Innovative Complex of Information and Technological Support of Professional Training in Smart Cities

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Abstract. It is proposed the training process of qualified specialists in accordance with the needs of a person and the requirements of the labor market in the smart city to be presented in the form of five consecutive functional stages: determination of professional inclinations and abilities; monitoring of the urban labor market; a choice of the future profession; a choice of educational institution; formation of an individual learning trajectory.
The paper provides the description of the architecture developed by the authors and the processes of main modules of the program and algorithmic complex of information and technological support for the training of specialists in smart cities. The peculiarities of program realization are revealed as well as the system functioning and the technical characteristics of the software product.

Keywords: smart city, OLAP, hypercube, knowledge potential, career orientation test, web application.

1 Introduction

In modern information society, an innovative type of social existence is formed, where everyone is technologically and institutionally guaranteed the effective implementation of two important information processes: the first one is free creation and dissemination, and the second one is receiving and processing of information [1, 2].

The formation of this social system led to a series of information and technological transformations and generated new tasks, the solution of which is possible only in the context of interdisciplinary research related, in particular, to the formation of high-tech social and communication environments in the cities that are actively turning into social polis with complex infrastructures [3]. These infrastructures need to be effectively shaped, developed, modernized and adapted to the needs of communities. One of the effective concepts of implementing such approach is the concept of smart city, which provides a radical reorganization of all life spheres in the city, including the social and communication environment based on modern information and communication technologies [4, 5]

According to the analysts, the city can be defined as smart provided that investments will focus on the training of a highly educated workforce, which serves as a

main driver of the city's innovative development. As a result, a new transformational paradigm has been formed, which IBM experts call the educational continuum, which includes: life-long learning technologies, data analysis for student and institutional data and performance indicators, personalized learning trajectories, the use of the acquired competences for the development of the economy and the growth of the city potential as a whole.

A significant number of large and small cities in the world use this innovation to implement projects that ensure their development with the introduction of intelligent digital information, communication networks and technologies. This, in turn, requires the development of unique innovative models of the hyper-complex system, which is a modern city, taking into account historical, mental, religious, political and economic peculiarities, and conducting systematic research on an interdisciplinary platform [6].

The city's social and communication environment is formed and functions in a complex system of information flows, where on the basis of modern communication networks, information and communication technology complexes, processes of creation, processing, storage and transmission of information between subjects that communicate take place. It combines medical, educational, cultural, scientific institutions, structures of municipal government, mass media, and others [7-10].

In such conditions, the need to develop a software and algorithmic complex that would implement the basic principles of information and technology support of the qualified specialist training in accordance with the needs of an individual and the requirements of the labor market in a smart city becomes evident.

The **purpose** of the paper is to formulate a set of requirements, system functional characteristics, analysis, architecture construction and program implementation of the software and algorithmic complex of information and technological support of specialist training in accordance with the needs of an individual and the requirements of the labor market in smart cities.

1.1 Related Work

Information systems that are used today to accompany the profession choice in cities are not effective enough. In particular, there is practically no possibility in one information point to analyze information about a person as an object of vocational and educational work and to obtain comprehensive information and analytical data of the regional labor market and educational services. Information is mainly provided without proper adequacy and structuring.

Information sources about the vocational orientation of the World Wide Web are divided into integrated and independent web pages.

Integrated web pages are pages of professional counseling organizations and institutions. They contain both general and specific information for this institution.

Independent web pages are non-interlinked web pages that include information about vacancies, professions, educational offers for schools and higher education institutions, work offers with company descriptions, as well as they assist in making decisions about choosing the future profession or about its change.

According to the functional purpose, information technologies focused on providing solutions to the problems of professional orientation of young people can be conditionally divided into the following classes:

The sites of educational institutions that inform about the terms of the entry and training directions, aimed, above all, at encouraging graduates to enter this or that higher educational institution. Such resources are not oriented to maintaining the processes of individual choice of profession, they do not give grounded advice to an entrant, but instead they create uncertainty about the profession, as a young person hesitates about several equal or similar options for choosing a possible specialty.

Educational portals. This type includes resources that contain comprehensive information on all aspects that relate to education in general. However, such sites do not provide clear advice for people who choose a profession, they do not give an opportunity for objective testing on the subject of professional orientation.

Resources of employment. This type of Internet resources is the most widespread among similar tools. As a rule, they can help you to get information about the list of vacancies, their features and additional requirements, the presence of vacancies in different regions, as well as to establish contact with an employer. The disadvantage of such IT is a lack of information about educational institutions, where it is possible to obtain the relevant profession, re-qualify or get a second higher education.

Test resources. This type of IT offers a considerable selection of different psychological tests that relate to the choice of profession. As a rule, their main drawback is that they do not contain information on the further direction of the profession search, that is, educational institutions, aspects of a profession, prospects of employment, the need for a profession in our time, etc.

The results of the comparison of the functional characteristics of existing foreign and domestic online resources of professional orientation are presented in Table 1.1, the analysis was conducted by the following parameters:

P_1 – definition of professional type of personality;

P_2 – examination of the urban labor market;

P_3 – recommendations for choosing a profession (according to the professional abilities and the required professions);

P_4 – examination of educational institutions functioning in the city;

P_5 – selection of educational institution according to chosen profession;

P_6 – the possibility of forming an individual learning trajectory (according to the level of knowledge potential).

Table 1. Comparative analysis of online resources

Resource name	**Evaluation was carried out using the following parameters**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**
SC Accelerate (USA)	+	+	+	+	+/-	+/-
Hobsons (USA)	-	-	-	+	+	+/-

Career Choice GPS (Canada)	+	+/-	+	+/-	+	+/-
Smartie (Russia)	+	-	+/-	-	-	-
My career (Ukraine)	+	-	+/-	+	+/-	-
Career (Ukraine)	+	+	+/-	+	-	-
Education .UA (Ukraine)	-	+/-	-	+	+	-

The analysis allows us to claim that the implemented software and algorithmic complex of information and technological support of the specialist training processes combines the main stages of specialist training taking into account the needs of an individual, economic and social development, and the requirements of the labor market in the city, community or region, as well as the systemic aspirations of the communities. And because of its functionality it is perhaps the most complete representation of the vital functions of such systems

2 Complex of Information and Technological Support of Professional Training

2.1 Specialist Training in Smart Cities

The process of qualified professional training in accordance with the needs of an individual and the requirements of the labor market in the smart city is a complex, multi-step, iterative process that requires consideration of a large number of parameters and prerequisites. It can be expanded in five consecutive functional steps: **stage 1** is the definition of professional inclinations and abilities; **stage 2** is the labor market monitoring in order to determine the trends of changes in the factors affecting the supply and demand of the workforce; **stage 3** is the choice of a future profession; **stage 4** is the choice of educational institution; **stage 5** is the formation of an individual learning trajectory (ILT).

On the basis of the above sequence of specialist training stages, the Diagram of using options (Fig. 1) of the software and algorithmic complex of information and technological support for the specialist training processes with external entities (user, administrator) and the requirements to the basic functions of the developed software and algorithmic complex was formed.

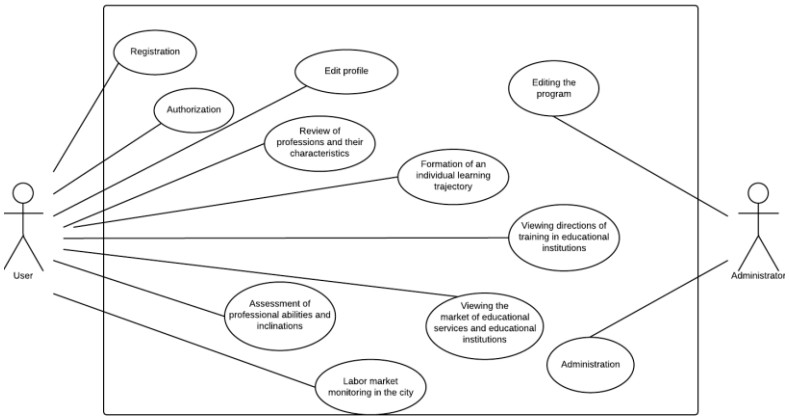

Fig. 1. Diagram of the using options of the program and algorithmic complex of information and technological support for the specialist training processes in accordance with the needs of an individual and the requirements of the labor market in the city

The main actors (an administrator and a user) are selected, users can be a person who makes decisions on their professional orientation (the entrant), their parents, employers, specialists of employment centers, and others. Actor User uses a system to monitor the labor market in the city, review information about educational institutions operating in the city, as well as to determine the professional abilities and to receive recommendations on the choice of profession and, accordingly, the revision of the system generated by an individual learning trajectory. Actor Administrator controls the technological aspect of the functioning of the software and algorithmic complex as well as monitors and eliminates possible errors or failures in the system.

2.2 Architecture of Software and Algorithmic Complex

The software and algorithmic complex of information and technological support of the processes of specialist training in accordance with the needs of an individual and the requirements of the labor market in a smart city is developed on the basis of three-level architecture (Fig. 2). This enabled to split it into separate interrelated parts, which divide the system functions and separate the user interface from the data.

Administration subsystem. The administration subsystem contains the following components: access right distribution module, user profile support module, identification and authentication module, and test support module.

The *access right distribution module* provides the user, in accordance with the rights of access, the ability to work in the available modes to them (to undergo testing, review vacancies, look at the city's educational institutions, etc.).

The *user profile support module* allows you to create, edit and delete user profiles.

The *identification and authentication module* provides the user with a possibility to enter login and password and establish the user's correspondence with the identifier provided to him.

The *test support module* allows you to add, edit and delete tests oriented to defining the vocational orientation (Holland and Yovashi tests) as well as tests for identifying the person's knowledge potential.

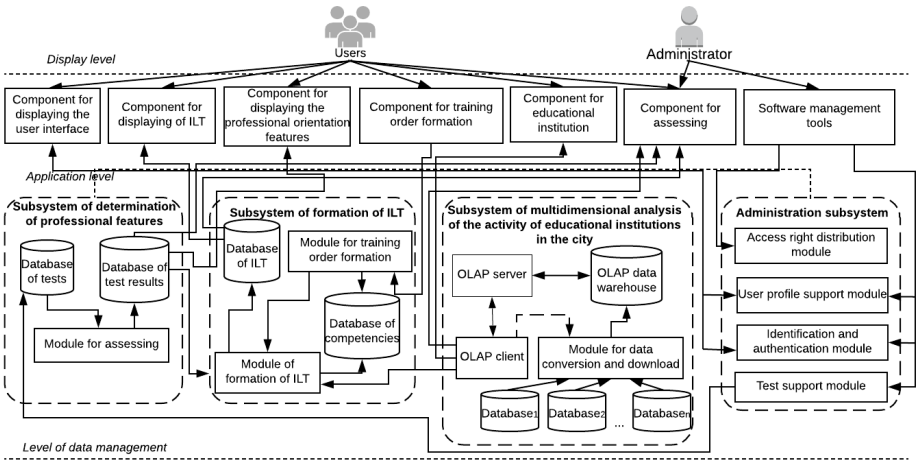

Fig. 2. Architecture of the software and algorithmic complex of information and technological support for the specialist training processes

Subsystem of the multidimensional data analysis. The subsystem of the multidimensional data analysis concerning the activities of the educational institutions in the city consists of OLAP data warehouses, data conversion and download module, OLAP server and OLAP client. The OLAP warehouse contains the source data for the analysis of the activities of educational institutions. The data structure is multidimensional and adapted for OLAP analysis. The main function of the module for data conversion and download is the formation and maintenance of relevant data in the repository.

The OLAP server performs operations to process queries for multidimensional data, as well as to ensure the counting and storage of aggregate (total, average, etc.) values.

The OLAP *client* displays the data received from the OLAP server in a user-friendly mode.

Developing data warehouse of software and algorithmic complex there were created multidimensional data cubes of different degrees of complexity [11]. In Fig. 3 a diagram of the multidimensional analysis process of an educational institution functioning is shown.

Data hypercube is not analyzed in all dimensions at the same time. Typically, a data sample from a hypercube is made for the specific values of a particular set of

measurements, and as a rule, one or two measurements are left to be free, using which further analysis is carried out.

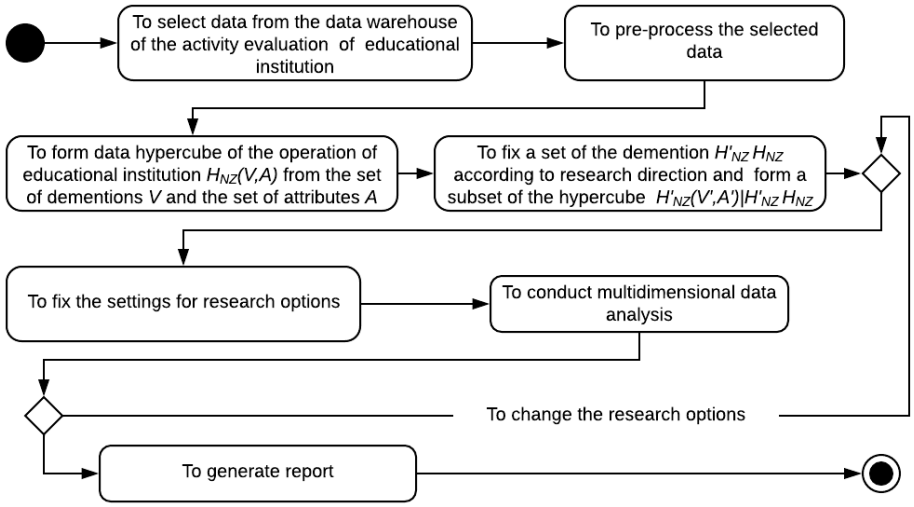

Fig.3. Diagram of the multidimensional analysis process of an educational institution functioning

The subsystem of determination of professional features allows users to define their professional inclinations, abilities and to choose a field of professional activity, includes a database of tests, a module for assessing and a database of test results [12].

The *database of tests* is intended for the storage of vocational guidance tests of Holland and Yovashi [13].

The *module for assessing the results* processes the test results and writes them to the database of test results.

Subsystem of formation of an individual learning trajectory. The subsystem of formation of ILT allows to create individual learning trajectories of users, includes the module for the formation of a training order, a database of competencies, the module for the formation of ILTs and the database of ILT.

The *module for training order formation* gives an opportunity to download from the server the reporting information and analytical and statistical materials of the city employment centers (information about the need of the city in the workers of one or another sphere) and save them in the database of competencies.

The *module of formation of ILT* creates individual learning trajectories for users on account of the implementation of diffusion-liked models of the knowledge potential dissemination developed by the authors in the educational social and communication environment in the smart city. The authors proposed and worked out variants of solving the problem of modeling the component interaction of the knowledge potential of different agents within the given clicks, as well as introduced a multicomponent vector of the knowledge potential (solving the corresponding problem for the system of

different equations) and presents the results of numerical experiments [14]. In the case when each k user (agent) is characterized by two knowledge potentials $\varphi_{l,k,m}$ ($l=1,2$, for example, potentials characterizing mathematical knowledge and language of k agent at the m moment of time, a model describing the redistribution of these potentials taking into account possible influences of one of them on another one (for example, obtaining a high knowledge potential in mathematics can affect the reduction of the knowledge potential of the language for a given object, or vice versa, positive interactions), appears in the form:

$$\begin{cases} \varphi_{1,k.m+1} = \varphi_{1,k,m} + \sum\limits_{i=1}^{k_j} \alpha_{1,k,i}(\varphi_{1,k,m} - \varphi_{1,k,i}) + f_{1,m} + g_{1,m}(\varphi_{1,k,m}, \varphi_{2,k,m}) \\ \varphi_{2,k,m+1} = \varphi_{2,k,m} + \sum\limits_{i=1}^{k_j} \alpha_{2,k,i}(\varphi_{2,k,m} - \varphi_{2,k,i}) + f_{2,m} + g_{2,m}(\varphi_{1,k,m}, \varphi_{2,k,m}) \end{cases} \quad (1)$$

where, $f_{1,m}$, $f_{2,m}$ are the intensity of the sources of knowledge transfer, $g_{1,m}(\varphi_{1,k,m}, \varphi_{2,k,m})$, $g_{2,m}(\varphi_{1,k,m}, \varphi_{2,k,m})$ are functions that characterize the interdependence (mutual influence) of studying in this case, mathematics and language.

Similarly, in the case when objects (agents) are characterized by many potentials, that is, $l=1,2,\ldots,l_*$, we have:

$$\varphi_{l,k.m+1} = \varphi_{l,k,m} + \sum_{i=1}^{k_j} \alpha_{l,k,i}(\varphi_{l,k,m} - \varphi_{l,k,i}) + f_{l,m} + g_{l,m}(\varphi_{1,k,m}, \ldots, \varphi_{l*,k,m}) \quad (2)$$

The algorithms of the corresponding numerical calculations for forecasting situational states presuppose their use in creating individual learning trajectories of users taking into account abilities, interests and opportunities.

In Fig. 4 there is a diagram of activity characterizing the process of identifying a multicomponent knowledge potential in order to form an individual learning trajectory. The inputs are the initial distributions of various types of knowledge potentials of agents, weight ratios, as well as the intensity of sources of knowledge distribution.

The *ILT database* provides the storage of generated individual learning trajectories of users for further analysis and use.

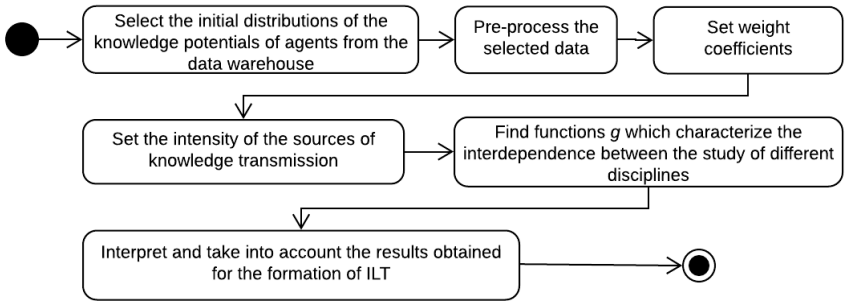

Fig.4. Diagram of activity of ILT formation

3 Principles of Software and Algorithmic Complex Functioning

The software and algorithmic complex of information and technological support of the training processes of qualified specialists in accordance with the needs of the individual and the requirements of the labor market in the smart city is developed in the form of a single-page application (SPA), which has several advantages: a rich functional interface ; quick reaction of the interface, due to the lack of need to contact the server at each action; a significant reduction in the load on the server; significant simplification of the logic and complexity of the server.

The architecture of the web application is designed on the basis of client-server technology, which allows you to work both locally and in network mode. The server part is written using the Vue.js environment and JavaScript framework that uses the MVVM template to create user interfaces based on data models through reactive bindings.

For users, the following modes of the web application function are defined: definition of professional abilities; review of vacancies; review of educational institutions in the city; career choices; viewing of an individual learning trajectory; administration. You can go to each of the modes by selecting the appropriate tab.

The admission of a user to work with a software and algorithmic complex involves the implementation of procedures for authorization or registration, the last one must necessarily be carried out with the introduction of such data as the city of residence, education level and birth date in order to their further multivariate analysis.

After authorization, users are given an opportunity to determine their professional abilities and inclinations through passing the vocational guidance test (different professions are presented in pairs; in each pair of professions one should be preferred).

To visualize and interpret the results of vocational guidance testing of users in the software and algorithmic complex, the procedures are developed such as Process, Prepare, Calculate, the program code of which is given below:

```
function CalculatePollResult(Poll poll, Collection us-
erSelectedVariants)

{
  Collection pollResultItems = fetchAllPollResultItems-
FormDB(poll)
  foreach pollResultItem in pollResultItems
      foreach userSelectedVariant in userSelectedVariants
          if userSelectedVariant.resultItem is equal to
pollResultItem
              add one point to pollResultItem.points
          end if
      end foreach
  end foreach
  foreach pollResultItem in pollResultItems
      if pollResultItem.points is equal to 0
          remove pollResultItem from pollResultItems
```

```
        end if
    end foreach
    return sortResultItemsByPoints(pollResultItems)
}
```

For example, Fig. 5 illustrates and interprets the results of the method of determining the professional type of personality.

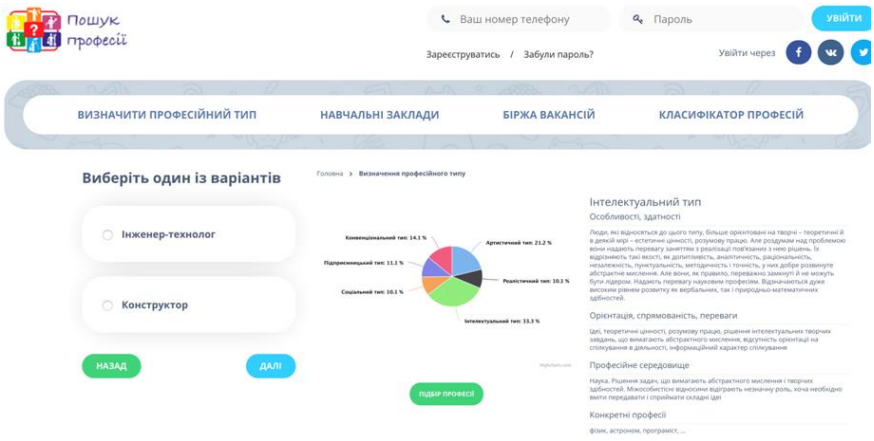

Fig. 5. Results of determining the professional type of personality

After completing a vocational guidance test, the opportunity to review vacancies (taking into account the needs of the city of the specialists) is given with the maximum of their compliance with the professional inclinations and abilities of a person identified as a result of testing, as well as the city's ability to ensure their training, that is, the availability of educational institutions that educate specialists for the chosen direction.

It should be noted that for a faster and more reliable implementation of the software product a set of independent components is formed, each of which performs own functions. This is in particular the component of job search for a specific professional type of personality.

4 Conclusion

The architecture of the software and algorithmic complex of information and technological support of the training specialist processes in the smart city is developed. Information is given about the main software modules of the software and algorithmic complex, the levels of display, application and data management are highlighted. Diagrams of multidimensional analysis of educational institution activities and process of determination of multi-component knowledge potential for formation of individual learning trajectories of agents are given. The software and algorithmic complex

is developed in the form of a one-page web application, which gives it signs of mobility and simplifies the implementation of data updating processes.

At the present time, the testing of the developed software and algorithmic complex is carried out on the basis of the city of Ternopil. Full-scale database filling and system debugging of all components of the complex is being implemented. Full-scale testing of the system in real conditions of the admission campaign to the university on the specialties of the educational branch Information Technologies is scheduled on May-August 2018. At the same time, analytical assessments of educational experts and representatives of firms - employers in the IT industry confirm previous positive feedback on the completeness, integrity and efficiency of the proposed architectural solutions of the system.

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