RTK corrections of the RTCM 2.x, 3.x, CMR format.
- SinoGNSS K501G is an entry-level dual-system dual-frequency board for global navigation satellite systems. Built-in memory of 100 MB, raw data is easily converted to RINEX format using a free utility. With the option open, RTK can receive / transmit corrections.
- SinoGNSS K726 is a compact dual-antenna board for global navigation satellite systems that allows you to determine high-precision coordinates with an accuracy of 1 cm, as well as a motion vector with an accuracy of 0.02 °. With its compact dimensions, the K726 is well suited for installation on unmanned aerial vehicle systems and other mobile platforms.

The task of determining the level of preference for the data of navigation receivers was solved using the specified values of the criteria (\( x_1, x_2, ..., x_n \)). The values of the criteria were reduced to fuzzy by setting the membership function of a specific value of the criterion \( \lambda_{x_i}(x) \).

Fuzzy preference areas are written in the form of a fuzzy implication of the form IF fuzzy values of the criteria THEN preference for the navigation receiver = fuzzy preference level \( p_k \) set for the region. This implication is written as:
\[ p_k \left( y, x_1, x_2, \ldots, x_n \right) = \min \left[ \min_i \left( \sup_x \left( \min \lambda_{x_i}^k (x), \mu_{\rho_kM_i}^k (x) \right) \right), \rho_k \left( y \right) \right] \] (4)

The combination of fuzzy rules in all areas of fuzzy preferences determines the integral fuzzy estimate of the navigation receiver:

\[ p \left( y, x_1, x_2, \ldots, x_n \right) = \max_k p_k \left( y, x_1, x_2, \ldots, x_n \right) \] (5)

The following is the defuzzification of preferences by the center of gravity method:

\[ p \left( x_1, x_2, \ldots, x_n \right) = \frac{\int_{x_1}^{x_2} y p \left( y, x_1, x_2, \ldots, x_n \right) dy}{\int_{x_1}^{x_2} p \left( y, x_1, x_2, \ldots, x_n \right) dy} \] (6)

The ws-dss portal has open access to a software implementation of this ranking method [7]. Ws-dss allows you to place software implementations of decision support and optimization methods in C++, R, Ruby, Python languages on global and corporate web-based networks. The portal provides the ability to connect third-party web services and organize the sequence of calls of mathematical models with the transfer of input / output parameters between them.

3. Conclusion
The implementation of the presented methodology for the selection of navigation receivers contributes to the competitiveness of enterprises, as it allows to solve a whole range of tasks aimed at improving the efficiency by affecting the following innovative activities:

- analysis of criteria for economic efficiency;
- search for the most significant parameters with respect to technical criteria,
- analysis of the sensitivity of the criteria with respect to changes in the input parameters of innovative production models;
- evaluation of the effectiveness of innovations in accordance with integral fuzzy estimates obtained on the basis of the vector criterion.

The method of fuzzy areas of preferences can be used to evaluate the components of innovative products as materials used in creating new problems are usually limited. Due to the invariance of the considered approach, it can be extended to the problems of choice in other areas of project innovation chain.

Acknowledgement
The study was carried out with the financial support of the Russian Federal Property Fund as a part of the scientific project No. 18-00-00012 (18-00-00011) KOMFI.

References
[1]   Intan R, Halim S and Dewi L 2018 Fuzzy Granularity in the Knowledge-based Dynamic Fuzzy Sets. Proc. of the 2018 2nd Int. Conf. on Computer Science and Artificial Intelligence (CSAI ’18) (Association for Computing Machinery New York NY, USA) pp 242–6
[2]   Dutov A V, Nesterov V A, Sudakov V A and Sypalo K I 2018 Fuzzy Preference Domains and Their Use for Selecting an Electronic Flight Bag for Flight Crews. Journal of Computer and Systems Sciences International 57 230–8
[3]   Krasilov A 2010 Testing GPS modules Wireless technology 3 48–51
[4] Batkovskiy A M, Kureenyk A E, Semenova E G, Sudakov V A, Fomina A V and Balashov V M 2019 Sustainable project management for multi-agent development of enterprise information systems Entrepreneurship and Sustainability Issues 7(1) 278–90

[5] Noghin V 2006 The Edgeworth-Pareto Principle in terms of a fuzzy choice function Computational Mathematics and Mathematical Physics 46 554–62

[6] Kostenko V V, Lviv O Yu 2017 Combined communication and navigation system of an autonomous underwater robot with a float module. Underwater research and robotics 1(23) 31–43

[7] Web Services for Decision Support Systems Retrieved from https://ws-dss.com/?locale=en