Models and Methods for E-Commerce Systems Designing in the Global Economy Development Conditions Based on Mealy and Moore Machines

Andrii Berko[a], Myroslava Bublyk[a], Lyubomyr Chyrun[b], Yurii Matseliukh[a], Roman Levus[a], Valentyna Panasyuk[c], Oksana Brodyak[a], Lyudmyla Dzyubyk[a] and Olga Garbich-Moshora[d]

[a] *Lviv Polytechnic National University, S. Bandera street, 12, Lviv, 79013, Ukraine*
[b] *Ivan Franko National University of Lviv, University street, 1, Lviv, 79000, Ukraine*
[c] *West Ukrainian National University, Lvivska Street, 11, Ternopil, 46004, Ukraine*
[d] *Drohobych Ivan Franko State Pedagogical University, Ivan Franko Street, 24,Drohobych, 82100, Ukraine*

Abstract

The article examines the features of conducting and organising e-commerce in the development of the global economy. The efficiency of e-commerce is assessed by complex factors of ensuring public access to the Internet, the established mechanism of payment and delivery, the convenience of services of postal and logistics companies. The main advantages of e-commerce are formed the institutional measures harmonisation in domestic and European markets, supporting the domestic e-business development and expanding potential markets by attracting EU residents, stimulating the e-business infrastructure development. The article proposes models and methods of designing EC information systems. This paper examines the EC development in Ukraine, disadvantages, advantages, services, security systems and payments through IN. A vital part of the article is the development of methods for determining the efficiency of the EC, and the mathematical model of the EC information is proposed. The article describes the developed software solution of the information system for searching for arbitrage situations in the cryptocurrency market. According to requirements, the description of software implementation is carried out according to the standard (GOST 19.402-78).

Keywords 1

E-commerce system, information system, cryptocurrency exchangeб cryptocurrency market, electronic auction, business process, arbitration transaction, data stream, web server, customer service, electronic auction system, developed software, security system, internal state, exchange rate, linear partial differential operator, arbitrage transaction, traditional business

1. Introduction

In globalisation and the dynamic development of information and telecommunication technologies, the global Internet has become increasingly used in everyday life. This network functions expansion with the annual growth of the audience with access to the World Wide Web. The information-search is added to the value of regulation, entertainment, and so on. The Internet has become a channel for the effective sale of goods and services. It has led to a revolution in the organisation and conduct of trade. Both the external relations between companies and their partners or clients and the internal structure of the companies themselves have changed. Not only new directions of business have appeared, but those that already exist have been modified.

COLINS-2021: 5th International Conference on Computational Linguistics and Intelligent Systems, April 22–23, 2021, Kharkiv, Ukraine
EMAIL: Andrii.Y.Berko@lpnu.ua (A. Berko); my.bublyk@gmail.com (M. Bublyk); Lyubomyr.Chyrun@lnu.edu.ua (L. Chyrun); indeed.post@gmail.com (Y. Matseliukh); romanlevus@gmail.com (R. Levus); v.panasiuk@tneu.edu.ua (V. Panasyuk); brodyakoksana1976@gmail.com (O. Brodyak); liudmyla.v.dziubyk@lpnu.ua (L. Dzyubyk); garbich79@gmail.com (O. Garbich-Moshora)
ORCID: 0000-0001-6756-5661 (A. Berko); 0000-0003-2403-0784 (M. Bublyk); 0000-0002-9448-1751 (L. Chyrun); 0000-0002-1721-7703 (Y. Matseliukh); 0000-0002-4855-1472 (R. Levus); 0000-0002-5133-6431 (V. Panasyuk); 0000-0002-9886-3589 (O. Brodyak); 0000-0001-6942-9436 (L. Dzyubyk); 0000-0002-3172-5499 (O. Garbich-Moshora)

Of particular relevance are studying in the field of Internet economics (digital economy) on the prospects for the development of e-business. E-business can be divided into two forms [1, 2]: E-business as a basis for business creation; E-business as an additional tool for the development of existing traditional business. E-business as a basis for creating a business is a business model, where most business processes are performed using information technology (IT) of the Internet [2].

2. Related works

The emergence and development of a new type of commercial activity, formed under the influence of Internet technologies, current trends in the development and application of the Internet in economic activities are studied in the works [3, 4], where e-business is the transformation of fundamental business processes with the help of IT. E-business has begun to revolutionise business entirely and the economy [4, 5]. It is any business activity that uses the opportunities of global information networks (Internet) for the transformation of internal and external links for profit. The internal organisation of the company based on the Intranet (a single information networks), which enhances the effectiveness of employee interaction and streamlines planning and management processes; Extranet (external interaction) with partners, suppliers, and customers are all part of e-business [6]. E-commerce is an essential element of e-business [7, 8]. E-commerce is any form of business transaction conducted with the help of the Internet. E-commerce in the broad sense (digital economy) is [9-14]:

- Global e-marketing, including the promotion of traditional goods/services (interactivity - the ability for dialogue - the media to change the paradigm of advertising and market research);
- E-commerce in the narrow sense that involves the trade-in of subtle goods (content) that are transmitted and/or paid for in digital form (such interests include content in text, graphic or audio format);
- Seized services (services related to consulting, legal and accounting support, and so on., which are held at a distance);
- Remote work (it becomes possible to organise distributed offices in the intangible production sphere; people work in different premises, cities, countries work together).

For Ukraine, according to the authors of [3, 15], it is imperative to enter the international system of e-commerce to prevent the gap in development and uneven accumulation of capital.

It should be noted that most research in the field of e-commerce, as a component of e-business, is carried out by specialised analytical companies and is narrow. However, the study of current trends and prospects for the development of e-business in terms of international experience is not thoroughly carried out, which necessitates this study.

The Internet has created and promoted new markets that make up the relevant segment of the world and national economy. Therefore, Ukraine's national economy is already facing an issue that requires comprehensive diagnostics to form a digital economy. According to the results of the assessment of trends in the national economy outlined in [9], it is envisaged to stimulate the electronic economic activity development (digital business). It is also to create conditions, in particular, for expanding the e-market as a system of economic relations in cyberspace using information and communication technologies. In the aggregate, determines the preconditions for the formation of the very concept of e-entrepreneurship (e-business) [3, 16-21] as an independent, systematic, risky economic activity in cyberspace, carried out using information and communication technologies to make a profit and achieve other economic and social results.

The construction and development of e-entrepreneurship, as a mechanism for the growth of national economies, is a strategic goal of the European Union, the United States, Canada, Japan and more. In these countries, electronic means of selling and promoting products have long been the basis of marketing policy for most businesses and organisations. Their impact on the economy as a whole, according to the authors [3, 22-27], is most noticeable here. At the same time, Ukraine's proximity to the EU and its strategic plans for European integration, in our opinion, necessitates constant monitoring of development trends and the impact of e-commerce on the national economy.

In addition, the dynamic development of information and communication technologies, the foundations of the traditional economy, and business principles have changed. A new way of conducting and organising business activities is electronic, which involves implementing economic

processes on the Internet. E-business should be understood as justified in work [3] any form of entrepreneurial activity that consists of Internet technology to transform business processes and (or) production and organisational relationships. The formation and promotion of new e-business in the modern world are due to objective conditions and preconditions. According to [2, 28-32], this is a high degree of computerisation and gadgetization of society. In addition, to spread e-business, it is necessary to provide access to the Internet for the public. Another prerequisite for business electrification is achieving a certain level of integration (content and technology) of internal corporate information systems and the Internet. The primary basis of e-commerce has become traditional commerce, but unlike the latter, information networks give e-commerce more flexibility. In works [2, 33-39], the author identifies 5 clusters of e-commerce entities:

- Consumers (C-consumer), individuals;
- Business organization (B-business);
- State bodies (G-government, sometimes A-administration);
- Employees (E-employee);
- Financial institutions (provide settlements between other e-commerce entities).

The most widespread are business models in the field:

- B2B (business – business) is the interaction of business structures in e-commerce (marketing, information services via the Internet, online tenders, sales of equipment for business, etc.)
- B2C (business – customer) is an end-user e-commerce system (online retail stores).

In the conditions of transformation of the national economy of Ukraine, the main advantages of conducting and organising e-business should be harmonisation of institutional measures for e-commerce in domestic and European markets, support for domestic e-business and expansion of potential markets by attracting EU residents, stimulating e-business development of infrastructure.

In the works [2, 40-45], it is noted that the efficiency of enterprises engaged in e-commerce is determined by some complex factors: the level of public access to the Internet, the mechanism of payment and delivery, the convenience of postal and logistics companies.

Currently, Internet users in Ukraine are more than 23 million people, which is about 58% of the population. Compared to European countries, this level is deficient: in the EU it is almost 82%. It is also worth noting that the number of Ukrainians who make online purchases is small. If in Ukraine, in 2015 3.7 million people did online shopping, which is 8.4% of the total population, and the average cost per person was 286 euros, the similar average value for European online shoppers was 43%, and the average price of 1,540 euros in the amount [14].

Despite the small share of Ukrainian buyers who make online purchases, there has been increasing sales (in monetary terms): in 2017, the figure reached 1.52 billion euros (Fig. 1). Although the share of e-commerce in total retail sales is insignificant (7.8%), given the growth rate of network penetration, the number of Internet users, and the dynamics of e-commerce revenue in previous years, the author [9] predicts its growth. Therefore, simple linear trends of both sales volumes on the Internet and their growth rates were constructed (Fig.1) with an allowable forecast accuracy of 95% and 94%, respectively. Their corresponding approximation equations and coefficients of determination are given in Table 1. Having constructed the forecast values of sales on the Internet and their growth rates in Ukraine in 2018-2022 in table 1, we see that online sales by 2022 should reach 2.3 billion euros, and growth rates should grow annually by more than 25%. So in 5 years, we will get a value close to 5 billion euros, twice the previous value. The latter value is more realistic in terms of the e-entrepreneurship dynamics, which is now in a phase of rapid growth. Despite the fact that now, there is a downward trend in the growth rates of developed markets; a significant increase is gaining in Southern and Eastern European countries. In terms of e-commerce growth in 2017 compared to 2010, Ukraine [14] ranks first with a rate of 760%. It is also worth noting that the average growth rate for the analysed period from 2010 to 2017 was 30.5%, which is the highest among Eastern European countries.

Postal and logistics operators note the growth of B2C e-commerce. Over the last few years, the annual number of B2C parcels sent to customers in the domestic market and abroad to other European countries has reached 4.2 billion in number [14]. The most common way to deliver goods ordered online are various delivery services. This method of order delivery is the best for large cities, but in small towns, there are some problems: low demand, difficulty controlling the quality of service, high cost. At the initial stage of e-business operation, you can use the outsourcing of delivery services and enter into

an agreement with a company that specialises in this. For example, in Ukraine Cargo Express, Mist Express and Nova Poshta offer such services. However, when the flow of orders becomes constant, you can already think about organising your own delivery service.

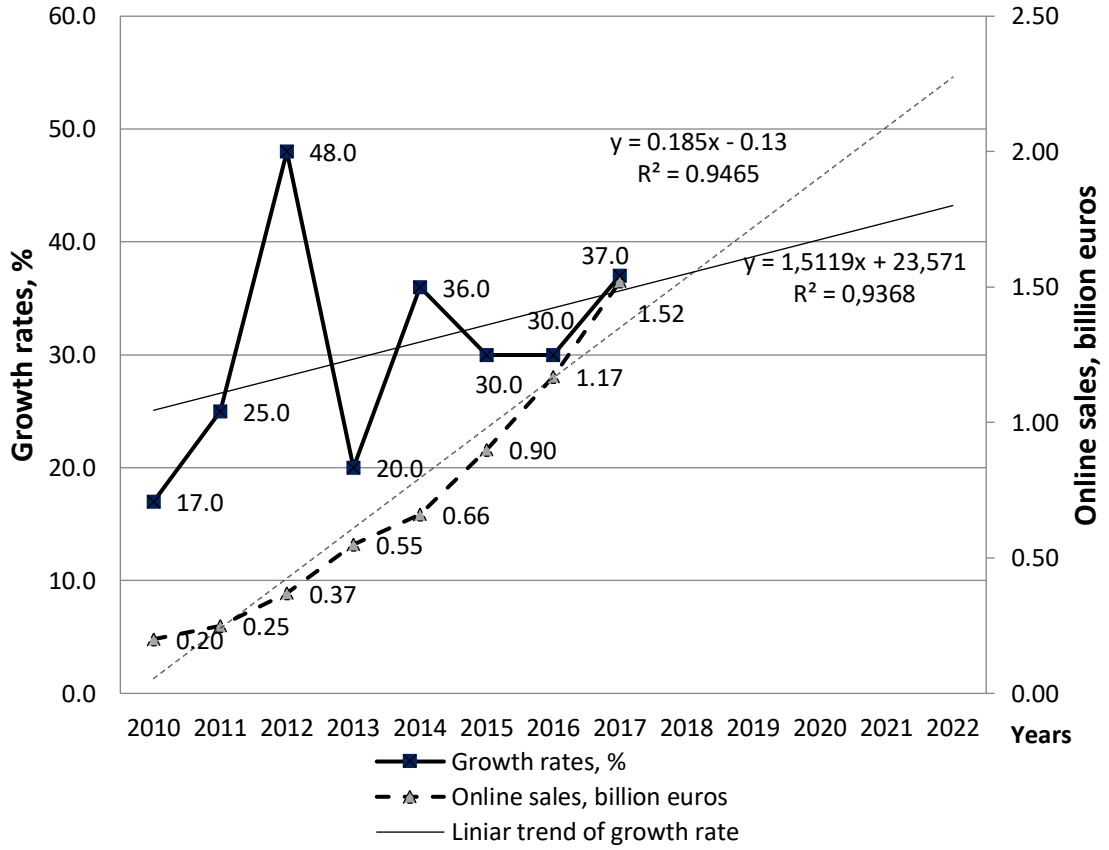

Figure 1: Sales volumes (B2C) and their growth rates on the Internet in Ukraine (2010-2022).
* Note: author's construction and calculation

Table 1
Forecast values of sales on the Internet, their growth rates in Ukraine in the period 2018-2022.

Years	Online sales, billion euros	Growth rates, %
2018	1,54	25,9
2019	1,72	26,2
2020	1,91	26,5
2021	2,09	26,7
2022	2,28	27,0
Approximation equation	y = 0,185x - 0,13	y = 1,5119x + 23,571
Coefficient of determination	R^2 = 0,9465	R^2 = 0,9368

To ensure the success of e-commerce, such an element as convenient payment is not enough. In addition, online merchants should offer flexible distribution solutions, free returns, and clear content about shipping locations and delivery times.

Convenient payment is an essential element of e-commerce. For successful cross-border sales, it is necessary to provide an ordering approach that will be localised for each market. In addition, this is the choice of a suitable payment service provider, which will meet the needs of a wide range of consumers. PayPal is one of the providers that already have comprehensive global coverage and reputation. But still does not work fully in Ukraine, but is only used to pay for purchases in foreign online stores, such as eBay, because money does not come to Ukraine abroad.

The authors of [3, 46-54] note that the product structure of online shopping has changed. In the pre-crisis period, including 2013, electronics and household appliances occupied the most significant niche.

The following most essential segments of online sales were tickets (aviation), clothing and footwear, goods for cars, goods for children, cosmetics and perfumes, tickets (events), books and others. Since 2014, commodity priorities have changed somewhat. In particular, security and protection goods, personal protective equipment, security and notification systems were actively growing. The Internet trade in building materials became more and more widely used.

The problem that constrains both the development and research of e-business is the partial definition of the top online stores, only comparing the number of visits to the site over a period. Unfortunately, such criteria as the number of pages viewed per visit, the time spent on the site, the volume of turnover are not collected centrally and are not available to the public, or are only available for a limited number of online stores. It is due to the low level of e-commerce development and its opacity in Ukraine, according to works [9, 55-61], and the market players instability.

Rozetka.com.ua remains the most prominent player in Ukrainian Internet commerce. Also in the five top are its competitors - allo.ua, citrus.ua, and comfy.ua. In fifth place - online cosmetics store makeup.com.ua, and in sixth place - modnakasta.ua. Thus, the positions of leaders almost correspond to the rating of the most popular product categories among Ukrainian online buyers - in Ukraine on the Internet most often buy home appliances and electronics (52%), clothing (45%), cosmetics and perfumes (34%) [9, 18, 62-70]. To ensure the growth of the Ukrainian segment of e-business, it is already necessary to analyse current trends in e-commerce. Here are the data for comparing the position of the world and Ukrainian leader in e-commerce (Table 2).

Table 2

Comparison of world and Ukrainian leaders of e-commerce

Characteristic	*Amazon.com*	*Rozetka.com.ua*
Global ranking of the site by oncoming traffic compared to other sites in the world	19	708
The total number of site visits in January 2018	2,69 billion	68,41 million
The average duration of visits, hours, in January 2018	00:06:21	00:05:35
The number of pages viewed per visit, pcs.	8,97	6,35
Percentage of visits to the site that ends with only 1 page of the site,%	36,35	26,10
Turnover of the online store, the latest data of 2017	79,27 billion dollars the USA	280 million dollars the USA
The cost of the brand	64 billion dollars the USA	179 million dollars the USA

As you can see, the gap is significant in all respects. Although Rozetka is far from the 50th position in the list of world leaders in terms of annual turnover, 708 place in the ranking of sites is worth acknowledging. Rozetka remains the undisputed leader in the Ukrainian market, is one of the most expensive Ukrainian brands and demonstrates Ukraine's potential in the field of e-commerce.

To construct a mathematical model of the e-commerce systems (ECS), we hypothesise that e-commerce is a component of the e-markets. E-markets use advanced IT for interaction among the business process or business to be effective with customers, suppliers, and business partners, including sales, marketing, financial analysis, payments, search for employees, customer support, and support partnerships [2, 4, 19]. Electronic Data Interchange (EDI) of e-markets imposes the basic requirements [2, 7, 20]: a single syntax of exchange; the ability to select data items; the only format for representing items when generating messages and files for sharing. Basic principles of e-markets [2, 21]:

- Simple and uniform application of standardised rules for electronic document drafting in the EB;
- Use of single specifications to the maximum extent possible;
- Provision of open e-commerce standards: B2B and B2C;
- Minimise the cost of sharing application-by-application;

- Providing multilingual support;
- Taking into account national and international trade rules;
- Respect for traditional EDI principles based on the UN / EDIFACT standard;
- Unified packet and routing specifications.

E-markets based on information management and the latest IT (knowledge management) are powerful tools that facilitate the functioning of virtual markets and make the virtual business profitable for e-commerce entities [2, 22]. Virtual-markets and e-commerce entities (groups of people) that jointly engage in commerce regardless of their physical location, crossing borders of businesses and countries, in real-time (synchronous) or delayed mode (asynchronous).

3. Material and methods

The e-commerce system is a system (black box) to which the input data is filmed output, which has certain internal states and processes. Information ECS is a set of internal processes, input and output, which are finite sets. ECS can be presented in the form of a mathematical scheme (*F*-scheme), which is characterised by six elements [2, 23-25]:

- A finited set of *X* input data (input alphabet);
- A limited set of *Y* outputs (output alphabet);
- A finited set of *Z* internal states (internal alphabet, state alphabet);
- Initial state z_0, $z_0 \in Z$;
- The function of transitions $\varphi(z, x)$;
- The output function $\psi(z, x)$.

The system is given by the *F*-scheme $F = <Z, X, Y, \varphi, \psi, z_0>$ and functions in a discrete system time, the moments of which are cycles (adjacent equal time intervals, each of which corresponds to the same values of the input, output and internal state).

Denote by $z(t)$, $x(t)$, $y(t)$ are internal state, incoming and outgoing data the *t*-th cycle, , $z(0) = z_0$. At time *t*, the abstract system perceives the input $x(t) \in X$, sets the output $y(t) \in Y$, $y(t) = \psi[z(t), x(t)]$ and goes from the state $z(t) \in Z$ to the state $z(t+1) \in Z$, $z(t+1) = \varphi[z(t), x(t)]$.

Based on the above, the first kind of ECS is determined by the following equations [2, 71-81]:

$$z(t+1) = \varphi[z(t), x(t)], t = 0, 1, 2, \ldots, \quad (1)$$

$$y(t) = \psi[z(t), x(t)], t = 0, 1, 2, \ldots, \quad (2)$$

where $x(t)$ is the input data at time *t*,
$z(t)$ is the state of the ECS at the time *t*,
φ is the function of transitioning the system to the next state $z(t+1)$,
ψ is the function of output data at the time *t*,
$y(t)$ is the output at the time *t* of the input data $x(t)$.

For ECS of a second kind [2, 71-81]:

$$z(t+1) = \varphi[z(t), x(t)], t = 0, 1, 2, \ldots \quad (3)$$

$$y(t) = \psi[z(t), x(t-1)], t = 0, 1, 2, \ldots, \quad (4)$$

where $x(t)$ is the input data at time *t*,
$z(t)$ is the state of the ECS at the time *t*,
φ is the function of transitioning the system to the next state $z(t+1)$,
ψ is t the function of output data at the time *t*,
$y(t)$ is the output at the time *t* of the input data $x(t-1)$.

Second-order systems [2, 71-81] for which is (5):

$$y(t) = \psi[z(t)], t = 0, 1, 2, \ldots. \quad (5)$$

The output function does not depend on the input variable $x(t)$. It is an example of an e-shop (ES) information system. It is the pre-determined price of the product or service, discounts, and only the right to choose the goods. The refusal of the services of this ES depends on the customer. Unsecured ECS have only one state others are called storage systems. The operation of the ECS without memory (combinational or logic circuits) is consistent with each input stream of one output [2, 71-81]:

$$y(t) = \psi[x(t)], t = 0, 1, 2, \ldots, \quad (6)$$

This function is a Boolean (alphabets *X* and *Y* are two letters). Example: an e-auction or system for cryptocurrency exchange, whose work depends entirely on the input of users (the choice of auction or cryptocurrency, product, bid), and the initial content is to answer the question of whether this product is sold and, if sold, to whom. The final ECS processes are divided into synchronous and asynchronous. Synchronous is readings of input information, and all changes occur at specific points in time, which are determined by an external source of synchronisation (the sale of goods in ES takes place in real-time). Asynchronous processes of the system read the input data constantly. And they change the output until they become stable, moving from one state to another several time. The e-auction or cryptocurrency exchange system reads the input data constantly and from one state to another. Gradually, it goes into a stable state of sale of goods according to the auction/ cryptocurrency exchange terms. The description of the finite processes of the system (assigning all elements of the set $F = <Z, X, Y, \varphi, \psi, z_0>$) is most often carried out in a tabular, graphical or matrix manner [2, 71-81].

The simplest way is a spreadsheet-based on conversion tables and outputs, the rows of which correspond to system input and the columns to its states. The first left column corresponds to the initial state z_0. At the intersection of the *i*-th row and the *k*-th column of the transition table, there is a corresponding value of the transition function $\varphi(z_k, x_i)$, and in the output table, the corresponding value of the process of outputs $\psi(z_k, x_i)$ [2]. The function of transitions of the information system ES [2] is presented in Table 3. Information system outputs function ES [2] is shown in Table 4.

Table 3

Function of transitions of the EC system

	z_0	z_1	…	z_K
x_1	$\varphi(z_0, x_1)$	$\varphi(z_1, x_1)$	…	$\varphi(z_K, x_1)$
x_2	$\varphi(z_0, x_2)$	$\varphi(z_1, x_2)$	…	$\varphi(z_K, x_2)$
…	…	…	…	…
x_I	$\varphi(z_0, x_I)$	$\varphi(z_1, x_I)$,	…	$\varphi(z_K, x_I)$

Table 4

EC system outputs function

	z_0	z_1	…	z_K
x_1	$\psi(z_0, x_1)$	$\psi(z_1, x_1)$	…	$\psi(z_K, x_1)$
x_2	$\psi(z_0, x_2)$	$\psi(z_1, x_2)$	…	$\psi(z_K, x_2)$
…	…	…	…	…
x_I	$\psi(z_0, x_I)$	$\psi(z_1, x_I)$	…	$\psi(z_K, x_I)$

For the *F*-system for e-auction/cryptocurrency exchange, both tables can be reconciled by obtaining a so-called process table in which above each state z_k of the system there are corresponding output data $\psi(z_i)$ [1-4,8,9]. Table 5 shows a marked information system for e-auction/cryptocurrency exchange.

Table 5

Marked EC system for e-auction / cryptocurrency exchange

	$\psi(z_0)$	$\psi(z_1)$		$\psi(z_K)$
	z_0	z_1	…	z_K
x_1	$\varphi(z_0, x_1)$	$\varphi(z_1, x_1)$	…	$\varphi(z_K, x_1)$
x_2	$\varphi(z_0, x_2)$	$\varphi(z_1, x_2)$	…	$\varphi(z_K, x_2)$
…	…	…	…	…
x_I	$\varphi(z_0, x_I)$	$\varphi(z_1, x_I)$	…	$\varphi(z_K, x_I)$

An example of a table problem of the *F*-system ES F_1 with three states, two input and two output data streams is given in Table 6, and the F_2 *F*-system for e-auction / cryptocurrency exchange with five states, two input data streams and three output ones, in Table 7 [1-4,9].

Table 7

The F1 table problem of the F-system with three states

	z_0	z_1	z_2
	Transitions		
x_1	z_2	z_0	z_0
x_2	z_0	z_2	z_1
	Outputs		
x_1	y_1	y_1	y_2
x_2	y_1	y_2	y_1

where x_1 is order of goods / cryptocurrency,
x_2 is payment for goods / cryptocurrency,
z_0 is start of basket formation,
z_1 is end of basket formation,
z_2 is invoice formation,
y_1 is order confirmation,
y_2 is payment confirmation.

Table 8

The F_2 F-system for e-auction / cryptocurrency exchange with five states

	y_1	y_1	y_3	y_2	y_3
	z_0	z_1	z_2	z_3	z_4
x_1	z_1	z_4	z_4	z_2	z_2
x_2	z_3	z_1	z_1	z_0	z_0
	y_1	y_1	y_3	y_2	y_3

where x_1 is registration in the e-auction / cryptocurrency exchange,
x_2 is bid,
z_0 is formation of a special code,
z_1 is provision of registration,
z_2 is formation / continuation of the list of players,
z_3 is beginning / continuation of the auction / cryptocurrency exchange,
z_4 is end of the auction / cryptocurrency exchange,
y_1 is special code for registration,
y_2 is confirmation of registration,
y_3 is the result of the auction / cryptocurrency exchange.

The graphical way of describing the *F*-system uses the notion of a directed ECS graph - a set of vertices that correspond to certain states and arcs that connect these vertices and communicate to transitions (processes) from one state to another. If the x_k input data stream causes the change (function) of the system from state z_i to state z_j, then on the system graph, the arc exiting the vertex z_i and entering the vertex z_j is denoted x_k. For the ES system, the output stream is indicated in the same turn. For the e-auction/cryptocurrency exchange system, the output signal is displayed above the top. Examples of descriptions of the above systems F_1 and F_2 using graphs are shown in Fig. 2 [4,9]. Mathematically most convenient is the matrix form of describing a finite set of ECS processes. The ECS connection matrix is a square matrix $\mathbf{C} = \|c_{ij}\|$, the rows corresponding to the output data streams and the columns to the transition states (processes). For the ES system, the element $c_{ij} = x_k/y_s$ at the intersection of the *i*-th row and the *j*-th column corresponds to the input data stream x_k, which causes a transition (process) from state z_i to state z_j, and output data y_s that appears in this transition.

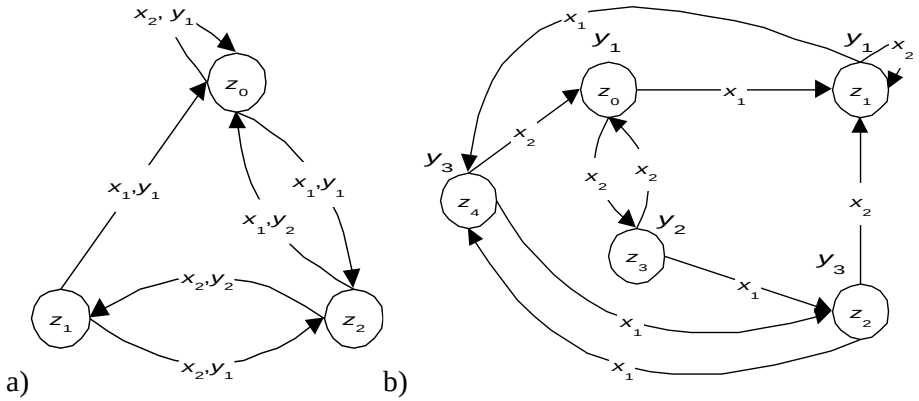

Figure 2: Graphs of ES systems (a) and the e-auction/cryptocurrency exchange (b)

For the F_1 system discussed above, the connection matrix will look as:

$$„_1 = \begin{Vmatrix} x_2 / y_1 & - & x_1 / y_1 \\ x_1 / y_1 & - & x_2 / y_2 \\ x_1 / y_2 & x_2 / y_1 & - \end{Vmatrix}$$

Suppose the transition (process) from state zi to state zj occurs under the action of multiple data streams. In that case, the element of the matrix c_{ij} is the set of input-output pairs for this transition connected by a disjunction sign. For the e-auction/cryptocurrency exchange *F*-system, the element c_{ij} is equal to the collection of input data flows during the transition (z_i, z_j), and the vector of the output data streams describes the output:

$$\bar{y} = \begin{Vmatrix} \psi(z_0) \\ \psi(z_1) \\ \dots \\ \psi(z_K) \end{Vmatrix}$$

i-th the component of which is the output data stream corresponding to the z_i state.

The F_2 system discussed above is the connection matrix and the output vector as follows:

$$„_1 = \begin{pmatrix} - & x_1 & - & x_2 & - \\ - & x_2 & - & - & x_1 \\ - & x_2 & - & - & x_1 \\ x_2 & - & x_1 & - & - \\ x_2 & - & x_1 & - & - \end{pmatrix}; \vec{y} = \begin{Vmatrix} y_1 \\ y_2 \\ y_3 \\ y_2 \\ y_3 \end{Vmatrix}$$

For *F*-systems, the concept of steady-state is introduced. A state z_k is said to be *stable* if for any input signal $x_i \in X$ when $\varphi(z_k,x_i) = z_k$,, the condition $\psi(z_k,x_i) = y_k$ holds. *F*-system processes are called *asynchronous* if each state $z_k \in Z$ is stable. An example of a graphical representation of an asynchronous e-auction/cryptocurrency exchange system is given in Fig. 3.

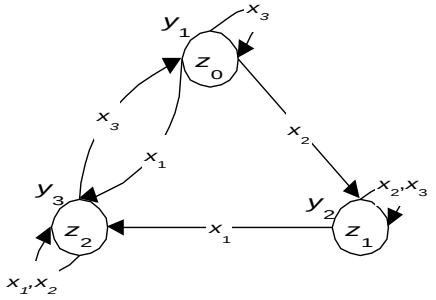

Figure 3: Graph of an asynchronous system for the e-auction/cryptocurrency exchange

In practice, ECS processes are always asynchronous, and the stability of their states is achieved in various ways, such as the introduction of threads/synchronisation processes. At the level of the abstract model, it is easier to operate finite synchronous operations of the ECS.

4. Experiments, results and discussion

The developed software product is designed to search for and fulfil arbitrage opportunities in the cryptocurrency market among some popular exchanges. The created application is called "arbitrage" and written in JavaScript, running on the Node.js platform. Several popular frameworks are used, including request, express, fs and others. The system is created using the Atom development environment. The developed software implementation of the program can be used as an information system for finding and analysing arbitrage opportunities in the cryptocurrency market among a wide range of exchanges and as management - for automation and control or reporting on arbitrage transactions. It is necessary to provide API keys from conversations with permission to trade, check balances, generate and obtain addresses for cryptocurrency deposit and permission to withdraw funds from the business to use this system, namely the automation of arbitrage transactions. It is also possible to control the system using third-party software - Telegram messenger, pre-creating a bot in it and giving the system it's API-key. Basic knowledge from the cryptocurrency principles peculiarities and a minimum understanding of the trading markets, in general, is needed to understand the processes taking place and manage the system. The software runs on operating systems such as Windows, Linux, Mac and all others that support installing the Node.js platform.

4.1. Classes of solvable problems and main characteristics and features of the program

The created software solves many problems, the end result of which is the detection of arbitrage situations in the cryptocurrency market among a number of exchanges; it is also possible to automatically conduct such transactions. After the user launches the system, the program makes a series of requests to the exchanges' servers to collect the necessary content [82-84]. It will be used to form a structured data set that will contain content on price changes in the cryptocurrency market on each of the exchanges presented in the system of cryptocurrency operations on these exchanges, etc. Based on the data previously described, their analysis is carried out by one of the components of the system, the result of which is the identification of arbitration opportunities. When the user agrees, the system executes the found arbitration transactions and notifies the user about their progress, from start to finish, in detail by sending information notifications.

The peculiarity of the program is that it can work in two modes:

1. An information system;
2. An information and management system.

In the first case, the system works purely as content when the user does not provide API keys from exchanges. Then the software only provides the ability to view the found arbitration opportunities and other data to the user that can be used for any purpose.

In the second case, the system provides the same function as in the first case, but if API keys from exchanges, the user can automatically conduct arbitrage transactions, thus controlling the process to carry out transactions on their exchange accounts. Checking the correctness of the system is carried out by the system itself. In case of an error, the system user will receive a detailed information message with its description. The user himself can hardly influence the program's correct operation because the input data and certain functionality do not affect the principles of the system. Information on functional limitations and applications to use this software requires a device running Windows, Linux, Mac, or any other operating system that supports the Node.js platform. As for the technical requirements, it is necessary to have a device with sufficient RAM and a modern processor to ensure fast calculation of operations, processing, and analysis of content for the system's productive operation. It is important to have high-speed Internet access, without which the system will not receive data and find solutions to problems and will be generally useless.

4.2. Analysis of the control example

Before starting the system itself, provided that the module that automates arbitrage transactions is used, the user must provide the system with API keys from their exchange accounts with permissions to perform

- Some transactions (the ability to trade, receive account information, withdraw cryptocurrencies);
- API key from the previously created bot in the Telegram messenger for the possibility of notifications and remote control of the system.

API keys are stored in the file arbitrage/automation/keys.json (Fig. 4).

keys.json

```
{
    "altilly":
    {
        "key":    "4d6d5901f95f497ebb6f7beaa451a611",
        "secret": "Y0hDW9lfK/ynuDyYIWL2uKKCjkTdHPSnAcJJtJ4pOFo="
    },
    "hitbtc":
    {
        "key":    "2e17d157d16d41f9ae185d08edce956f",
        "secret": "HP/yzKuRXdMUm6mXY/51X8R4dt9AIRueJGQGIfMKqTQ="
    }
}
```

Figure 4: The structure of the file containing the API keys

Next is the need to install the Node.js platform version 8.11.3 or later. The system itself is started using the console. You need to go to the project's root folder (arbitrage) and run the command "node app.js". If necessary, the system will load all the necessary modules for its operation at the first start. After their successful installation, the system itself starts working directly. Immediately after its launch, the system sends requests (Fig. 5). To the servers of exchanges, obtain the necessary data and their further analysis and processing, after which the corresponding exchange objects will be formed.

```
Poloniex build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
SouthXchange build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
STEX build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
Tidex build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
Txbit build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
VCCExchange build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Sending requests...
Warning!
API responses from Txbit have returned different number of markets!
/getmarkets: 229
/getmarketsummaries: 208
Txbit is ready. Timestamp: Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Elapsed time: 0.211 seconds.
Poloniex is ready. Timestamp: Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Elapsed time: 0.301 seconds.
Kuna is ready. Timestamp: Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).
Elapsed time: 0.307 seconds.
Tidex is ready. Timestamp: Mon May 11 2020 00:59:20 GMT+0300 (FLE Daylight Time).
Elapsed time: 0.344 seconds.
```

Figure 5: Sending requests by the system

It is followed by analysing the data contained in the objects of exchanges and the search for price differences. The next step is to run the analysis "in-depth" and generate results. The output of messages on the application of this analysis is shown in Figure 6.

```
Received NIM/BTC order book from HitBTC. Elapsed time: 1.511 seconds.
Received COCOS/BTC order book from HitBTC. Elapsed time: 1.534 seconds.
Received DCT/BTC order book from HitBTC. Elapsed time: 2.558 seconds.
Arbitrage opportunity "Bittrex:DCT-HitBTC:DCT" has been rejected!
Volume (0.00040200 BTC) is less than minimum trade size on Bittrex (0.0005 BTC).
Arbitrage opportunity "Bittrex:DCT-HitBTC:DCT" has been rejected!
Volume (0.00010700 BTC) is less than minimum trade size on Bittrex (0.0005 BTC).
Bittrex:DCT-HitBTC:DCT is not profitable at all!
Received BLUR/BTC order book from Txbit. Elapsed time: 0.374 seconds.
Txbit:BLUR-Altilly:BLUR is not profitable at all!
Received NIM/BTC order book from Hotbit. Elapsed time: 1.666 seconds.
Hotbit:NIM-HitBTC:NIM
Volume: 0.006621 BTC (64.22 $); 94349.250000 NIM; Profit: 0.000018 BTC (0.17 $) - 0.27 %
Received CND/BTC order book from Binance. Elapsed time: 1.365 seconds.
Received OLT/BTC order book from Kucoin. Elapsed time: 1.46 seconds.
Received AKRO/BTC order book from Kucoin. Elapsed time: 1.514 seconds.
Kucoin:AKRO-Bittrex:AKRO is not profitable at all!
Received OLT/BTC order book from Hotbit. Elapsed time: 1.464 seconds.
Kucoin:OLT-Hotbit:OLT is not profitable at all!
Received NPXS/BTC order book from Hotbit. Elapsed time: 2.161 seconds.
Hotbit:NPXS-Graviex:NPXS is not profitable at all!
Received LOOM/BTC order book from Kucoin. Elapsed time: 1.907 seconds.
Received CND/BTC order book from Livecoin. Elapsed time: 1.83 seconds.
Livecoin:CND-Binance:CND
Volume: 0.003200 BTC (31.04 $); 5883.778890 CND; Profit: 0.000007 BTC (0.07 $) - 0.22 %
```

Figure 6: The Execution of the system of analyses "in depth."

The results are presented on the main page of the system, located at 127.0.0.1:3000 (Fig. 7). On the main page, the user can disable or enable periodic data updates, hide the result of calculations "in depth", and set filters: select the list of exchanges to buy and sell, set the status of cryptocurrency exchanges, the ability to trade, choose quota currencies, etc. (Fig. 8). Below the page, there is an arbitration table (Fig. 9). It provides data on arbitrage situations found, without in-depth analysis, i.e. without considering volumes, but only the lowest selling price and the highest buying price in the stock exchange glass. The presentation of data on the found arbitration situations with the analysis "in depth" is given in Fig. 10.

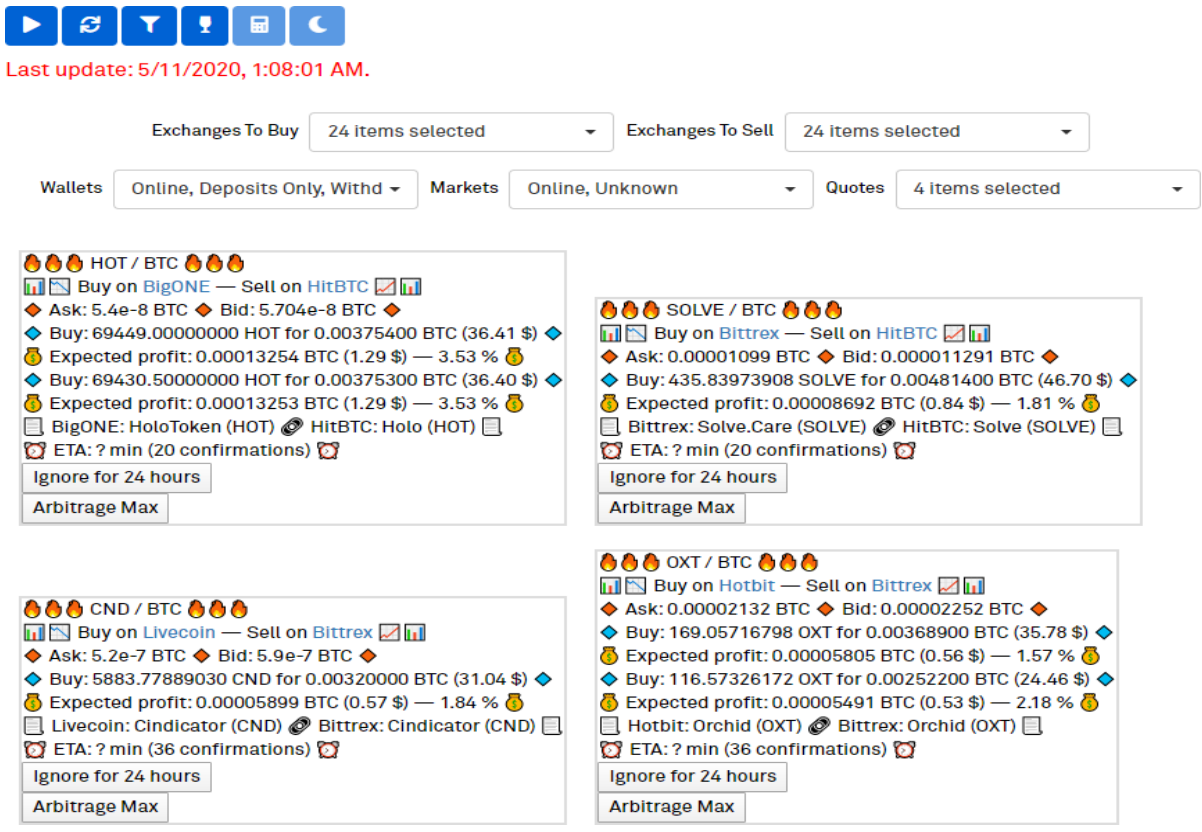

Figure 7: Home page of the system

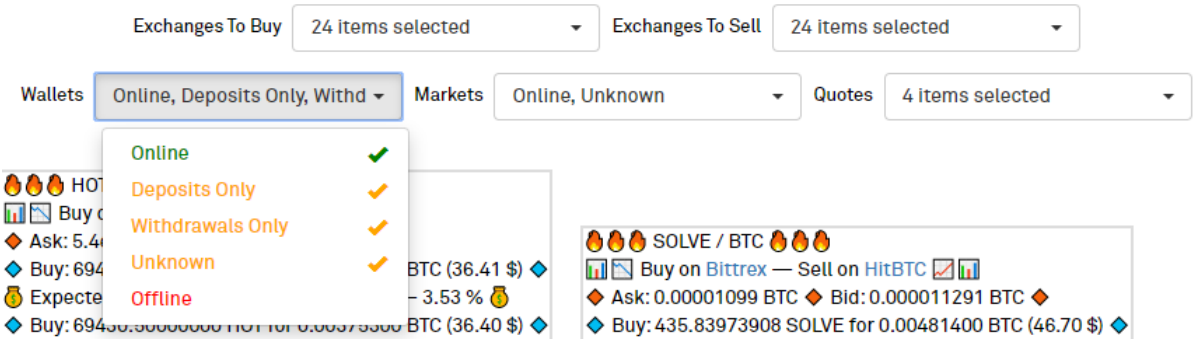

Figure 8: Filters for selection of results (wallet status filter is open)

% CHANGE	ASSET	QUOTE	BUY	WALLET STATUS	MARKET STATUS	ASK	BID	MARKET STATUS	WALLET STATUS	SELL	CONFIRMS
96.50	XCELTOKEN PLUS (XLAB)	BTC	Livecoin	Online	Unknown	0.00000001	0.00000002	Unknown	Online	Hotbit	?
95.75	Zencashcoin (ZEN)	USDT	Graviex	Online	Unknown	1.55850000	3.06000000	Unknown	Online	STEX	100
84.35	Hubii (HBT)	ETH	HitBTC	Online	Unknown	0.00041230	0.00080010	Unknown	Online	Altilly	20
80.88	Absolute (ABS)	BTC	STEX	Online	Unknown	0.00000016	0.00000029	Online	Withdrawals Only	Crex24	95
69.71	VouchForMe (IPL)	BTC	HitBTC	Online	Unknown	0.00000013	0.00000024	Unknown	Withdrawals Only	Livecoin	?
68.48	Credits (CS)	BTC	Kucoin	Online	Online	0.00000384	0.00000650	Online	Withdrawals Only	Mercatox	?
68.32	IQ Receipt (IQ)	ETH	Hotbit	Online	Unknown	0.00005887	0.00010000	Online	Online	Mercatox	?
67.41	Credits (CS)	ETH	Kucoin	Online	Online	0.00017850	0.00030004	Online	Withdrawals Only	Mercatox	?

Figure 9: The Arbitration table

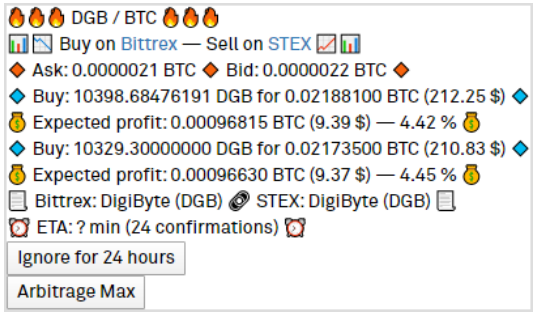

Figure 10: Presentation of the search result of the arbitration situation

This message consists of:

- The name of the cryptocurrency pair,
- The terms of exchanges for buying and selling,
- The names of cryptocurrencies on various exchanges and their tickers,
- A direct link to trading on these exchanges, the amount that can be purchased,
- The amount of purchase and sale,
- Potential profit,
- Approximate the time of the transaction and the number of required confirmations in the cryptocurrency network needed for the exchange, where it is transferred, etc.

When an API key is provided to a bot in Telegram Messenger, the user is immediately notified that an arbitration situation has been found according to predefined criteria. The message sent (Fig. 11) is identical to the content provided on the system's main page. Sending notifications to the messenger eliminates the need for the user to be constantly near the monitor screen to wait for the arbitration transaction.

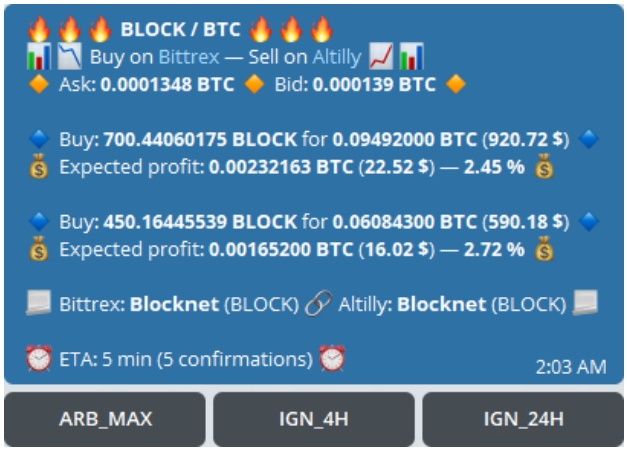

Figure 11: The Telegram messenger interface. Notification of finding an arbitration transaction

Both on the system's web page and with the help of a bot in the Telegram messenger, the user has the opportunity to conduct an arbitration transaction. It is done by clicking the appropriate button below the message. It is also possible to ignore a specific transaction. For one reason or another, the arbitrage option with the specified parameters will be missed by searching for the selected period. If the user has decided to conduct an arbitration transaction and clicked on the appropriate button, the messenger receives a message about its successful acceptance for processing by the system (Fig. 12).

Figure 12: The Notification of acceptance of the arbitration transaction for processing by the system

The following notification to the user is receiving a message about the amount of purchased cryptocurrency and spent quota currency (Fig. 13).

Figure 13: The Notification of purchased cryptocurrency

The last notification is the result of the arbitration transaction (Fig. 14). The message consists of the following data:

- Transaction ID,
- Cryptocurrency name,
- Ticker,
- Names of exchanges for buying and selling realised profit,
- Conversion of realised profit into dollar (at the current rate or the rate specified in the system code),

- Percentage change in balance,
- Quantity of purchased cryptocurrency,
- The amount of received quota,
- The number of cryptocurrencies that was not sold,
- At the time of the transaction,
- The initial parameters for buying and selling etc.

In case of an error, the user receives a message with a detailed description (Fig. 15).

Figure 14: The Notification of the completion of the arbitration transaction and its outcome

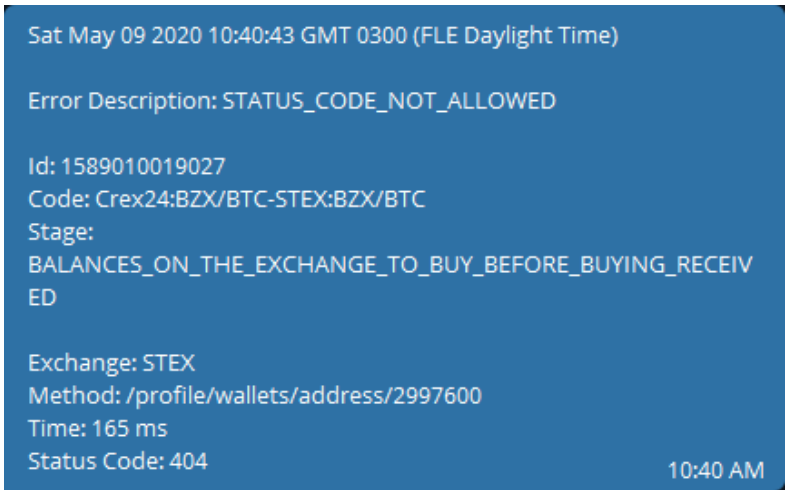

Figure 15: The Displays an error notification

To end the program, press Ctrl + C in the console with the system running.

The functionality of the developed system, principles and features of work, its purpose are considered. Input and output files, their contents, the structure of intermediate data used by the system's main processes are described. A control example of using the program is given, and starting and installing the system is considered.

5. Conclusions

This paper examines the development of EC in Ukraine, disadvantages, advantages, services, security systems and payments through IN. A key part of the article is the development of methods for determining the efficiency of the ECS, and the mathematical model of the information ECS is proposed.

The article describes the developed software solution of the information system for searching for arbitrage situations in the cryptocurrency market. According to requirements, the description of software implementation is carried out according to the standard (GOST 19.402-78). The programming language used in system development, frameworks, development environment and other technologies used in system development are indicated. The technical requirements for the installation and proper functioning of the developed system are determined. A user manual has created that contains the necessary content on the specifics of the operation of this software. The functionality of the developed system, principles and features of work, its purpose are considered. Input and output files, their contents, the structure of intermediate data used by the system's main processes are described. A control example of using the program is given, and starting and installing the system is considered.

6. References

[1] V. Vysotska, L. Chyrun, L. Chyrun, Information Technology of Processing Information Resources in Electronic Content Commerce Systems, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2016, pp. 212-222.

[2] A. Berko, V. Vysotska, Modeli ta metody proektuvannya informatsiynykh system elektronnoyi komertsiyi, volume 138 of ASU y prybory avtomatyky, 2007, pp. 55-66

[3] M. I. Bublyk, R. V. Medvid, Current trends and prospects of e-business development in condition of Ukraine's european integration, volume 899 of Bulletin of Lviv Polytechnic National University, Series: Management and Entrepreneurship in Ukraine: Stages of Formation and Problems of Development, 2018, pp. 31-39.

[4] P. Cunningham, Friedrich Fröschl Electronic Business Revolution, Springer, 1999.

[5] V. Lytvyn, V. Vysotska, Designing architecture of electronic content commerce system, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2015, pp. 115-119.

[6] V. Vysotska, R. Hasko, V. Kuchkovskiy, Process analysis in electronic content commerce system, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2015, pp. 120-123.

[7] D. Chaffey, T. Hemphill, D. Edmundson-Bird, Digital Business and E-commerce Management Pearson, 2018.

[8] V. Vysotska, L. Chyrun, Methods of information resources processing in electronic content commerce systems, in: Proceedings of 13th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM 2015-February, 2015.

[9] L. V. Hranat, Korporatyvni brendy internet-mahazyniv: bencharmarky ta tendentsiyi, volume 3 of Molodyy vchenyy, 2018, pp. 336-340.

[10] H. Lipyanina, A. Sachenko, T. Lendyuk, S. Nadvynychny, S. Grodskyi, Decision tree based targeting model of customer interaction with business page, volume Vol-2608 of CEUR Workshop Proceedings, 2020, pp. 1001-1012.

[11] R. Yurynets, Z. Yurynets, I. Myshchyshyn, N. Zhyhaylo, A. Pekhnyk, Optimal Strategy for the Development of Insurance Business Structures in a Competitive Environment, volume Vol-2631 of CEUR Workshop Proceedings, 2020, pp. 79-94.

[12] R. Yurynets, Z. Yurynets, M. Kokhan, Econometric Analysis of the Impact of Expert Assessments on the Business Activity in the Context of Investment and Innovation Development, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 680-694.

[13] V. Lytvyn, V. Vysotska, A. Demchuk, I. Demkiv, O. Ukhanska, V. Hladun, R. Kovalchuk, O. Petruchenko, L. Dzyubyk, N. Sokulska, Design of the architecture of an intelligent system for distributing commercial content in the internet space based on SEO-technologies, neural networks, and Machine Learning, volume 2(2-98) of Eastern-European Journal of Enterprise Technologies, 2019, pp. 15-34. https://doi.org/10.15587/1729-4061.2019.164441

[14] O. Krinitsyn, B2C v elektronniy komertsiyi: Yevropeys′kyy vektor Ukrayiny, USAID LEV, 2016. URL: http://lev.org.ua/articles/b2c_in_ecommerece.html.

[15] V. Vysotska, A. Berko, M. Bublyk, L. Chyrun, A. Vysotsky, K. Doroshkevych, Methods and tools for web resources processing in e-commercial content systems, in: Proceedings of 15th

International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT, 1, 2020, pp. 114-118.
[16] K. Alieksieieva, A. Berko, V. Vysotska, Technology of commercial web-resource processing, in: Proceedings of 13th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM 2015-February, 2015.
[17] V. Vysotska, I. Rishnyak, L. Chyrun, Analysis and evaluation of risks in electronic commerce, in: Proceedings of the 9th International Conference of CAD Systems in Microelectronics, 2007, pp. 332-333.
[18] V. Andrunyk, L. Chyrun, V. Vysotska, Electronic content commerce system development, in: Proceedings of 13th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM 2015-February, 2015.
[19] V. Vysotska, L. Chyrun, L. Chyrun, The Commercial Content Digest Formation and Distributional Process, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2016, pp. 186-189.
[20] V. Lytvyn, V. Vysotska, V. Shatskykh, I. Kohut, O. Petruchenko, L. Dzyubyk, V. Bobrivetc, V. Panasyuk, S. Sachenko, M. Komar, Design of a recommendation system based on Collaborative Filtering and machine learning considering personal needs of the user, volume 4(2-100) of Eastern-European Journal of Enterprise Technologies, 2019, pp. 6-28.
[21] P. Pukach, K. Shakhovska, The Mathematical Method Development of Decisions Supporting Concerning Products Placement Based on Analysis of Market Basket Content, in: Proceedings of the Experience of Designing and Application of CAD Systems in Microelectronics, CADSM, 2017, pp. 347-350.
[22] V. Vysotska, V.B. Fernandes, M. Emmerich, Web content support method in electronic business systems, volume Vol-2136 of CEUR Workshop Proceedings, 2018, pp. 20-41.
[23] S. Orekhov, H. Malyhon, I. Liutenko, T. Goncharenko, Using Internet News Flows as Marketing Data Component, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 358-373.
[24] I. Oksanych, I. Shevchenko, I. Shcherbak, S. Shcherbak, Development of specialised services for predicting the business activity indicators based on micro-service architecture, volume 2(2-86) of Eastern-European Journal of Enterprise Technologies, 2017, pp. 50-55.
[25] A. Berko, Consolidated data models for electronic business systems, in: Proceedings of The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM, 2007, pp. 341-342.
[26] A.Y. Berko, Methods and models of data integration in E-business systems, volume 10 of Actual Problems of Economics, 2008, pp. 17-24.
[27] A.Y. Berko, Models of data integration in open information systems, volume 10 of Actual Problems of Economics, 2010, pp. 147-152.
[28] A.Y. Berko, K.A. Aliekseyeva, Quality evaluation of information resources in web-projects, volume 136(10) of Actual Problems of Economics, 2012, pp. 226-234.
[29] A. Berko, V. Alieksieiev, A Method to Solve Uncertainty Problem for Big Data Sources, in: Proceedings of International Conference on Data Stream Mining and Processing, DSMP, 2018, pp. 32-37.
[30] A. Gozhyj, I. Kalinina, V. Vysotska, S. Sachenko, R. Kovalchuk, Qualitative and Quantitative Characteristics Analysis for Information Security Risk Assessment in E-Commerce Systems, volume Vol-2762 of CEUR Workshop Proceedings, 2020, pp. 177-190.
[31] A. Demchuk, V. Lytvyn, V. Vysotska, M. Dilai, Methods and Means of Web Content Personalization for Commercial Information Products Distribution, volume 1020 of Advances in Intelligent Systems and Computing, 2020, pp. 332–347.
[32] O. Artemenko, V. Pasichnyk, N. Kunanets, K. Shunevych, Using sentiment text analysis of user reviews in social media for e-tourism mobile recommender systems, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 259-271.
[33] B. Rusyn, L. Pohreliuk, O. Kapshii, J. Varetskyy, A. Demchuk, I. Karpov, A. Gozhyj, V. Gozhyj, I. Kalinina, An Intelligent System for Commercial of Information Products Distribution Based SEO and Sitecore CMS, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 760-777.

[34] B.E. Kapustiy, B.P. Rusyn, V.A. Tayanov, Peculiarities of Application of Statistical Detection Criteria for Problem of Pattern Recognition, volume 37(2) of Journal of Automation and Information Science, 2005, pp. 30-36.
[35] B. Rusyn, V. Lytvyn, V. Vysotska, M. Emmerich, L. Pohreliuk, The Virtual Library System Design and Development, volume 871 of Advances in Intelligent Systems and Computing, 2019, pp. 328-349.
[36] B. Rusyn, V. Vysotska, L. Pohreliuk, Model and architecture for virtual library information system, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2018, pp. 37-41.
[37] V. Lytvyn, V. Vysotska, B. Rusyn, L. Pohreliuk, P. Berezin, O. Naum, Textual Content Categorizing Technology Development Based on Ontology, volume Vol-2386 of CEUR Workshop Proceedings, 2019, pp. 234-254.
[38] V. Lytvyn, V. Vysotska, I. Peleshchak, T. Basyuk, V. Kovalchuk, S. Kubinska, L. Chyrun, B. Rusyn, L. Pohreliuk, T. Salo, Identifying Textual Content Based on Thematic Analysis of Similar Texts in Big Data, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2019, pp. 84-91.
[39] V. Vysotska, V. Lytvyn, V. Kovalchuk, S. Kubinska, M. Dilai, B. Rusyn, L. Pohreliuk, L. Chyrun, S. Chyrun, O. Brodyak, Method of Similar Textual Content Selection Based on Thematic Information Retrieval, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2019, pp. 1-6.
[40] O. Veres, B. Rusyn, A. Sachenko, I. Rishniak, Choosing the mathod of finding similar images in the reverse search system, volume Vol-2136 of CEUR Workshop Proceedings, 2018, pp.99-107.
[41] V. Husak, O. Lozynska, I. Karpov, I. Peleshchak, S. Chyrun, A. Vysotskyi, Information System for Recommendation List Formation of Clothes Style Image Selection According to User's Needs Based on NLP and Chatbots, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 788-818.
[42] S. Makara, L. Chyrun, Y. Burov, Z. Rybchak, I. Peleshchak, R. Peleshchak, R. Holoshchuk, S. Kubinska, A. Dmytriv, An Intelligent System for Generating End-User Symptom Recommendations Based on Machine Learning Technology, volume Vol-2604 of CEUR Workshop Proceedings, 2020, pp. 844-883.
[43] O. Soprun, M. Bublyk, Y. Matseliukh, V. Andrunyk, L. Chyrun, I. Dyyak, A. Yakovlev, M. Emmerich, O. Osolinsky, A. Sachenko, Forecasting temperatures of a synchronous motor with permanent magnets using machine learning, volume Vol-2631 of CEUR workshop proceedings, 2020, pp. 95-120.
[44] D. Koshtura, M. Bublyk, Y. Matseliukh, D. Dosyn, L. Chyrun, O. Lozynska, I. Karpov, I. Peleshchak, M. Maslak, O. Sachenko, Analysis of the demand for bicycle use in a smart city based on machine learning, volume Vol-2631 of CEUR workshop proceedings, 2020, pp. 172-183.
[45] L. Podlesna, M. Bublyk, I. Grybyk, Y. Matseliukh, Y. Burov, P. Kravets, O. Lozynska, I. Karpov, I. Peleshchak, R. Peleshchak, Optimisation model of the buses number on the route based on queueing theory in a smart city, volume Vol-2631 of CEUR workshop proceedings, 2020, pp. 502-515.
[46] I. Bodnar, M. Bublyk, O. Veres, O. Lozynska, I. Karpov, Y. Burov, P. Kravets, I. Peleshchak, O. Vovk, O. Maslak, Forecasting the risk of cervical cancer in women in the human capital development context using machine learning, volume Vol-2631 of CEUR workshop proceedings, 2020, pp. 491-501.
[47] M. Bublyk, Y. Matseliukh, U. Motorniuk, M. Terebukh, Intelligent system of passenger transportation by autopiloted electric buses in Smart City, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 1280-1294.
[48] Y. Matseliukh, V. Vysotska, M. Bublyk, Intelligent System of Visual Simulation of Passenger Flows, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 906-920.
[49] A. Berko, I. Pelekh, L. Chyrun, M. Bublyk, I. Bobyk, Y. Matseliukh, L. Chyrun, Application of ontologies and meta-models for dynamic integration of weakly structured data, in: Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP, 2020, pp. 432-437.

[50] M. Bublyk, V. Vysotska, Y. Matseliukh, V. Mayik, M. Nashkerska, Assessing losses of human capital due to man-made pollution caused by emergencies, volume Vol-2805 of CEUR Workshop Proceedings, 2020, pp. 74-86.
[51] I. Rishnyak, O. Veres, V. Lytvyn, M. Bublyk, I. Karpov, V. Vysotska, V. Panasyuk, Implementation models application for IT project risk management, volume Vol-2805 of CEUR Workshop Proceedings, 2020, pp. 102-117.
[52] I. Kalinina, V. Vysotska, P. Bidyuk, A. Gozhyj, M. Vasilev, R. Malets, Forecasting Nonlinear Nonstationary Processes in Machine Learning Task, in: Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP, 2020, pp. 28-32.
[53] N. Shpak, N. Seliuchenko, V. Kharchuk, N. Kosar, W. Sroka, Evaluation of Product Competitiveness: A Case Study Analysis, volume 52(2) of Organizacija, 2019, pp. 107-125. DOI: 10.2478/orga-2019-0008.
[54] N. Shpak, N. Podolchak, V. Karkovska, W. Sroka, The Influence of Age Factors on the Reform of the Public Service of Ukraine, volume 13(2) of Central European Journal of Public Policy, 2019, pp. 40-52. DOI: 10.2478/cejpp-2019-0006.
[55] N. Shpak, Z Dvulit, T. Luchnikova, W. Sroka, Strategic development of cargo transit services: a case study analysis, volume 10(4) of Engineering Management in Production and Services, 2018, pp. 76-84. DOI: 10.2478/emj-2018-0024.
[56] N. Shpak, O. Kuzmin, Z. Dvulit, T. Onysenko, W. Sroka, Digitalization of the Marketing Activities of Enterprises: Case Study, volume 11 of Information, 2020, p. 109. DOI: 10.3390/info11020109.
[57] N. Shpak, O. Kuzmin, O. Melnyk, M. Ruda, W. Sroka, Implementation of a Circular Economy in Ukraine: The Context of European Integration, volume 9(8) of Resources, 2020, p. 96. DOI: 10.3390/resources9080096.
[58] M. Sharko, N. Shpak, O. Gonchar, K. Vorobyova, O. Lepokhina, J. Burenko, Methodological basis of causal forecasting of the economic systems development management processes under the uncertainty, volume 1246 of Advances in Intelligent Systems and Computing, AISC, 2021, pp. 423-436. DOI: 10.1007/978-3-030-54215-3_27.
[59] N. Shpak, T. Kyrylych, J. Greblikaite, Diversification Models of Sales Activity for Steady Development of an Enterprise, volume 8(4) of Sustainability, 2016. DOI: 10.3390/su8040393.
[60] OD. Vytvytska, O.A. Martynyuk, N.O. Shpak, G.T. Karcheva, I.P. Medynsky, L.S. Nodzhak, Modern Structural-functional modeling for the determination of the company's equilibrium conditions in the dynamic business environment, volume 7(1) of Mathematical Modeling and Computing, 2020, pp. 104-111. DOI: 10.23939/mmc2020.01.104.
[61] Y. Tverdokhlib, V. Andrunyk, L. Chyrun, L. Chyrun, N. Antonyuk, I. Dyyak, O. Naum, D. Uhryn, V. Basto-Fernandes, Analysis and Estimation of Popular Places in Online Tourism Based on Machine Learning Technology, volume Vol-2631 of CEUR Workshop Proceedings, 2020, pp P. 457-470.
[62] L. Chyrun, I. Turok, I. Dyyak, Information Model of the Tendering System for Large Projects, volume Vol-2604 of CEUR Workshop Proceedings, 2020, pp. 1224-1236.
[63] A. Vysotsky, V. Lytvyn, V. Vysotska, D. Dosyn, I. Lyudkevych, N. Antonyuk, O. Naum, A. Vysotskyi, L. Chyrun, O. Slyusarchuk, Online Tourism System for Proposals Formation to User Based on Data Integration from Various Sources, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2019, pp. 92-97. DOI: 10.1109/STC-CSIT.2019.8929849
[64] V. Lytvyn, A. Gozhyj, I. Kalinina, V. Vysotska, V. Shatskykh, L. Chyrun, Y. Borzov, An intelligent system of the content relevance at the example of films according to user needs, volume Vol-2516 of CEUR Workshop Proceedings, 2019, pp. 1-23.
[65] Y. Kis, L. Chyrun, T. Tsymbaliak, L. Chyrun, Development of System for Managers Relationship Management with Customers, volume 1020 of Lecture Notes in Computational Intelligence and Decision Making, 2020, p. 405-421.
[66] N. Antonyuk, A. Vysotsky, V. Vysotska, V. Lytvyn, Y. Burov, A. Demchuk, I. Lyudkevych, L. Chyrun, S. Chyrun, I. Bobyk, Consolidated Information Web Resource for Online Tourism Based on Data Integration and Geolocation, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2019, pp. 15-20. DOI: 10.1109/STC-CSIT.2019.8929790

[67] L. Chyrun, A. Kowalska-Styczen, Y. Burov, A. Berko, A. Vasevych, I. Pelekh, Y. Ryshkovets, Heterogeneous Data with Agreed Content Aggregation System Development, volume Vol-2386 of CEUR Workshop Proceedings, 2019, pp. 35-54.
[68] L. Chyrun, Y. Burov, B. Rusyn, L. Pohreliuk, O. Oleshek, A. Gozhyj, I. Bobyk, Web Resource Changes Monitoring System Development, volume Vol-2386 of CEUR Workshop Proceedings, 2019, pp. 255-273.
[69] L. Chyrun, A. Gozhyj, I. Yevseyeva, D. Dosyn, V. Tyhonov, M. Zakharchuk, Web Content Monitoring System Development, volume Vol-2362 of CEUR Workshop Proceedings, 2019, pp. 126-142.
[70] A. Gozhyj, I. Kalinina, V. Gozhyj, V. Vysotska, Web service interaction modeling with colored petri nets, in: Proceedings of International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS, 1, 2019, pp. 319-323.
[71] C. C. Wei, DNA approach for password conversion generator, in: Proceedings of International Symposium on Biometrics and Security Technologies, ISBAST, 2014, pp. 161-165.
[72] V. V. Solov'ev, T. N. Grzes, (). An iteration algorithm of coding internal states of finite-state machines for minimising the power consumption, volume 42(3) of Russian Microelectronics, 2013, pp. 189-195.
[73] T. Bultan, X. Fu, R. Hull, J. Su, Conversation specification: a new approach to design and analysis of e-service composition, in: Proceedings of the 12th international conference on World Wide Web, 2003, pp. 403-410.
[74] L. Rodriguez-Benitez, J. Moreno-Garcia, J. Castro-Schez, C. Solana, L. Jimenez, Action recognition in video sequences using a mealy machine, volume 31 of World Congress of Science, Engineering and Technology, 2008, pp. 42-48.
[75] Z. Xiaodong, C. Dianhui, M. Meng, The flexible design and research technology of mobile commerce in: Proceedings of the International Conference on Computer Application and System Modeling, ICCASM, 5, 2010, pp. V5-472.
[76] R. Hull, J. Su, Tools for composite web services: a short overview, volume 34(2) of ACM SIGMOD Record, 2005, pp. 86-95.
[77] M. Núñez, I. Rodríguez, F. Rubio, Specification and testing of autonomous agents in e-commerce systems, volume 15(4) of Software Testing, Verification and Reliability, 2005, pp. 211-233.
[78] M. Li, S. Shao, Q. Ye, G. Xu, G. Q. Huang, Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail, volume 65 of Robotics and Computer-Integrated Manufacturing, 65, 2020, p. 101962.
[79] F. Howar, B. Jonsson, M. Merten, B. Steffen, S. Cassel, On handling data in automata learning, in: Proceedings of the International Symposium On Leveraging Applications of Formal Methods, Verification and Validation, 2010, pp. 221-235.
[80] R. Hull, M. Benedikt, V. Christophides, J. Su, E-services: a look behind the curtain, in: Proceedings of the twenty-second ACM SIGMOD-SIGACT-SIGART symposium on Principles of database systems, 2003, pp. 1-14.
[81] M. Merten, F. Howar, B. Steffen, P. Pellicione, M. Tivoli, Automated inference of models for black box systems based on interface descriptions, in: Proceedings of the International Symposium On Leveraging Applications of Formal Methods, Verification and Validation, 2012, pp. 79-96.
[82] V. Lytvyn, R. Vovnyanka, O. Oborska, D. Dosyn, V. Vysotska, V. Panasyuk, Intelligent Agent Behavior Simulation Based on Reinforcement Learning, in: Proceedings of the 15th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT, 2020, 1, pp. 285-290.
[83] V. Lytvyn, V. Kuchkovskiy, V. Vysotska, O. Markiv, V. Pabyrivskyy, Architecture of system for content integration and formation based on cryptographic consumer needs, in: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 2018, pp. 391-395.
[84] V. Lytvyn, V. Vysotska, V. Kuchkovskiy, I. Bobyk, O. Malanchuk, Y. Ryshkovets I. Pelekh, O. Brodyak, V. Bobrivetc, V. Panasyuk, Development of the system to integrate and generate content considering the cryptocurrent needs of users, volume 1(2-97) of Eastern-European Journal of Enterprise Technologies, 2019, pp. 18-39.