E-health artificial intelligence system implementation: case study of knowledge management dashboard of epidemiological data in Poland

P. Ziuziański, M. Furmankiewicz, and A. Sołtysik-Piorunkiewicz

***Abstract*—** The aim of this paper was to show the state of art in e-health artificial intelligence systems and describe the concept of methodology of dashboard implementation in e-health knowledge management especially for monitoring epidemiological data. In this paper the authors characterized the different data sources of epidemic diseases' and describe the case study based on own dashboard project of epidemiological data in Poland. There is a variety of those tools including artificial intelligence systems like expert systems or multi-agent systems, Business Intelligence and performance dashboards. Nowadays, application of this kind of systems in e-health has increased significantly, which was highlighted by presented examples. The last chapter presents a project of performance dashboard for monitoring epidemic diseases.

***Keywords*—** dashboard, e-health, epidemiological data, expert systems, multi-agent systems

I. Introduction

E - health could be recognized as a buzzword which means everything connected with medicine and computers. Eysenbach defines e-health as a "an emerging field in the intersection of medical informatics, public health and business" [1]. Development of e-health is possible thanks to advances in computers, telecommunication and network [2, 3]. This is one of a fastest growing sector worldwide because of global health needs [4] and healthcare industry [5]. Following the United States of America, where couple of years ago they realized as the first real the value of e-health, important steps have taken place the latest years in Europe [6].

Nowadays healthcare units must efficiently manage their knowledge to provide high quality services. Computer science utilization and new information and communication technologies (ICT) give these opportunities [7]. The main new research of ICT tools for the healthcare and e-health area is focused on Ambient Intelligent with Web based technology [8, 9] with methods of data mining and knowledge discovery [10, 11].

This publication touches topic of modern systems using in e-health including Artificial intelligence and Business Intelligence systems. The second chapter describe AI e-health systems, particularly agent systems and expert systems. The third chapter shows the different data sources of epidemic diseases' for BI e-health dashboard system. The last chapter describes the project of epidemic data visualization on performance dashboard. The project of dashboard implementation shows the steps of the development of the performance dashboard. The implementation methodology of knowledge management dashboard for epidemiological data is based on layered project structure and performance dashboard lifecycle phases.

II. AI E-health systems

Artificial intelligence (AI), which is regarded as a scientific discipline, has emerged after the introduction of the first computers. Those were ascribed to the skills characteristic of intelligent beings, including proving hypotheses, concluding, and games playmaking [12].

Currently, the concept of the artificial intelligence is understood as a branch of IT, whose subject is the study of the rules governing the so-called intelligent human activities, and the creation of formal models of these behaviours, which in turn leads to the creation of computer programs that will simulate these behaviours. The above mentioned intelligent behaviours are [13]:

1) perception,
2) learning,
3) recognition,
4) usage of language,
5) symbol manipulation,
6) creativity,
7) solving problems.

Piotr Ziuziański – M.Sc., University of Economics in Katowice, Poland; e-mail: piotrziuzianski@gmail.com.

Małgorzata Furmankiewicz – M.Sc., University of Economics in Katowice, Poland; e-mail: malgorzata.furmankiewicz@gmail.com.

Anna Sołtysik-Piorunkiewicz – Ph.D. is employed at the University of Economics in Katowice as lecturer on Faculty of Informatics and Communication, at Department of Informatics, Katowice, Poland; e-mail: anna.soltysik-piorunkiewicz@ue.katowice.pl. Major Fields of Scientific Research: computer science, systems analysis and computer system design, management information systems, e-business, e-health and public informatics.

Computer programs are used both for experimental and practical purposes, such as [13]:

1) sounds recognition (speech),
2) recognition of shapes (for example letters),
3) theorem proving,
4) running games (chess),
5) translation from one language to another,
6) music composition,
7) formulation of medical diagnoses,
8) expertise formulation.

Artificial intelligence is used in e-health. Authors decided to describe agent technology, especially multi-agent systems and expert systems as an example of AI tools in e-health.

III. Agent Technology

Lately one of the most important area of research Artificial Intelligence became agent technology. At present applying it in healthcare is very interesting topic. Fig. 1 presents examples of using multi-agent systems in e-health [14, 15, 16, 17].

An agent is an entity capable of performing some tasks and help human user in that way. Agents can be biologic (for example people), computational (software agents) or robotic. Software agents could be defines as a computer program that aim is carrying out some task on behalf of a user. The most important properties of agents are: intelligence, autonomy, cooperation and ability to learn. [18]

Combined agents into one system are named multi-agent system and it could be very powerful tool. Characteristic in multi-agent systems are those statements [11]:

1) each agent dispose not complete information that is why agent is not capable to solve entire problem on its own,
2) only combined agents can solve problem,
3) system do not use any centralized mechanism for solving problem.

Main aim of agents is observing knowledge base in current situation context and supporting in process of making decision on action by experts in their domain. The last step is executing that action on the environment [14].

Agents are often confused with expert systems. This results from the fact that those two entities have knowledge base. Basic difference between them is how they use knowledge base. Experts systems use logic in every situations, while agents act more like people: more important is to find result and accept some level of its probability than find perfect result [19].

There is a diversity of areas in medical industry and health care systems that could benefit from systems based on agent technology, especially on MAS [14]:

1) systems diagnosing diseases,
2) systems that recommend treatment,
3) patient history examination systems,
4) the support of palliative care units.

Examples of e-health MAS with short characteristics are presented in Fig. 1 [15].

Area	Name	Description
Assistive Living Applications	**CASIS** Context-Aware Service Integration System	Supplying context-aware healthcare services to the elderly resident in the intelligent space.
	K4CARE	Project combining healthcare and ICT experiences to develop, apply, and validate a knowledge-based healthcare model for assistance to patients living at home (elderly, the disabled persons, and the patients with chronic diseases).
Diagnosis	**OHDS** Ontology based Holonic Diagnostic System	System supporting doctors in the diagnostic and treatment, and overseeing processes of the evolution of new epidemics. System is based on the exploration of all data pertinent to each case and on the scientific data contained in various professional databases
	HealthAgents	Research project with the goal of improving the classification of brain tumours distributed network of local databases.
Physical Telemonitoring	**U-R-SAFE** Universal Remote Signal Acquisition For hEalth	Research project with the goal of realizing a telemonitoring environment for elderly people and patients with chronic diseases.
	MyHeart	Research project whose focus was on preventing cardiovascular diseases using sensors integrated in clothing to monitor heart activity.
Smart-Hospital, Smart-Emergency Applications	**ERMA** Emergency Medical Assistant	The main aim of ERMA was providing meaningful diagnoses and intervention suggestions to the healthcare team acting on behalf of the patient in the cases of emergency trauma with particular emphasis on types of shock and stabilization of arterial blood gases.
	Akogrimo	Research project whose main goal is the integration of the next generation Grids with the next generation networks.

Fig. 1 Examples of MAS in e-health

IV. Expert Systems

Artificial intelligence is used in many areas in business and science. One of the first area where AI was applied was medical diagnosis. In this area the largest impact has got expert systems. Expert systems are AI tools which gained recognition both commercial and individual users. There are two expert systems classes [20]:

1) large one built by corporations for commercial or their own aims,
2) small one built to work on individual computers used to solve problems.

Expert system is a computer program which uses "knowledge base" to perform tasks in many categories (for example medical diagnosis) [19].

An exemplary expert system architecture includes: knowledge base, fact database, explanation system, knowledge base editor and user interface. Communication between mentioned elements is shown in Fig. 2 [18].

There is special, separated area named expert system shell in expert system. Elements of this area do not contain specific information. Expert system shell therefore is general toolkit which can be used to build many different expert systems.

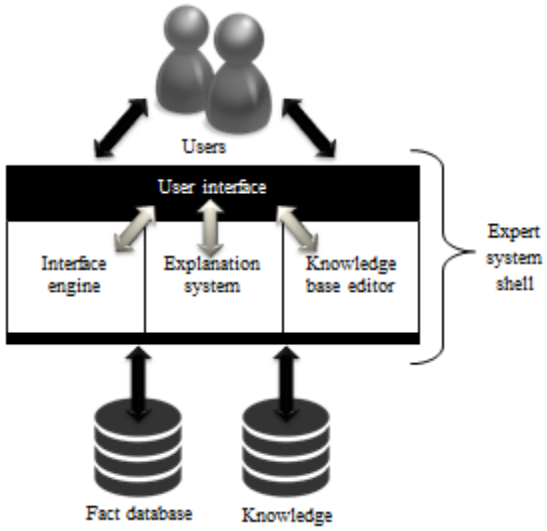

Fig. 2 Architecture of expert system

Domain of this system is dependent on added knowledge base to the shell [18].

Knowledge base stores domain knowledge to resolve problem and derive conclusion based on facts. This knowledge is represented in the form of number of rules. The fact database includes characteristic data for particular case used to derive a conclusion. For example medical experts system fact table could contain pieces of information obtained about the patient's condition. Role of explanation system is delivering information for user how the inference engine found conclusion. It is relevant especially if expert system user should examine the data provided by the explanation system (for example medical issues) [18].

Communication between system and user takes place through user interface which supplies access to explanation system, inference engine and knowledge-base editor. Thanks to the last one expert knowledge engineer has the possibility to edit information in knowledge base. However the inference engine as a part of the system delivering conclusions based on rules and facts uses one of following methods (or combination of them) [19], [21]:

1) forward chaining (data-driven reasoning)– reasoning from set of facts and rules to the conclusion (goal),
2) backward chaining (goal-driven reasoning) – starts from the goal back to the starting premises.

As authors pointed earlier, medicine was one of the first area which expert systems were applied. Probably the most popular early expert system connected with medicine was MYCIN [22]. This project started in 1972 and its main aim was diagnosing infectious blood diseases thanks to about 450 implemented rules [21]. Fig. 3 includes review of expert systems uses in the medicine. Most important growth of expert systems was in the last century 70's in United States of America [22, 23, 24].

Nowadays expert systems in medicine are used by doctors to support with hard to diagnose symptoms. Moreover experts systems are used to help prescribing treatments when even specialists have difficulties [18].

Simple expert systems using for self-treatment and auto

Name	Year(s)	Description
PIP	1970s	PIP (Present Illness Program) – generating hypotheses based on gathered data from patients about renal disease.
AAPHELP	1972	Supporting the diagnosis of acute abdominal pain, based on analysis, and need for surgery; using naive Bayesian approach.
INTERNIST I	1974	Recognizing the complex diagnosis problems in general internal medicine.
MYCIN	1976	Diagnosing and recommend treatment for infectious blood diseases.
EMYCIN	1980	EMYCIN (Essential MYCIN) – Expert system shell, employing MYCIN's control structures.
ONCOCIN	1981	Helping physicians in treatment of cancer patients receiving chemotherapy
ABEL	early 1980s	Causal reasoning, management of electrolyte and acid base derangements

Fig. 3 Examples of expert systems in e-health

diagnosis are available on mobile devices and computer connected to Internet. For example there is an application on mobile devices called WebMD Symptom Checker for Android, iPhone and iPad. The application give their users the opportunity to diagnose and treat themselves [25].

Similar to WebMD Symptom Checker is for example website http://www.dooktor.pl/diagnoza. User entering symptoms has ability to find out possible disease [26].

V. Epidemiological Data Visualization on E-Health BI Performance Dashboard

Epidemiology is a branch of medicine that deals with the study of the incidence, distribution and control of diseases and other health-related factors. In this area also fits indicating the possibility of controlling or preventing health problems.

Disease prevention is possible by vaccination protective programs, health promotion and early detection of the diseases and treatment [27].

Monitoring the incidence of the population have impacts enormously on preventive health. An important element is both tracking epidemiological phenomena and related preventive actions [28]. Every country need special government units which aim is to monitor epidemiological situation.

Using Business Intelligence (BI), which is developed primarily as a system for solving analytical tasks, is mainly considered to be a way of supporting in making decision, reducing costs and improving the quality and performance [29]. The information data analytical system is the main point of business success in organization, it is making fast and good decision by executives. Thanks to BI tools users can fast afford to information and use it to help organisation and create strategic competitive advantages. The BI technology is the way to make this decision in much shorter timescales [30]. Competitive Intelligence (CI) tools are the important issue at the building of information system for the operational and strategic management. Such a methods of BI/ CI as Data Mining and Process Mining can be used to make the proper decision by corporate managers and decision makers [31]. The management dashboard as a kind of enterprise portal enables organizations to store, consolidate, manage, analyze distributed information from internal and external data sources [32], as one of the conditions necessary for obtaining knowledge makers and presented the use of various forms of data presentation to ensure the fullest possible data visualization of shared data and sophisticated information [33, 34, 35].

VI. Polish Epidemiological Data Sources

There are two kinds of epidemiological data sources: private and public. Public sources are provided by governmental health services while private sources are provided by companies connected with healthcare. Data could be shared in many formats like XLS or CSV files or webpage analysis. Polish health services provide reports i.e. in PDF formats included on their webpage.

For project described more particularly in next chapter, two areas have been chosen: Flu and Cancer situation in Poland. For these areas three different data sources have been selected as it is presented in Table 3. Also worth mentioning is that data warehouses (DW) in the last years become significant in new systems considering easy access to information for decision making. Then, also e-health environments started to adopt DWs [36].

Google Flu Trends pointed in Fig. 4 is an interesting project which allows estimating the number of influenza cases based on keywords searched by the users all over the world. It is available in Poland from 2009 [28]. Polish data is available from 2004. Destination for Flu data is relational database, however for Cancer area is data warehouse. It is directly connected with amount of data needed to store. The Cancer area data are available on webpage in HTML format.

VII. E-health Performance Dashboard

Performance dashboard is an extremely interesting form of data visualization, which is a kind of combination of different visual elements. Among the graphic images used to visualize the data depending on the type of graphical methods can be identified: drawings, photographs, icons, maps, diagrams, graphs, tables [37].

One of the most important advantages of this kind of visualization is clear viewing of data. Performance dashboard can be defined as a kind of dashboard that displays the most important information needed to achieve one or more objectives that have been collected on a single computer screen [38].

Category	Flu		Cancer
Data source	Governemental epidemiological reports	Data based on searched words on Google	National Cancer Registry
Unit	National Institute of Public Health - National Institute of Hygiene	Google Inc.	The Marie Skłodowska-Curie Institute of Oncology in Warsaw
Format	PDF	CSV	HTML
Webpage	pzh.gov.pl/oldpage/epimeld/grypa/	google.org/flutrends/pl/#PL	epid.coi.waw.pl/krn/
Date	2010-current data	2004-current data	1999-2010
Destination	Relational database (RDB)	Relational database (RDB)	Data warehouse (DW)

Fig. 4 Data sources and project areas

The basic properties of dashboard are [39]:

1) graphical presentation of data (such as maps and statistical graphs),
2) the presentation of conclusions so that the user is relieved of the need to perform its own analysis,
3) presentation of data that are most important.

History of dashboards is directly linked to the history of Business Intelligence, which dates back to the 80s of last century. Then it was noted that the Management Information Systems are no longer sufficient and it is too narrow solution. Due to the growing needs of executives at the beginning of the 20th century emerged Business Intelligence solutions that are the basis for creating dashboards [40]. It can be argued that dashboards are modern form of Management Information Systems [41].

Dashboards are used primarily for monitoring the

performance of the organization and as a tool for visualization of business data. The dashboard user is equipped in set of graphs and charts that allow monitoring organization performance [42]. Dashboards are widely used in various areas such as: sales, production, marketing, finance, technical support, human resource management [43].

Performance dashboard could be perceived as a multilayer application built on a BI and data integration infrastructure that enables organizations to measure, monitor, and manage business performance more effectively [44].

Dashboards with its main features can be used in the monitoring and management in critical areas for information society due to idea of ubiquitous computing [45]. E-health can be identified as an area of dashboard application, for example in monitoring the risk of morbidity by viral diseases at Poland and voivodeship level.

The main role of performance dashboards is providing appropriate information and knowledge for the appropriate user timely to optimize the decision-making process, increase productivity and improve business results for the organization [34]. Referring to these words about performance dashboard using by healthcare unit involved in the monitoring of the epidemiological status of the society can be said that e-health performance dashboard should provide the most accurate, complete, reliable and timely information about the epidemiological situation in Poland for users in specific organizational units of the sanitary system at different levels in the hierarchy of the unit in the shortest possible time in order to monitor, decision making and prevention.

VIII. Dashboard Implementation

Projects for developing and implementing IT systems in health care for knowledge management are complex and complicated undertakings. These processes should be carried out in stages. To achieve best effects, individual stages should be implemented efficiently and consistently.

Any IT systems implemented in health care must comply with legal standards in force and be adaptable to changes made to the national law. Due to the mass scale of health care, they must also be efficient both for patient and health protection system [46].

Dashboard implementation is a complicated process dependent on many factors. There is possible to distinguish three layers of developed project: data source layer, BI layer and data visualization layer. It is presented in Fig. 5.

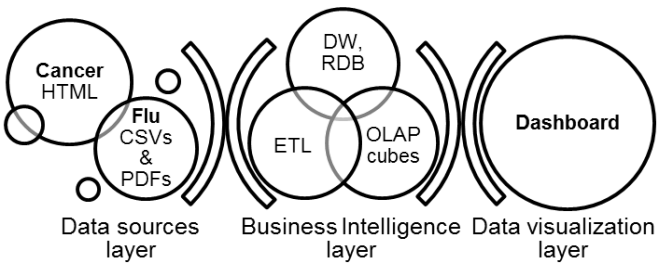

Fig. 5 Layered project structure

As Fig. 5 presents dashboard visualize data extracted, transformed from sources and loaded to database and to data warehouse. Detailed pieces of information about data sources were included in previous chapter.

IX. Development of the Performance Dashboard

For dashboard development could be suggested lifecycle approach. It is presented in Fig. 6 pre-phase of performance dashboard lifecycle consists defining and initiation of governance, resources and strategies. First phase is for designing technical and business solutions and KPIs (Key Performance Indicators). KPIs are set of measures which are focused on those aspects of company performance that are the most critical for the current and future success [47]. For e-health dashboard for monitoring epidemiological society situation examples of KPIs could be [48, 49]:

1) number of deaths or cases;
2) death (mortality) rate - measure of the number of deaths due to a specific disease in a population, scaled to the size of that population, per unit of time;
3) incidence rate – measure of the risk of developing some new condition at a given period of time;
4) prevalence rate – measure of the number of people in a population who have a disease at a given period of time.

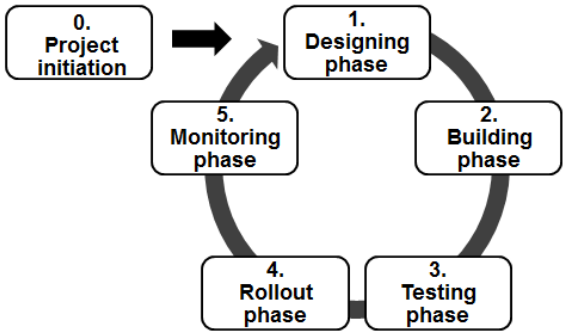

Fig. 6 Performance dashboard lifecycle [47].

During building phase data access is constructed and tools are chosen. After that testing phase starts. If project passed this phase users participate in conduct pilot. Last phase in cycle is for monitoring dashboard, evaluating feedback and prepare for next iteration [50].

During development of e-health performance dashboard six steps from requirements specification to implementation have been distinguished as Fig. 7 presenting.

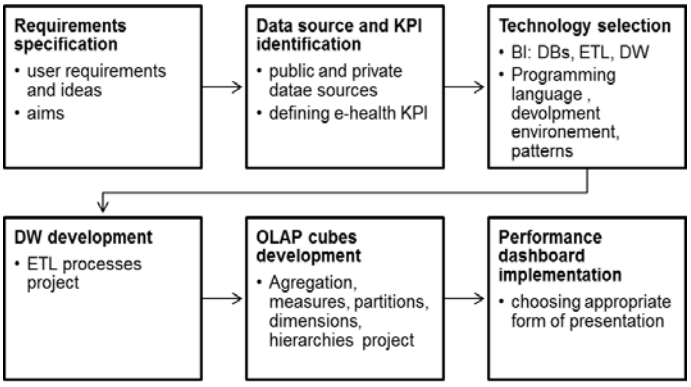

Fig. 7 Phases of development of the performance dashboard

One might say that pointed steps from requirements specification through data source, key performance indicators and technology selection to performance dashboard implementation are stages of pre-phase in described earlier iterative approach. After this preparation steps effective, development of performance dashboard is possible.

Technology chosen like programming language, framework, IDE and Business Intelligence platform is presented closely in Fig. 8 [51].

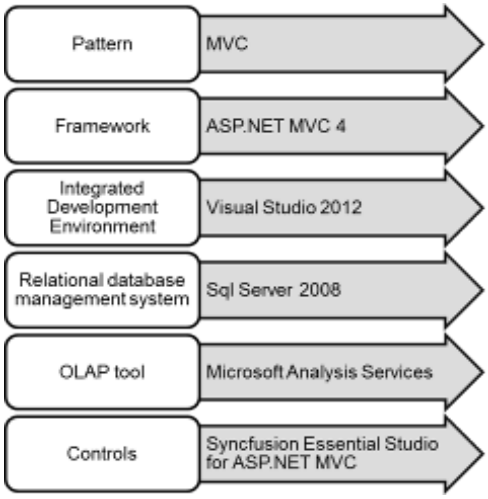

Fig. 8 Chosen technologies and tools to develop dashboard

The important thing was projecting and accomplishing DW for Cancer area and preparing cube. Simple DW schema for this area is presented in Fig. 9 [51].

It is data source view from SQL Server Analysis Services. For the cube have been defined two calculations: prevalence rate and death rate as a percentage values.

From end user point of view developed dashboard is a webpage which needs JavaScript enabled because of applied following form:

1) charts – JavaScript library called Highcharts,
2) maps – JavaScript based plugin jVectorMap,
3) calendar – jQuery plugin UI Datapicker.

Dashboard uses popular JavaScript library called jQuery which helps in communication between user and dashboard.

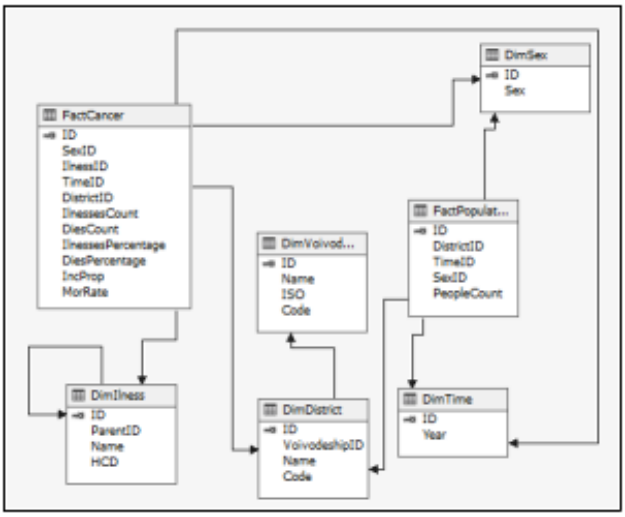

Fig. 9 DW scheme for Cancer area

X. Functionality of Developed Dashboard and Prospects

As mentioned above performance dashboards should integrate many data sources and be perspicuous and easy to interpret. These features of dashboard were the most important aim of developed dashboard. That is why methods of visualization has been chosen with great caution.

Screenshot of developed dashboard in Flu area is presented in Fig. 10 [51]. It allows users to view the current epidemiological situation. Dashboard in Flu is includes following pieces of information with applied dedicated method of visualization:

1) **numbers** of the total deaths and the incidence of influenza virus from the last report with icons informing about decrease (green down arrow) or increase (red up arrow) in the number of cases; below special **calendar** control is located which allows user to download report from specific period of time;
2) health **map** by voivodships: areas marked intense green color means low incidence, red color indicates high incidence;
3) incidence by age group presented in a **horizontal bar chart** with three data series;
4) located in the upper right part of dashboard **pie chart** indicates the reasons for referral to the hospital because of the flu;
5) **line chart** at the bottom left includes three data series (current period, previous and one earlier period) with respect to the incidence of the flu on the basis of reports by month and each week months;
6) last **line chart** presents information about the incidence of influenza by described Google Flu Trends.

Dashboard in Cancer area is presented in Fig. 11 [51]. Data could be presented to users in a pivot table or chart form. It is possible to make actions like: drill-down, drill-up, slice&dice, filtering using presented pivot table. Those possibilities give user great flexibility and independence. User can create many kinds of reports depended on his individual needs. One of useful feature this cube browser is exporting data to Microsoft Excel file. Other feature is possibility of saving report and loading reports. Data presented in pivot table is based on before prepared cube in SQL Server Analysis Services.

XI. Conclusion

There is variety of artificial intelligent systems using in e-health for knowledge management [52]. The information dashboard is a chance for healthcare executives for effective decision supporting. Combination of mentioned tools could give extraordinarily effects in performance, quality and profitability of healthcare. Integrating this systems and technology cooperation became one of the most important issues nowadays. Performance dashboards visualize data and integrate data sources for making decision faster and more accurate. It is important especially in such a critic area like monitoring epidemiological status of the society.

Fig. 10 E-health dashboard with map and charts in Flu area

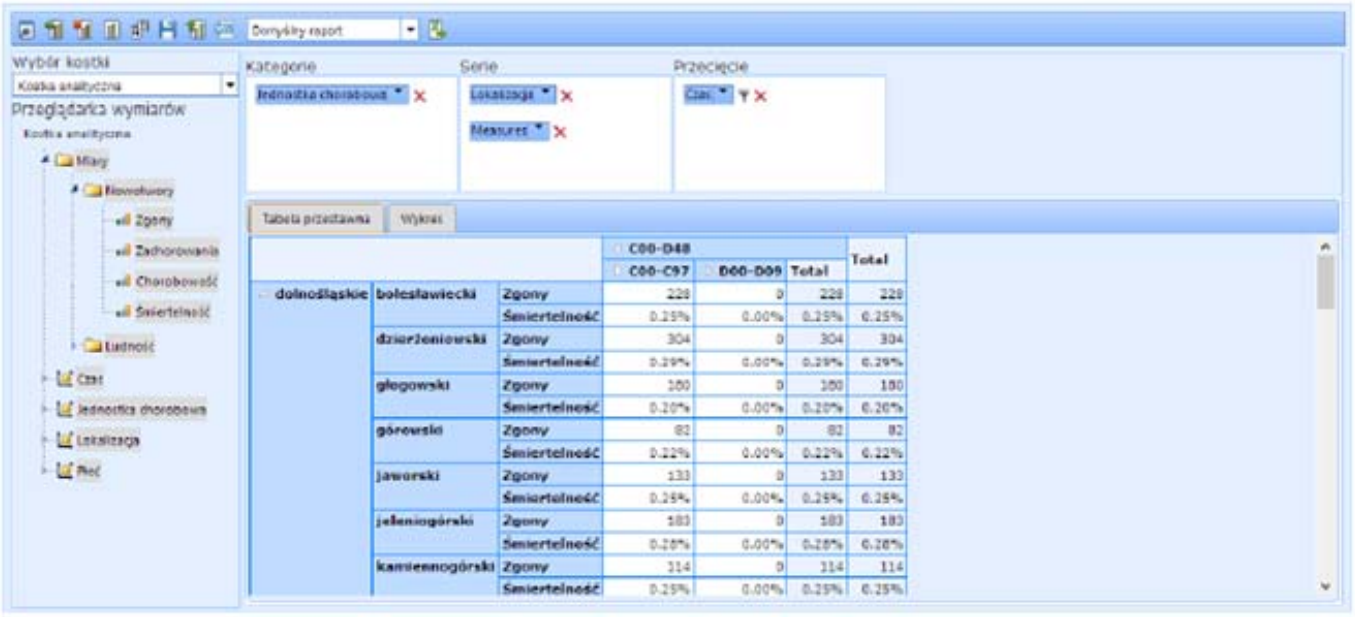

Fig. 11. E-health dashboard with pivot table in Cancer area

Presented dash board could be used not only by healthcare governmental units to monitor epidemiological situation over the Poland but also by ordinary internet user. Performance dashboard could be a part of medical portal. Implementing expert system diagnosing flu, cancer and other diseases on portal and using agent technology could extremely expand the capabilities of presented project. It should be subject of future researches.

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