# Chapter 17
# Integration of Agents and Data Mining in Interactive Web Environment for Psychometric Diagnostics

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**Abstract** Information technologies are intensively used in modern psychometric. Interactive environment for psychometrics diagnostics enables evaluation of cognitive capabilities using several multimedial tests, collecting information about users, organizing this information in user's personal profiles, visualization, interpretation and analysis of tests results, control over procedure of testing and making conclusions on collected data. Agents supervise user's actions in the interactive environment and they are trying to adjust questionnaires, diagnostic tests, training programs and other integrated tools to user's personal needs making this environment easier for use. Interactive environment contains agents for helping users in process registration, agents for guiding users trough process of diagnostics and training, and agents for helping psychologists in their activities on this system. Internet environment that contains diagnostic tests and questionnaires generates large volumes of data that should be processed. Data mining is integrated in interactive environment for diagnostic of cognitive functions and it's used for searching of potentially interesting information that this data contains. Agents use data mining system to make their decisions more precise.

## 17.1 Introduction

Agents are computer programs that can assist the user with computer applications to accomplish their tasks. Agents should be able to sense and act autonomously in their environment. Agents present software that, in interaction with environment, is capable to react flexible and autonomous by following assigned goals. Interaction with environment means that agent is capable of responding on input values from sensors, which it reads from environment, and it is capable to take a course of actions in order to change agent's environment [9]. Agent's environment can be real world or virtual (software environment implemented on computer or on Internet). Agents must be able to process data, and for that purpose may have several processing strategies. They should be designed to use simple strategies (algorithms), or they could use complex reasoning and learning strategies to achieve their tasks. There are several

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techniques that agents can be trained for improving agent performance and better understanding their environment using computational intelligence techniques, such as using evolutionary computing systems, neural networks, adaptive fuzzy logic, expert systems and data mining, etc [19, 26]. The concept of interface agents that collaborate with the user in the same work environment, helping him/her to perform various computer-related tasks, was introduced by in the 90's with a reasonable success. This help may range from hiding the complexity of difficult tasks, training the user or making suggestions about how to achieve specific activities, to directly execute actions on the user's behalf [5]. In order to provide personalized assistance, agents rely on user profiles modeling user information preferences, interests and habits. Inserted in communities of people with similar interests, personal agents can improve their assistance by gathering knowledge extracted from the observed common behaviors of single users. Agents help users find relevant information based on detailed models of their interests contained in user profiles [7].

Systems for intelligent data analysis (data mining or knowledge discovery in databases) represent software tools capable to analyze content of large databases and to find relations between data [21]. Increasing database volumes leads to increasing demands for development efficient software tools for data analysis. Collecting large amount of various data in modern information systems creates need for software that can efficiently retrieve and select information when they are needed [8]. Structure, format and meaning of this data is various and usually it can not be modeled mathematically, that's why overall analysis is complex or sometimes impossible using standard methods [14].

Data mining can be defined as efficient discovering human knowledge and interesting rules from large databases. This technology is motivated by the need for new techniques to help analyze, understand and visualize the huge amount of stored data gathered from scientific and business applications. Data mining involves the semiautomatic discovery of interesting knowledge, such as patterns, associations, changes, anomalies and significant structures from large amounts of data stored in databases and other information repositories. Data mining differs from traditional statistics in several ways. Statistical inference is assumption-driven, in the sense that a hypothesis is formed and validated against the data. By contrast, data mining is discovery driven; patterns and hypotheses are automatically extracted from large databases. Second, the goal of data mining is to extract qualitative models that can easily be translated into business patterns, associations or logical rules. The major data mining functions that have been developed for the commercial and research communities include generalization, summarization, classification, association, prediction-based similarity search, and clustering [15]. Using a combination of machine learning, statistical analysis, modeling techniques and database technology, data mining finds patterns and subtle relationships in data and infers rules that allow the prediction of future results. Combining agent and data mining these two innovative technologies together can improve their performance. Integrating agents into data mining systems, flexibility of data mining systems can be greatly improved. Equipping agents with data mining capabilities, the agents are much smarter and more adaptable [13, 30].

Modern psychometric uses information technologies intensively [6, 20]. Psychologist can use several software tools that can enable fast and precise diagnostics [16, 24], and there are several tools that can be used for therapy [2, 28]. This software tools can be used alone or as addition to standard diagnostic and therapeutic methods. Advantage of implementation diagnostic tests on Internet environment is that it enables diagnostic of large number of patients. Computer version of the tests directly stores results in database and automatically process data, which eliminates costs and errors that can appear during analyzing results of paper version of tests. Applying computerized adaptive testing (CAT) can provide interaction with users in a real time and generates optimal tests for individual user [17]. Implementation of psychological tests on computers provides evaluation and creation of reports immediately after testing. This enables users to get faster feedback information about achieved results [25]. The overall time testing decreases, safety of testing procedure increases and testing can be performed more often than in classic form [4]. Framework for Integrated Testing (FIT) represents online environment that contains diagnostic tests or tests for knowledge evaluation. FIT environment enables collaboration of different categories of users: patients, psychologists and software developers. Diagnostic tests on Internet environment generate large amount of information that need to be processed [3, 29]. Data mining can be efficiently used for processing this kind of data. Agents integrated in web environment can use data mining for extracting knowledge from collected data to enhance their performance [18, 22].

## 17.2 Interactive Environment for Psychometrics Diagnostics

Interactive environment for psychometrics diagnostics enables evaluation of cognitive capabilities using several multimedial tests, collecting information about users, organizing this information in user's personal profiles, training programs (therapy), visualizations, interpretation and analysis of test results, control over procedure of testing (individual users and group of users) and making conclusions on collected data [11]. Interactive environment for psychometrics diagnostics is based on combination of two technologies: content management system (CMS) and computer supported cooperative work (CSCW) [27]. Environment for psychometric diagnostic and psychotherapy represents a place for gathering different categories of users, which could use long distance diagnostic of cognitive abilities. Beside tools for diagnostics and therapy, environment enables methods for communication and interaction of persons interested for evaluation of their cognitive capabilities (patients) and field experts (psychologists/therapists). Open architecture of this environment allows adding easily new tools and services [23].

Agents guide the users trough available tools on the interactive environment for psychometric diagnostic. They monitor the user's activities on environment, provide help and assistance when it's required, trying to find the best way how to present the next problem or instructional sequence; diagnose problems and provide corrective feedback. Based on users' profiles, agents trying to anticipate what users should do next in the diagnostic and training process and they respond immediately to take cor-

rective action. Agent is trying to replicate relation one-to-one between psychologist and patient on environment.

Overview of all subsystems of interactive environment for psychometrics diagnostics can be seen on Fig. 17.1. Main subsystems of interactive web environment for psychometrics diagnostics are: subsystem for collecting information about users, multimedial psychometrics tests, subsystem for evaluation and preprocessing results, subsystem for interpretation and visualization results, training programs, support for web seminars, forum, web calendar and wiki.

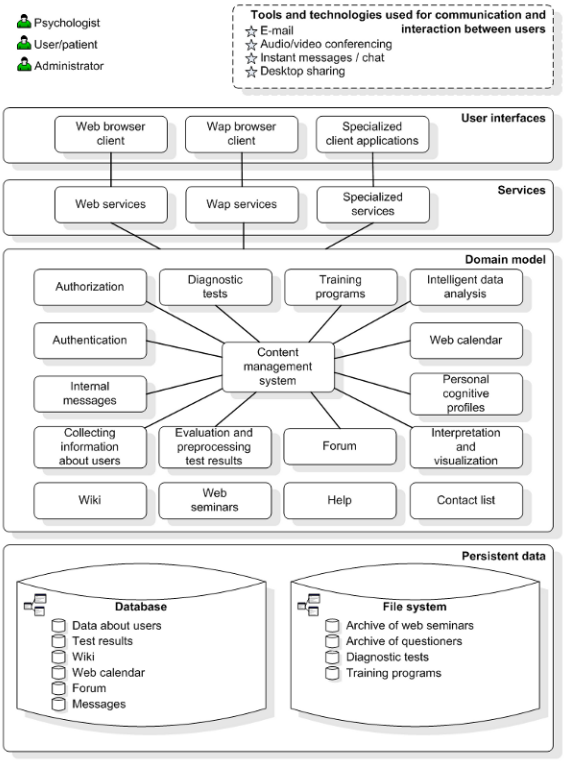


Fig. 17.1: Overview of all subsystems of interactive environment for psychometrics diagnostics

## 17.3 Collecting Information about Users

Subsystem for collecting information about users is activated when user visits environment for psychological diagnostics for the first time. Subsystem contains several questionnaires for collecting demographics, medical and psychological data about users. Agent A1 assists in creating the initial profile. Setting the initial profile will influence the further updates and usage of it, therefore, special care should be taken at this stage to assist the user in completing the questionnaire. At this stage, the

agent will use stored knowledge about typical users characteristics to set values in the users profile.

Agent A1 supervises users during their first visit the environment for psychometric diagnostic and helps them to fill questionnaires (Fig. 17.2). Answers from questionnaires are evaluated in subsystem for reviewing and preprocessing before recording in database. Agent A1 checks over the answers and depending on answer in some question, it can add some additional questions. Agent A1 provides dynamical questionnaires and it has a goal to create more precise user's profile. This method provides mechanism for avoiding other users to waste their time on irrelevant questions. Agent A1 can provide help and assistance with text, animation or video if it is necessary. A first-time user, who is registering in the environment for psychometric

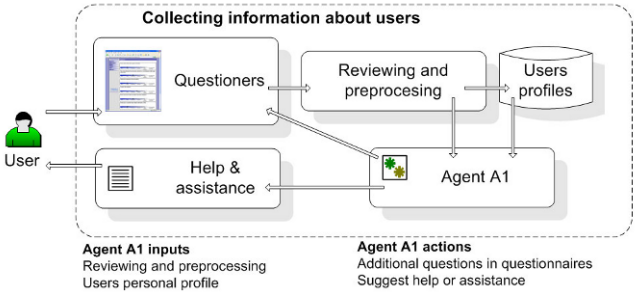


Fig. 17.2: Assisting users to fill questionnaires during their first visit the environment

diagnostic, might not want to give all the information during the first visit. Forcing users to complete a really long questionnaire could cause that they give up at start, before they get access to tests and training programs. The information that the user supplies can go in the user's profile directly, but many parameter values will remain empty because of the lack of direct user's input. To fill the missing information in the user's profile, the agent can apply a set of rules based on stereotypes. Agent A1 will help users to understand the implications of the presented questions and to make correct choices. When user fills set of base questions, agent A1 can allow user to stop filling questionnaires, even he/she hasn't answered on all questions. User can do some tests even registration is not finished and user's profile is not completed. But, some tests require user to fill questions that haven't been filled during the registration. In that moment, agent A1 activates questionnaires again asking users to fill missing questions.

## 17.4 Guiding Users Trough Diagnostic Tests and Training Programs

Multimedial diagnostic tests are used for evaluation cognitive user's capabilities such as attention and working memory. The tests are similar to simple computer

games. Users have to solve given task, while reactions, exactness of procedures, speed and other parameters are monitored in the background. Using such tests, it can be possible to perform patients testing on distance [10]. For example, the users have to detect meaningful patterns in a noisy background. The success in such a task depends crucially on the capability to suppress noisy stimuli by increasing inhibition levels.

Diagnostic tests generate detail data, based on that data complete process of testing for each user can be reconstructed. Results that are generated by diagnostic tests (raw data) aren't suitable for comparing and analyzing and it is necessary to process them before storing in database. Subsystem for reviewing and preprocessing evaluates these tests results before storing in database. Metadata are added to perform easier managing results of the testing. This metadata layer contains additional information of tests results. Psychologist may supervise the testing personally and he/she can write complains about the testing in metadata if he/she notices some irregularities during the testing. Diagnostic tests are used for examination of various cognitive parameters and the final result of each test is presented as single value (score) that combines values of all measured parameters. Score is expressed as value in interval from 0 to 100 and this makes easier to understand the test results. According to achieved results, the environment recommends training programs for users to practice and enhance their cognitive capabilities in areas with weaker test results.

User modeling can be useful for providing personalized services to a particular user, providing proactive feedback to assist the user and for presenting the information in a way suitable to the user's needs [1]. Environment contains large number of different diagnostic tests and training program. This can confuse new users and cause lack of their motivation. Agent A2 helps new users during process of testing to avoid this situation.

User interfaces play an important role in achieving user acceptance. Environment guides testing and user's actions by the test selection page. Agent A2 controls content of this page (Fig. 17.3). When user starts to use environment, agent A2 doesn't have much information about certain user and in this case usually suggests one of the predefined list of tests that best fit to that user according to information from user's profile.

As environment collects more information about some users, agent A2 has more possibilities to make more precise suggestions for user's next steps. Agent A2 monitors events on environment such as: results of latest test, previous results of the same test (if user used that test previously), results of other diagnostic tests, information from user's profile and information from data mining. Based on this information, agent A2 tries to make decisions about further optimal steps for that user. Agent A2 can suggests users: to go on next test, to repeat same test, to do additional test for detecting same cognitive capabilities, training programs, to provide help and additional information (text, animation or video), or to suggest live communication between user and psychologist. Agent A2 is trying to provide optimal difficulties of diagnostic tests and training programs, it gradually increases difficulties as user accomplish given tasks. Agent A2 uses data mining subsystem to make more efficient decisions for suggestions about optimal actions of particular user based on

available information. Beside that, agent A2 uses data mining to analyze its own previous decisions from the similar situation and uses that for self improvement in next decision process. Interaction between users and environment are changing in

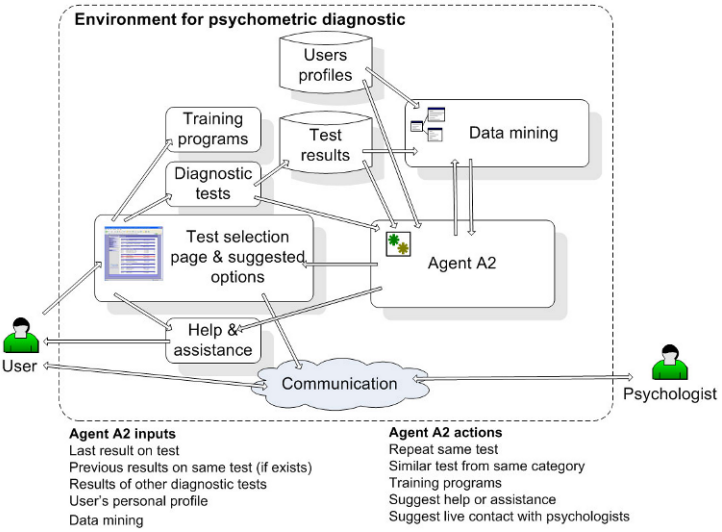


Fig. 17.3: Guiding users trough process of diagnostics and training

time. Agents guide new users until they finish basic set of tests necessary for completing user's psychological profile. After completing user's psychological profile, agents are reducing their involvement by giving suggestions to users and allowing them to select tests and training programs.

## 17.5 Interpretation and Visualization of Results

Subsystem for interpretation and visualization of results generates the reports based on information collected in database (table about users and table with test results). Using this subsystem, users can visually compare their own results with results of other users. Subsystem for interpretation and visualization generates the reports of test results with multiple detail levels. First level of reports shows changing test results per sessions and compares user's results of the last tests with results of other users. If user is interested for more detail results, he can look on the next pages: session results, trend sessions, results comparing, and more detail results. The Fig. 17.4 shows the organization structure of results pages. The page with brief results is the same for every tests and it shows only the final test result (score). On this page, user can compare his/her latest achieved result with own results from previous sessions, and also he/she can compare his/she results with other user's results (displayed on

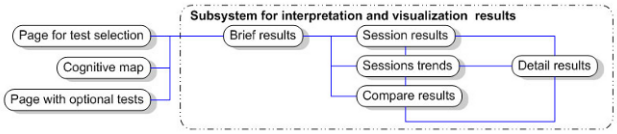


Fig. 17.4: Organization of pages with results

two graphs). The page with session results displays all the detail significant tests parameters used for score calculation. Page with sessions trends displays chaining of those parameters per sessions. Page for comparing results enables comparing user's parameters with the same parameters of other users. The page with detail results is the same by content as the page of session results, but there are more details and it contains table with every single action of users. The page with session results, sessions trends, compared results and detail results is different from test to test, while the page with brief result is the same for all the tests. Test results can be accessed trough the page with tests list or cognitive map.

## 17.6 Cognitive Profile of User

Cognitive map is generated based on achieved results from testing. Test results are displayed visually and this makes their understanding easier. Personal cognitive profile contains summary of all achieved user's results from diagnostic testing. According on user's profile, user can get comparative summary of his/her advantages and weaknesses. The report is generated from results achieved during the testing which are stored in database. Report contains only final result (score) of single tests that are displayed numerically and graphically with progress bar. At the bottom of the page, there is a graph in flower shape and its petals represents test results, blue color represents user's results and red color represents average results of other users.

This report allows users to have a complete overview of achieved results at the same place. Users, interested in additional information about a single test and explanation of how final result is evaluated, can take a look at the pages with more detailed reports. Page with cognitive map is linked with previously described subsystem for interpretation and visualization of test results (brief results, session results, session trends, page for comparing results, detail results).

## 17.7 Analysis of Psychometric Data

Data mining represents process of extracting potentially interesting information from data. Data mining, as subsystem of interactive environment for psychometric diagnostic of cognitive functions, can be used by psychologist for finding the correlation between user's data (demographic, psychological and medical data) and results gained from diagnostic testing [12].

To make explanation of procedure of data analysis easier, information from database is represented as matrix (Fig. 17.5). Matrix is gained by combining information from table about users and table with test results. This software is capable to choose one or several fields from matrix (databases), to perform data segmentation based on selected field and to search correlations with other data from matrix's fields. One of the main goals of analysis is to find correlations between results achieved in diagnostic tests and demographic, psychological and medical data. Database can be analyzed through table segmentation by one or several fields. By

| | Demographic data | | | | Medical data | | | | Psychological data | | | | Test results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $D_1$ | $D_2$ | ... | $D_j$ | $M_1$ | $M_2$ | ... | $M_j$ | $P_1$ | $P_2$ | ... | $P_j$ | $T_1$ | $T_2$ | ... | $T_j$ |
| Record 1 | $d_{11}$ | $d_{12}$ | ... | $d_{1j}$ | $m_{11}$ | $m_{12}$ | ... | $m_{1j}$ | $p_{11}$ | $P_{12}$ | ... | $p_{1j}$ | $t_{11}$ | $t_{12}$ | ... | $t_{1j}$ |
| Record 2 | $d_{21}$ | $d_{22}$ | ... | $d_{2j}$ | $m_{21}$ | $m_{22}$ | ... | $m_{2j}$ | $p_{21}$ | $P_{22}$ | ... | $p_{2j}$ | $t_{21}$ | $t_{22}$ | ... | $t_{2j}$ |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| Record i | $d_{i1}$ | $d_{i2}$ | ... | $d_{ij}$ | $m_{i1}$ | $m_{i2}$ | ... | $m_{ij}$ | $p_{i1}$ | $p_{i2}$ | ... | $p_{ij}$ | $t_{i1}$ | $t_{i2}$ | ... | $t_{ij}$ |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| . | . | . | ... | . | . | . | ... | . | . | . | ... | . | . | . | ... | . |
| Record n | $d_{n1}$ | $d_{n2}$ | ... | $d_{nj}$ | $m_{n1}$ | $m_{n2}$ | ... | $m_{nj}$ | $p_{n1}$ | $p_{n2}$ | ... | $p_{nj}$ | $t_{n1}$ | $t_{n2}$ | ... | $t_{nj}$ |

Fig. 17.5: Database represent as matrix

segmenting, the records are grouped according fields values, while symbol * marks free fields. Each group of records is analyzed by evaluation of correlation between free fields and the field used for grouping records. For example, in table that contains four fields ($X_1$, $X_2$, $X_3$ and $X_4$), term ($X_1$, *, *, *) means that the records from database are segmented based on function on field $X_1$. In following step, correlation between selected field ($X_1$) and free fields, in this case ($X_2$, $X_3$, $X_4$), are examined. Fig. 17.6 shows tree with all possible combinations of fields used for segmentation and free fields. Database table shown on Fig. 17.7 contains demographic, psycho-

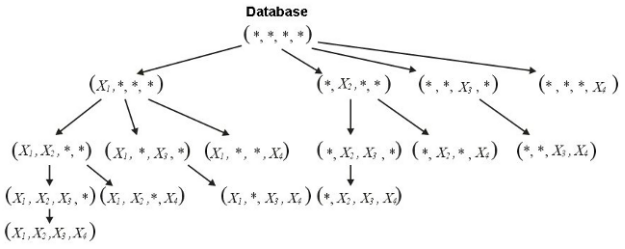


Fig. 17.6: Tree with all possible combinations

logical, medical data and test results. This table can be segmented, for example, by content of field $D_1$ and according syntax from Fig. 17.6 it can be written as ($D_1$, *, *, ... ,*). Field $D_1$ shown on Fig. 17.7, contains three groups (*G1*, *G2*, *G3*) and based on this classification, three subcategories can be created and further analyzed.

This procedure enables examination of degree of correlation between selected field and other (free) database fields. In this example, database is segmented by content of field $D_1$, but segmentation can be performed by any other field or combination of fields. Free fields in subcategories are marked as $X_1$, $X_2$, ... $X_n$. Boolean data sets can be segmented on two categories (true/false). Data sets that contain fields where users select one of several items from list can be segmented by those items. Other data sets can be segmented on more then one way (i.e. numeric fields or date fields). Numeric fields can be segmented by defined intervals or using fuzzy functions. Date fields can be segmented by years, months, weeks, seasons or some other defined periods. If we want to analyze database automatically, environment should "know" all types of segmentation related to each database fields. Field $X_1$ in subcategories S1

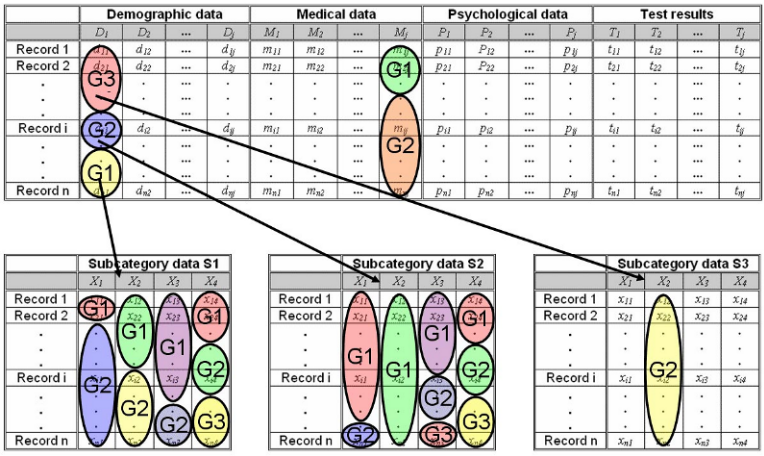


Fig. 17.7: Example of data segmentation

and S2 have differences in number of elements of group *G1* and *G2*. Subcategory S1 contains two groups of elements *G1* and *G2* in field $X_2$, while subcategories S2 and S3 contain only one group of data (*G1* or *G2*). It can be noticed that subcategories S2 contains new group of data *G3* in field $X_3$ that hasn't appeared in subcategories S1. Fig. 17.7 shows that field D1 doesn't influence significantly on $X_4$ because fields from subcategories S1 and S2 have the same number of groups and elements. Both groups contain approximately equal number of elements.

Fig. 17.8 shows procedure of collecting information about users by using questionnaires and diagnostic test until performing conclusions based on collected data. Data are stored in database after users fill questionnaires and perform diagnostic tests. This data are processed in appropriate form before storing in databases. In process of analyzing databases (data mining), software is trying to find relations between data about users and their achieved test results.

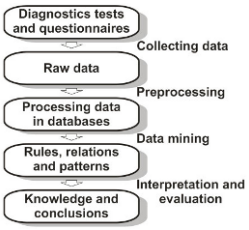


Fig. 17.8: Procedure from collecting information to knowledge extracting

## 17.8 Helping Psychologist in Their Activities

Environment for psychometric diagnostic should be considered as a tool that helps psychologists in their work but not as solution that completely avoids them. Psychologists evaluate test results and user's profiles, and they can communicate with users when that is necessary. Agent A3 (Fig. 17.9) helps psychologists with their activities in the environment. Agent A3 monitors information from user's profile and results of diagnostic tests that could be interesting for psychologist as reports or it can suggests live communication between psychologist and user. Agent A3 selects information that is generated by data mining and reports psychologist about it. Agent A3 uses data mining to improve its own decision process.

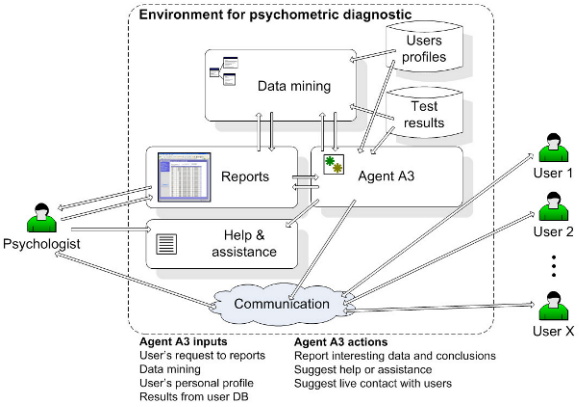


Fig. 17.9: Helping psychologists in their activities

## 17.9 Agent's Role in Environment for Psychometric Diagnostic

The role of the agents is to provide task-related feedback and assistance to the users and to guide the users through diagnostic and training process and help them to reach

his/her goals. Agents, in the environment for psychometric diagnostic, are used for helping users during process of registration (agent A1), guiding users trough diagnostic tests and training programs (agent A2), and for helping psychologists in their work on system (agent A3).

**Agent A1** helps users during their first visit to environment for psychometric diagnostic and helps them to fill questionnaires. Main goal of agent A1 is to create more precise user's profile by providing dynamical questionnaires, checking over the answers and adding some additional questions. Agent A1 isn't connected with data mining subsystem and it doesn't have possibility to enhance its own performance, this agent just follows predefined set of rules.

**Agent A2** guides testing and user's actions by controlling the test selection page based on real-time events. This agent uses user's profile to make personalized test selection page. Agent doesn't force users to follow advices and suggestions strictly, these can be ignored. Agent A2 makes decisions based on predefined rules, but it also uses data mining subsystem to make more efficient suggestions. Agent A2 relies on users' profiles and their achieved results to provide optimal difficulties of diagnostic tests and training programs, also it increases difficulties gradually as user accomplish given tasks. Agent tries to learn from users' performance. Based on users' achieved results, agent receives positive or negative marks. Environment tracks users' activities (order of using diagnostic test and training programs) and their progress (achieved results) and records it in web logs. Analysis of web log files has several goals to evaluate efficiency of diagnostic tests and training programs, to improve agent's ability to guide users efficiently and to find optimal list of tests. Agent A2 is able to select the appropriate interface for different ability levels of users. New users need a simple interface that provides the ability to get help when required, while more experienced users may need minimal help and may want to skip some of the steps in the using available tools.

**Agent A3** helps psychologists with their activities (monitoring users, evaluating test results and user's profiles) in the environment. This agent offers to the psychologist overview information about the users' performances. Agent A3 searches for interesting information from user's profiles, test results stored in databases, and results generated by data mining and reports about them. Agent specifies the importance of each advice. Importance of rating could be modified by the frequency of appearance and by user reactions. The agent uses this information to degrade the potential output to a less important level. Importance of some suggestions could have a varying level of importance over time.

The basic idea is that agents monitor given set of information and process them trying to find suitable suggestions for users. Initially, the agents start with general information about users. As a user interacts with the diagnostic tests, questionnaires and other tools on environment, he/she provides more information about itself. All this information about the user constitutes the user profile. Once the agent gets certain degree of competence, it can deliver pieces of advice that are expected to be relevant for the actual user's context. An important aspect of the user-agent interaction is that the agent usually does its work in an autonomous way, although the user can still require the agent's guidance explicitly or even bypass the agent. Another

important source of knowledge is the user's feedback. This means that the user can express his/her degree of satisfaction with respect to a recommendation, or he/she can even want to inspect alternative solutions. Agents can collect this feedback that will lead to improving the accuracy of future suggestions. Equipping agents with data mining capabilities, the agents are much efficient and more adaptable. In this way, the performance of whole environment can be improved.

## 17.10 Conclusion

Technology integrated into web environment can improve the efficiency of psychometric diagnostics, psychotherapy, collaboration and communication between users. Environment can be used on several ways considering relation patient-environment-psychologists (therapist), patient can use system alone (or with minimal interaction with psychologist), patient and psychologist can use available tools and use environment for communication (synchronous or asynchronous) and psychologists can use tools from environment as additional tool in classic diagnostics and therapy.

Agents supervise user's actions in the interactive environment and they are trying to adjust questionnaires, diagnostic tests, training programs and other integrated tools to personal user's needs making this environment easier for use. Agents use data mining to make more efficiently decisions for suggestions about optimal actions of particular user based on available information. Agents use data mining to analyze their own decisions from the similar situation and use that for self improvement in next decision process.

Integration of data mining in environment for psychometric diagnostic simplifies procedure for analyzing of collected data and reduces time for processing results. Data mining allows processing of the large amount of data and reports potentially interesting data without user's intervention.

For psychologists, diagnostic tests from interactive environment represent easy available diagnostic tool for identification of persons with disorder of cognitive functions. Result analysis of diagnostic tests can identify persons with this kind disorder. Information from cognitive profile of patients can be used for individual and problem oriented therapy prescription.

For patients interested in quick evaluation of their cognitive capabilities, environment for psychometric diagnostic enables comparing achieved results with results of other users and they can identify their cognitive advantages and weaknesses on the cognitive map.

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