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

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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 exchange\textsuperscript{a} 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.

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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).](image)

*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.

<table>
<thead>
<tr>
<th>Years</th>
<th>Online sales, billion euros</th>
<th>Growth rates, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>1,54</td>
<td>25,9</td>
</tr>
<tr>
<td>2019</td>
<td>1,72</td>
<td>26,2</td>
</tr>
<tr>
<td>2020</td>
<td>1,91</td>
<td>26,5</td>
</tr>
<tr>
<td>2021</td>
<td>2,09</td>
<td>26,7</td>
</tr>
<tr>
<td>2022</td>
<td>2,28</td>
<td>27,0</td>
</tr>
</tbody>
</table>

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

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]:

\[
\begin{align*}
  z(t + 1) &= \varphi(z(t), x(t)), t = 0, 1, 2, \\
y(t) &= \psi(z(t), x(t)), t = 0, 1, 2, 
\end{align*}
\]  

(1)  

(2)

where \(x(t)\) is the input data at time \(t\),  
\(z(t)\) is the state of the ECS at the time \(t\), 
\(\varphi\) is the function of transitioning the system to the next state \(z(t+1)\), 
\(\psi\) 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]:

\[
\begin{align*}
  z(t + 1) &= \varphi(z(t), x(t)), t = 0, 1, 2, \\
y(t) &= \psi(z(t), x(t-1)), t = 0, 1, 2, 
\end{align*}
\]  

(3)  

(4)

where \(x(t)\) is the input data at time \(t\),  
\(z(t)\) is the state of the ECS at the time \(t\), 
\(\varphi\) is the function of transitioning the system to the next state \(z(t+1)\), 
\(\psi\) is the function of output data at the time \(t\), 
\(y(t)\) is the output at the time \(t\) of the input data \(x(t-1)\).

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

\[
  y(t) = \psi[z(t)], t = 0, 1, 2, ..., 
\]  

(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]:

\[
  y(t) = \psi[x(t)], t = 0, 1, 2, ..., 
\]  

(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 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 times. 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 \( F = \langle Z, X, Y, \varphi, \psi, z_0 \rangle \)) 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 \( \varphi(z_i, x_k) \), and in the output table, the corresponding value of the process of outputs \( \psi(z_i, x_k) \) [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

<table>
<thead>
<tr>
<th>( x_1 )</th>
<th>( \varphi(z_0, x_1) )</th>
<th>( \varphi(z_1, x_1) )</th>
<th>...</th>
<th>( \varphi(z_k, x_1) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_2 )</td>
<td>( \varphi(z_0, x_2) )</td>
<td>( \varphi(z_1, x_2) )</td>
<td>...</td>
<td>( \varphi(z_k, x_2) )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( x_i )</td>
<td>( \varphi(z_0, x_i) )</td>
<td>( \varphi(z_1, x_i) )</td>
<td>...</td>
<td>( \varphi(z_k, x_i) )</td>
</tr>
</tbody>
</table>

### Table 4

EC system outputs function

<table>
<thead>
<tr>
<th>( z_0 )</th>
<th>( z_1 )</th>
<th>...</th>
<th>( z_k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_1 )</td>
<td>( \psi(z_0, x_1) )</td>
<td>( \psi(z_1, x_1) )</td>
<td>...</td>
</tr>
<tr>
<td>( x_2 )</td>
<td>( \psi(z_0, x_2) )</td>
<td>( \psi(z_1, x_2) )</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( x_i )</td>
<td>( \psi(z_0, x_i) )</td>
<td>( \psi(z_1, x_i) )</td>
<td>...</td>
</tr>
</tbody>
</table>

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 \( \psi(z_k) \) [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

<table>
<thead>
<tr>
<th>( \psi(z_0) )</th>
<th>( \psi(z_1) )</th>
<th>( \psi(z_k) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( z_0 )</td>
<td>( \varphi(z_0, x_1) )</td>
<td>( \varphi(z_1, x_1) )</td>
</tr>
<tr>
<td>( z_1 )</td>
<td>( \varphi(z_0, x_2) )</td>
<td>( \varphi(z_1, x_2) )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( z_i )</td>
<td>( \varphi(z_0, x_i) )</td>
<td>( \varphi(z_1, x_i) )</td>
</tr>
</tbody>
</table>

An example of a table problem of the \( F \)-system \( F_1 \) 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].
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 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 $C = [c_{ij}]$, 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:

$$
\begin{bmatrix}
  x_2 / y_1 & x_1 / y_1 \\
  x_1 / y_1 & x_2 / y_2 \\
  x_1 / y_2 & x_2 / y_2
\end{bmatrix}
$$

Suppose the transition (process) from state $z_i$ to state $z_j$ 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:

$$
\tilde{y} = \begin{bmatrix}
  \psi(z_0) \\
  \psi(z_1) \\
  \vdots \\
  \psi(z_K)
\end{bmatrix}
$$

$i$-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:

$$
\begin{bmatrix}
  - x_1 & - x_2 & - \\
  - x_2 & - - x_1 \\
  - x_1 & - - x_1 \\
  x_2 & - - x_1 \\
  x_2 & - - x_1
\end{bmatrix} \tilde{y} = \begin{bmatrix}
  y_1 \\
  y_2 \\
  y_3 \\
  y_4 \\
  y_5
\end{bmatrix}
$$

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).

```
keysjson

1 {  
2   "altilly":  
3   {  
4     "key": "4d6d5901f95f497eb6f7beaa451a611",
5     "secret": "Y0hDw91FK/yndY1wL2uKJCjTdHPsnAcJJt34p0Foz=
6   },
7   "hitbtc":  
8   {  
9     "key": "3e17d157d16d1f9ae85d08edce956f",
10    "secret": "HP/y2kRXdUMw6XY/51X8R4dt9A1Rue3GQ6IfMKqTQz=
11   }
12 }
```

**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...  
Tbbit build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).  
Sending requests...  
VCExchange build method was executed at Mon May 11 2020 00:59:19 GMT+0300 (FLE Daylight Time).  
Sending requests...  
Warning!  
API responses from Tbbit have returned different number of markets!  
```

**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.
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.

![Home page of the system](image)

**Figure 7: Home page of the system**
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.
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).

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

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.

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