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Some Aspects of Designing All-In-One Personal Software Support for Human-Centered Computing

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***Abstract*— Human-computer interaction is a multidisciplinary field that aims to streamline and automate human activities that involve working with computers. This field includes IT support for mental processes, which is based on a human-centered approach that involves either human-centered computing or a focus on the individual user. There is a lack of universal software, so that the user must use dozens of different single-purpose software products to process large amounts of information; the user must adapt to the technology. Our research approach is based on the design of a so-called virtual knowledge, the basis of which is an ordinary database table, into which the user inserts his information in natural language. This informatics structure representing knowledge is controlled by the software Writing Pad (WPad). It is developed as an all-in-one tool to replace the dozens of software products that the user would have to use instead. It also reduces the number of user interfaces and the thousands of necessary mouse clicks between online links and offline paths. The paper explains this human-centered software design, including a demonstration of how we used the knowledge table when writing this paper. The use of such tables for visually impaired users in computer-based learning solutions is also described.**

Keywords—human-computer interaction, user-centered software design, human-centered computing, computer-based learning

I. Introduction

At the previous ICECET conference, we presented a human-centered software design for knowledge-based processes such as teaching and research. The design, based on a database structure that represents knowledge, is so versatile that it covers a dozen areas of computer science and ICT. From the point of view of the individual user, it functions as a multi-purpose IT tool, i.e., as an all-in-one software product. We have been publishing our research on WPad software development for over ten years in various conference proceedings and journals; we have explored topics such as educational software, user-centered database applications, e-learning tools, knowledge management systems, personal information systems, educational technology, tools for technology-enhanced learning, human knowledge processing, and even artificial intelligence (as a cybernetic principle of virtual knowledge that interfaces between the computer and human mental processes). We have not found any description of similar multifunctional software in the scientific literature, nor have we found a similar research approach. The field of human-computer interaction (HCI), or the related field of human-centered computing, seem to be the most relevant to our approach, because the interaction between the user and the computer occurs only through virtual knowledge.

The designer of WPad (the first author of the paper), due to the fact that Windows and various browsers have reached such a high level over the years, can complete all his daily activities (work, programming, publishing, leisure) by controlling virtual knowledge and using only one piece of software. It is important to realize that every human being performs a huge number of knowledge-based activities that go far beyond working with big data. Moreover, automating these activities is time-consuming and represents a high workload due to the need to ensure compatibility with the operating system, intranet, networks, web, and clouds. Currently, individuals perform a huge number of activities; they are overwhelmed by a flood of information, information overload prevails, and computers are unable to deal with these problems in a unified way. This is simply due to the fact that the computer does not know what knowledge or (human) information is. The added value of our contribution is that the virtual knowledge, which is a common information structure for a computer, represents human knowledge at a lay level because it takes the form of a single row of a database table. Moreover, it is an abstract entity independent of any database platform. Therefore, the user can insert human information and knowledge (henceforth knowledge) as macro-substitutions into the fields in the row. This allows the user to create virtual knowledge tables for certain topics and domains. If the user produces these tables on a daily basis over time, he will create his own knowledge base with a simple ontology and semantics. WPad software is the tool used to manage the tables in which the user has personal content (educational content, self-study content, entertainment, administrative information, etc.).

The tables, like other computer files, can be saved, emailed, and uploaded to the web, and the content of the tables can be transferred between offline and online environments. If WPad is installed on a virtual machine, multiple users can also share it and produce knowledge tables together. From a practical point of view, it is important that WPad also works as a simple HTML editor. The user just needs to press the CTRL+F1 key to view the generated HTML tables in a browser and upload them to a university server. It is useful for teachers who need to quickly create e-learning course material. The benefit here is the speed of processing: even a teacher with poor computer skills can generate such material in a few days. Otherwise, this task could take him months. Unlike ordinary users, who exchange content only through computer files, WPad users exchange only useful, reduced content through the table files.

Such an approach is so unique that to the best of our knowledge, there are no similar background studies or related works in the literature. Therefore, a comparison with the human-computer interaction (HCI) and human-centered computing (HCC) fields is made in section II to make the differences between our approach and other state-of-the-art alternatives clear. The next section presents our human-centered design using practical examples from user-centered publishing support and computer-based learning for visually impaired students.

II. Conceptual Framework

From the point of view of solving the simulation of an individual's activity, it is important to realize that, unlike the mass processing of simple data, the processing of knowledge is more complex, because knowledge is hierarchically at a higher level than data. For example, as far as data is concerned, just a simple copying of computer files with the Robocopy command contains more than 50 parameters. Similarly, it is complicated to address how knowledge in heterogeneous formats should be processed and placed on a single screen. Automating user activities therefore means that key activities must be selected by generalization from an infinite number of potential solutions. The human-centered approach of software design is thus based on the fact that from all user activities, one must select those that WPad (the computer) is supposed to simulate. A user menu can only contain certain categories of items (source codes), so it cannot comprehensively cover or automate everything. However, this is only a basic assumption. The goal of this research is to determine how the user should insert knowledge into the knowledge tables as quickly as possible; then, this knowledge should be concentrated and selected to support the user's ongoing activities in the required amount of time. In this way, we can minimize the information overload of users. In this context, it should be mentioned that the automation of user activities on the computer cannot be addressed in a standard way. The paradigm of the batch processing of information and the knowledge implemented by WPad practically means that the user has to work not only with a large number of files but also folders, which he has to be able to browse, edit, or move in batches between offline and online spaces. Based on previous experience, just naming such a huge number of files or folders is complicated.

The IT dictionary describes HCI as a multidisciplinary field whose goal is to create and improve user interfaces to increase intuitiveness, efficiency, and user convenience [1]. Similarly, according to [2], HCI is a multidisciplinary field of study focusing on the interaction between humans (the users) and computers that would expand to incorporate multiple disciplines, such as computer science, cognitive science, and human-factors engineering. HCI represents a broad field that overlaps with areas such as user-centered design (UCD), user interface (UI) design, and user experience (UX) design.

Without a more detailed explanation of a number of literary sources, it can be mentioned that some of the sources focus more on the technical side of human-computer interaction (hardware tools). The author of the WPad software was also more focused on the technical side at the time of his habilitation on the topic of mass content construction and e-learning, when one of the opponents described his approach as HCI [3]. In other words, at the time (2012), the author did not even know what HCI was, because it was originally his hobby to program for his own use. Previously, as a researcher at an industrial R&D center, he automated his computer work with the goal of minimizing the number of offline and online interfaces, developing a personal multi-purpose program for the mass processing of computer files and creating an expert system for solving technical problems. Paradoxically, the author considered his tables to be an expert system for dealing with corrosion protection issues, although computer science has applied expert systems to other issues.

The principle of WPad programming is close to the area of HCC, which is a part of HCI. HCC, in a Quora Internet discussion, was described as a reaction to the early emphasis on HCI that argued that there is a better understanding of what humans want and need: “putting the focus of adaptation on the shoulders of the computer rather than the human” [4]. The classification of HCC in [5] as “an emerging field that aims at bridging the existing gaps between the various disciplines involved with the design and implementation of computing systems that support human’s activities” is appropriate. The claim that “HCC aims at tightly integrating human sciences (social and cognitive) and computer science (human-computer interaction) for the design of computing systems with a human focus from the beginning to the end” corresponds very well with our focus on automating knowledge-based processes [6]. The interdisciplinarity of HCI can be seen from various ACM conferences, such as conferences on intelligent user interfaces or human factors in computing systems [7].

For a better understanding of WPad design in relation to the above-mentioned context of UCD in [2], it is helpful to consider some details from [8]. According to [8], the basis for UCD includes the needs, requirements, and limitations of the user and their interaction interface; it is a multi-stage process that requires designers to analyze and predict user behavior in a given application. The command user interface (CUI; command line), graphical user interface (GUI; windows, menus, forms), voice user interface (VUI; controlled by natural language), and multimodal user interface (MUI; combination of interfaces,

interfaces used by disadvantaged users) are given as user interfaces. The need for testing with real users is stressed. Activity-centered design (ACD), scenario-based design (SBD), and usage-centered design (UCD) are possible concepts that can be emphasized in development. It should be added here that our research is multidisciplinary: the WPad application covers elements of UCD, ACD, and SBD simultaneously, as all possible categories of activities that a user performs on a daily basis are supported. For example, WPad can be used by a teacher who is doing research or creating e-learning content, or it can be used for various decision-making processes. All user interface types are applied in the design of WPad. Part of the menu uses CUI commands, the GUI is implemented using two interfaces (Visual FoxPro database platform and a web browser—HTML and modifications for the blind and visually impaired), and the VUI and MUI are partially implemented on the designer's computers. The basic concept of the WPad design is to manage the user data structure (virtual knowledge), which simulates the user's human knowledge and is understood by the computer and applied in registered technical solutions that enable the processing of unstructured data [7, 8]. Essentially, the idea is that the user inserts unstructured or semi-structured data in natural language as plain text into a default structure (knowledge table). The computer can read and process it as the standard information structure.

From the comparison with the literature, it can be concluded that all the aforementioned user interface types are applied in the design of WPad. Part of the menu uses CUI commands, the GUI is implemented using two interfaces (the Visual FoxPro database platform and the web browser), and the VUI and MUI are partially implemented on the designer's computers. From this point of view, it is crucial to understand that the basic technical solution, which is registered at the Slovak Patent Office, allows WPad to manage the user's data structure (so-called virtual knowledge), which simulates the user's human knowledge and is understood by the computer as a representation of information (knowledge) [9, 10]. Essentially, the idea is that into this data structure (knowledge table), the user or computer puts unstructured or semi-structured data in natural language; then, WPad processes it into the desired output. Due to the fact that the user uses this information structure and inserts tacit knowledge or information into it according to personal need, it is clear that this is a kind of human-centered computing or user-centered design. In this case, since the IT-enabled automation of teaching and research processes is being addressed, there is clearly an overlap between cognitive science and computer science.

A key element of our approach to HCC is that the software is designed primarily according to the specific actions and needs of the user, e.g., for teaching or writing scientific articles. This is consistent with HCC, as NASA highlights when defining HCC [11]: "The human-centered computing approach starts with people, and designs technology for them, rather than forcing them to distort their work to suit the technology." Information overload is often mentioned today. Given the overwhelming flood of information pouring in, users need to filter information, sort it, and switch between different types of information. This automatically implies the need to address multitasking, which is one of the priorities of human-centered informatics [12]. According to [13], the biggest problem is that the speed at which information is fed into the computer lags far behind the speed at which it is processed by the computer (humans cannot transfer information to the computer quickly). We have stated in several publications that the reason for this is that there is no suitable knowledge representation that can be simultaneously understood by both humans and computers. Current representations are either unacceptable to humans (when knowledge is defined as certain rules) or very general (when, for example, knowledge representations are defined as pictures, graphs, and audiovisual outputs). In this context, the authors respected the basic cybernetic principle that there must be some kind of isomorphic switch or transducer between machine and human activities. This concept is exactly matched by the concept of the above data structure and virtual knowledge tables. Since ontologically the tables are a kind of object representing different domains (science, work, entertainment, publishing, literature), the user can quickly switch between them, and thus, they are able to multitask. Storing selected or concentrated knowledge content in knowledge tables (in natural language) allows the more efficient input of information into the computer at a lower information entropy. The optimal design of human action algorithms allows for the parallel efficient design of information algorithms so that the computer delivers the desired output to the user almost instantaneously.

However, research so far has shown that synchronizing human activities is very complicated because the current method of working and the state of the art are insufficient. Currently, this synchronization occurs only at the level of data, which is hierarchically lower than human information or knowledge. In fact, it can be said that human mental processes are so diverse and extensive that a computer should be able to enable a user not only to process a large number of computer files, but also to work in bulk with folders and incompatible heterogeneous formats. The WPad software allows an individual to create large-scale tables with thousands and hundreds of thousands of rows. One could say that personal computer support for users who work with "big personal information" (teachers, researchers, students, engineers) is also provided. Given Martens' [14] assertion that there is an absence of software for educational technology or Technology-enhanced Learning (TEL), the software application is a valuable contribution to the state of the art. This applies at the least to content processing.

Because we work in education, we logically apply the solutions to teaching, learning, self-study, research, and publishing (the basic idea was suggested by the author of a program from industrial research in which the information system of an ISO 9001 accredited surface treatment laboratory was programmed). However, it should be emphasized here that the teacher must work with the content and use the selected concentrated content as needed within the time limits dictated by the teacher's activities [15]. For example, someone may have excellent e-learning content, but the lesson lasts only 50 minutes. During lectures or exercises, the teacher needs to deal with constant inputs and outputs related to the material. Therefore, any educational technology needs to encompass diverse areas. In [16], it is stated that three basic types of technology have been identified: technology for content delivery, technology for learning enrichment, and technology for transforming education so that it involves more self-directed learning. This is exactly in line with our findings, as WPad is applied to each of these areas: it functions as an educational all-in-one tool.

However, the aforementioned division of technologies and the current literature do not take into account the differences between transforming knowledge into a digital form and transferring knowledge within personal computers, the Internet, networks, and clouds. We thus embed educational content in knowledge tables and at the same time develop a combined offline-online underlying IT infrastructure that provides avenues for knowledge transfer between humans and computers. Our research has thus reached the stage in which it is possible to simulate human activities in the context of learning, research, publishing, self-study, entertainment, etc. However, this is a very challenging activity. Its basis is the identification of algorithms of human activities in the knowledge-based process and the construction of computer algorithms according to these human activity algorithms. However, this is a very challenging activity because current computer science cannot comprehensively address these problems. The solution requires the mastery of several IT domains; for example, the knowledge must be synchronized on a given IT infrastructure. In terms of automation, the slowest point is the adaptation to operating systems, networks, and clouds [17].

It should be pointed out that the basic use of the WPad for the average user is probably the cheapest solution in the world, as the Windows operating system is sufficient for the use of WPad. The WPad application itself is a kind of switch between humans, Windows, browsers, and applications. This is due to the fact that it is programmed on the principle that the user should be able to do everything as quickly and easily as possible. In other words, if Windows, browsers, or applications can handle certain tasks faster, WPad will assign them tasks to perform for the user. However, the advanced use of WPad in online spaces is professionally and financially unsolvable for the average user. Nevertheless, we found a solution while testing WPad on faculty servers that simulate virtual machines and then on a Microsoft Azure virtual machine on a Windows 2016 server. Therefore, in principle, any individual who can pay 50–100 EUR per month can use this software, or a group of individuals can share a computer on a rented virtual machine. However, a comprehensive solution also requires FTP transfers and the use of database servers.

It is necessary to mention that the huge advantage of WPad tables is that they have content in their rows (information, knowledge). In addition, on the designer's computer, rows can contain source code enabling the knowledge table to control itself. Database technologies do not allow this because the data are stored on a database server and extracted from it using a programming language. Therefore, unlike WPad tables, database tables cannot be transferred like regular computer files. WPad can be also used as an editor for programming languages when source code is inserted in rows of a knowledge table (C++, HTML, PHP, SQL). It can also be mentioned that although in academic research, the mass processing of information is tested by using various external datasets and corpora from Internet sources, the WPad application uses personal data and information. This is due to the fact that basically every user working with information has a "small Internet" on their computer and uses many Internet resources, so some menu items allow online and offline search (currently, a regular user has hundreds of thousands of files on his personal computer).

III. PRACTICAL EXAMPLES OF HUMAN-CENTERED SOFTWARE DESIGN

The topic of this paper overlaps with the following conference topics: human-computer interaction, software engineering, web applications, and computer-based learning. As explained in the previous section, the software is conceptually designed for the individual user as a personal-universal human-centered tool. It is based on offline WPad (but WPad also works on a virtual machine, which is part of the online cloud) and the PIKS (web application) derived from it in the form of multi-purpose personal communication channels. The coverage of these conference topics is demonstrated in this section using examples from the use of this software by an individual user. At the same time, several functional elements that are useful for concentrating the user's knowledge but are absent in other software will be presented. From the point of view of programming, it is important to understand that virtual knowledge is an abstraction of a certain activity of the user or his knowledge. This allows macro-substitutions to be used in software design. Therefore, in the same table, a user may have content related to conference data, a list of files in a folder, Internet links, offline paths, article text, conference proceedings, or even a computer file of a different format (this is rare, because it depends on the size of the file and the computer memory). However, for a computer, it is always the same, i.e., virtual knowledge enables macro-substitution.

A. *User-centered Support of Publishing*

Every author knows that writing an article is a very complex undertaking. Authors must deal with a large amount of information, search for a suitable journal or conference, and investigate to what extent it matches their expertise. If they find a suitable conference, they must examine its web page, which contains dozens of different items—basic data, the focus of the conference, guidelines for authors, and other information. In the instructions for authors, there are items such as an article template with prescribed formatting, standards for references, and deadlines for stages of paper approval. According to conference practice, these deadlines refer to the submission of an abstract, extended abstract, or paper, the review process, and the uploading of the final paper to an electronic system such as Conftool. Thus, the user must visit all these links, clicking between them, but they also must search through directories on their computer or through the library of documents from previous conferences. A separate activity is a literature search, i.e., finding various web pages with sources to use for the introduction, references, and literature review sections. It is already clear from this brief listing of items that users need to concentrate all of this information in one place. Otherwise, they need to perform hundreds of redundant mouse clicks.

In our case, the user can store information and tacit knowledge in one or more rows of the table (content in the text box and meta-information in the columns). From the text window, the user can directly open online links and offline paths without having to type them into the browser or Windows

Explorer. Fig. 1 illustrates such a user table, which shows that the user has five rows in the table with entries related to multiple conferences (ICECET, EDUCON, ICL, EDULEARN, FTC). This allows the user to apply multitasking, i.e., to switch conveniently between the information in the rows and to search, filter, and process this information into the necessary outputs. Moreover, from the text fields and columns of tables, the user can switch between Internet links, files, and directories on his computer, as seen in Fig. 1.

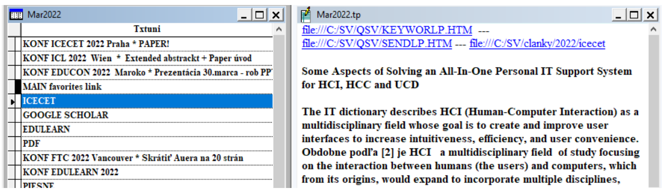

Fig. 1. Screenshot of user's knowledge table (no third-party software is needed).

The table in Fig. 1 had about thirty rows at the time of writing, and two of those rows were related to this conference. WPad has a useful feature that allows the information to be filtered, so that the user sees only the rows related to a given topic. Fig. 2 illustrates how, after pressing F6, the user sees only two rows out of the thirty rows in the table. Thus, the user can now work with two rows or add additional rows with records (e.g., literature search results, article notes, miscellaneous ideas).

Fig. 2. Screenshot of filtered IEEE table that only shows rows containing the keyword "ICECET."

The WPad table acts as a switch (spider) between links and offline paths, either in the user interface of the database application or from the HTML table, which is created using the CTRL-F1 keyboard shortcut. In the latter case, the HTML table is automatically opened by the default browser and the user can use it as an "offline web page" or can transfer it to his organization's web or online space using upload or FTP. Fig. 3 illustrates that if the user clicks on the record number of either of the two ICECET-related lines, the user is shown the conference web page in the right-hand window, so that it can be browsed in parallel.

Fig. 3. Screenshot of part of the IEEE table converted into HTML.

From the point of view of creating web content, e.g., for e-learning, it is important to realize that after converting a WPad table to an HTML table with CTRL-F1, each row represents, in principle, one web page. Therefore, if the user knows the HTML language, he can create such tables and build his own web page from them or even create a specific portal. This method was commonly used in teaching undergraduates. According to the curriculum, tailor-made tables were created that were then used by students as study materials. From a practical point of view, the self-sorting of rows is very useful. If the user changes the text in the column by which the table is indexed, the text is moved to a new position according to the date or alphabetical order, for example. Fig. 4 illustrates how the order of the rows in the table changed when the user changed the date for the row for ICECET to 12/16/2022. Since that date does not yet exist, the row was moved to the first position of the table. This allows the user to create a planning table or a personal organizer. Comparatively, in relational database tables, such a dynamic option for changing the order of rows is not possible.

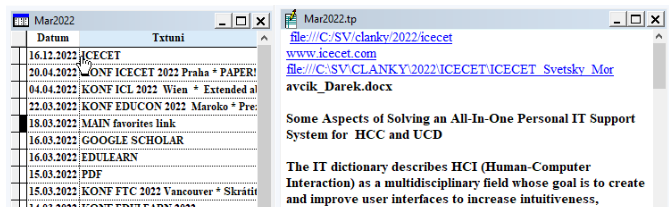

Fig. 4. Example of self-sorting rows of an indexed table (sorted by date).

WPad also allows the user to perform various combination activities, such as the batch Internet search illustrated in Fig. 5. As can be seen, after four words were typed into the text window of the table, the Microsoft Edge browser automatically opened four windows with the search results. The user can examine them and copy the selected content into the WPad table or make manual notes in the table. He can then generate an HTML table, which he can then use when writing an article, usually for the introduction and reference sections.

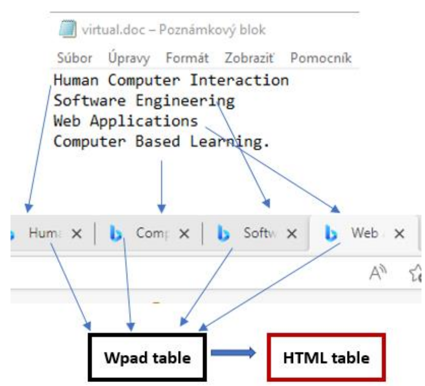

Fig. 5. Multi-search principle for four inserted keywords.

B. Application for blind and visually impaired users

The WPad software was also used to support the teaching of a master's degree in computer science, considering the student's and teacher's exceptional needs related to their disabilities. The teacher was a blind person, while the student was deaf. The WPad application was used to prepare materials for a deaf student during classes on the development of Internet and distributed applications. The course was realized during the first semester of supplementary master's studies (fourth year of studies). A group of non-disabled students also participated in the same classes. To facilitate communication between the teacher and the deaf student, a sign language interpreter was present during the classes. The interpreter helped with basic communication tasks. However, it turned out that in terms of explaining programming, the code and application architecture, project details, etc., the sign language interpreter was not able to translate the professional terminology in a sufficient way. Therefore, the WPad tool was used to support this communication. The student did not use the WPad tool directly because he was used to working with materials available through a browser and standard documents (MS Word and PDF documents). At the beginning, the student received the same instructions for completing the tasks as the other students; these materials were available on the website and in the form of instructions in PDF format. However, the student needed additional explanations and asked many additional detailed questions.

The teacher prepared additional materials for the deaf student using the WPad software. An educational package concerning the conducted course in the form of a table in the WPad program was prepared. The package contained instructions for completing tasks, answers to questions, and code snippets with explanations. These tables were then converted to HTML by the WPad software. In the next step, this resulting HTML package was checked by the student during individual classes. The teacher made corrections to the original table and generated another version of the package. Then, he made it available to the student in HTML form on his website. The student used the knowledge contained therein, solved the required tasks, and created a programming project according to the instructions. The student was also able to pass the electronic test. In summary, the WPad tool was used in a very unusual case, namely for educational communication between a blind teacher and a deaf student. This confirmed the versatility and flexibility of this solution.

IV. Conclusion

In this paper, a universal software support system aimed at teachers, researchers, and individuals was introduced. From the point of view of individual users, it is a user-friendly and efficient HCC tool that allows users to process a huge amount of information. In addition, the basic use of the WPad software does not require any specific IT skills, and only WPad and Windows are required. Users simply input their information and tacit knowledge into knowledge tables that the computer can process according to their needs. Its multifunctional use was explained using the examples of solutions for the IT support of publishing activities and computer-based learning for the blind and visually impaired. However, there is a paradox: while the basic use of WPad by students was seamless under a teacher's instructions, only some teachers were able to use WPad without instructions. Therefore, future research is also aimed at creating WPad table templates for teachers and researchers; this will allow us to define certain patterns of use of this human-centered application. The research will also focus on the development of an Internet application, the so-called PIKS channels, which use the same data structure as the offline WPad application.

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