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Does a Semantic Desktop Facilitate Your Daily Tasks?

Summative Evaluation of Semantic Tools for Email and File Management

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ABSTRACT

Semantic desktop environments aim at improving the effectiveness and efficiency of users carrying out daily tasks within their personal information management infrastructure (PIM). They support the user by transferring and exploiting the explicit semantics of data items across different PIM applications. Whether such an approach does indeed reach its aim of facilitating users' life and — if so — to which extent, however, remains an open question that we address in this paper with the first summative evaluation of a semantic desktop approach. We approach the research question exploiting our own semantic desktop infrastructure, X-COSIM. As data corpus, we have used over 100 emails and 50 documents extracted from the organizers of a conference-like event at our university. The evaluation has been carried out with 18 subjects. We have developed a test environment to evaluate COSIMail and COSIFile, two semantic PIM applications based on X-COSIM. As result, we have found a significant improvement for typical PIM tasks compared to a standard desktop environment.

Author Keywords

summative evaluation, semantic desktop, personal information management

INTRODUCTION

The aim of semantics desktops is to foster personal information management (PIM) by linking and reusing information across different PIM applications. Semantic Web technologies such as RDF and formal ontologies provide the building blocks for a semantic desktop as they enable the formal representation of meta data that links personal information. In the past, many different semantic desktops and semantic PIM applications have been developed such as [14, 7, 13]. Although the use of semantic desktops has been studied in formative evaluations, the users' benefits of semantic desktops and their applications are still unclear due to a lack of summative evaluations. To the best of our knowledge, there is so far no summative evaluation published that deals with typical email and file management tasks in a semantic desktop environment. However, as Whittaker et al. [21] claim such evaluations are necessary to produce comparable and reproducible results in human computer interaction (HCI) research. In this paper, we aim at filling this gap by presenting the design and results of a reproducible, task-based, and summative evaluation of our semantic PIM tools COSIMail and COSIFile. COSIMail and COSIFile are extensions of the email client Thunderbird and the KDE file manager Dolphin, respectively. Both, COSIMail and COSIFile are part of our original semantic desktop framework X-COSIM [10].

The summative evaluation presented in this paper enables the comparison of PIM applications with respect to typical email and file management tasks. The evaluation bases on a realistic task set and data corpus extracted from organizers of a conference-like event at our local university. It required test persons to work under laboratory conditions, which naturally differ from the personal work environments. Thus, the evaluation has been designed and carried out considering the individual PIM strategies of users [15]. We took several measures to familiarize the test persons with our test environment. This is reflected in the evaluation process, selection of test persons, and design of the data corpus on which the PIM tasks are executed. By quantitative and qualitative measures, we evaluated that our semantic desktop tools COSIMail and COSIFile result in significant PIM improvements for specific types of PIM tasks compared to the corresponding tools in a conventional desktop.

THE X-COSIM SEMANTIC DESKTOP ENVIRONMENT

To foster personal information management, semantic desktops aim at linking and reusing information across different PIM applications [19]. They support users in an intelligent way to better and more efficiently conduct their PIM tasks. The X-COSIM framework [10] is an example of such a semantic desktop. It has been developed in the frame of the EU project X-Media[1] that deals with a large-scale knowledge management and cross-media reuse. It was nominated for best paper award at the K-CAP 2007 conference and differs from other semantic desktops by basing on a formal ontol-

[1] http://www.x-media-project.org

ogy for describing personal information management. The architecture of the X-COSIM framework[2] is depicted in Figure 1.

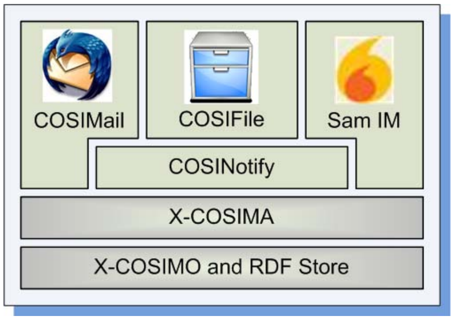

Figure 1. Architecture of the X-COSIM framework

It consists of four layers: The bottom layer provides an RDF store where all meta data is kept. The meta data is described by the X-COSIM ontology [10] that enables formally precise descriptions in spite of context-dependent conceptualizations as commonly employed by end-user applications.
The second layer, X-COSIMA, transforms between contextualized views of information—as employed in applications—and the more general and complex representation of the X-COSIM ontology. It enables programmatic access to stored metadata offering domain specific programming objects that abstract from the complexity of the underlying conceptual model given by the X-COSIM ontology. It serves as mapping layer between semantic desktop applications and the service and application layers on top.
The third layer provides generic services such as COSINotify, a software component running as background process. COSINotify updates the meta data in the RDF store about files that are moved, copied, or deleted.
The top layer comprises applications building upon the lower layers for mapping and representing personal information. They contribute and retrieve semantic meta data about the information they deal with, e.g., email messages, file system information, and to-do descriptions. The email client COSIMail, file manager COSIFile, and the instant messenger Sam are examples for such applications.

In this paper, we evaluate the two tools COSIMail and COSIFile. We choose to include the semantic email software COSIMail in the evaluation as email clients are well-known to users and play an important role in PIM (are considered as a "habitat" for personal information management [8]). We also decided to develop and include the file manager COSIFile as file managers support manual search, the preferred search strategy by users when compared to the utilization of a desktop search tool [5, 17, 4].

Both, COSIMail and COSIFile are semantic desktop applications that establish and exploit connections between files on the file system and their associated emails (if they have been sent or received as attachments of emails). Their design is motivated by the hypothesis that interlinked information—as it is established in semantic desktops—is beneficial for PIM. In [17], the authors interviewed users who confirmed that a separation of files, emails, and bookmarks is "inconvenient for their work". The further, this separation leads to "unwanted redundancy". This is supported by the findings in [5], where the authors report significant overlaps between created email folders and file system folders. To relieve this situation, the X-COSIM framework and their applications COSIMail and COSIFile support for managing and leveraging links between the emails and files. Thus, the two applications are described in more detail below.

COSIMail

COSIMail is an add-on for the Thunderbird[3] email application. It enables its users to track the location of email attachments that have been saved to the file system. Further, it allows to open such files directly from the email client or to open the file system folder where they are located. The functionality is based on the exploitation of semantic meta data that links files on the file system to email messages they have been attached to. It is presented to the users by an additional widget that displays the location of saved attachments as a link (see Figure 2). Using left or right mouse clicks, users can choose to open the saved file or corresponding folder.

By means of the mapping layer X-COSIMA, COSIMail contributes meta data about email communications to the semantic desktop store. Among others, this meta data includes an email's body and subject, sender and recipients, sent date, and information about attached files. To gather meta data about attachments saved by the users, the standard "save" operation for attachments is intercepted by COSIMail and leveraged for enabling the semantic linkage between the file and the email.

COSIFile

COSIFile is an extension of the file manager Dolphin[4], which is part of the KDE desktop[5]. The design of COSIFile is motivated by studies on users' file management behavior, particularly the document retrieval strategies. COSIFile has been designed to improve manual search and supporting explorative search across the boundaries of the file manager application. COSIFile features the utilization of additional file attributes, namely the sender, recipient, and subject for files that have been retrieved as email attachments. The provision of additional file attributes is motivated by a study on users' re-finding behaviors [4], claiming that many document attributes available in desktop search tools are not considered useful by humans while others that are not available are recalled with higher precision, e.g., associated people, documents, emails.

Figure 3 illustrates how the COSIFile additions implemented are integrated into Dolphin. As shown, COSIFile provides a detail view enabling users to select additional file

[2] `http://www.uni-koblenz-landau.de/koblenz/fb4/institute/IFI/AGStaab/Research/x-cosim`

[3] `http://www.mozilla.com/thunderbird/`

[4] `http://dolphin.kde.org/`

[5] `http://kde.org/`

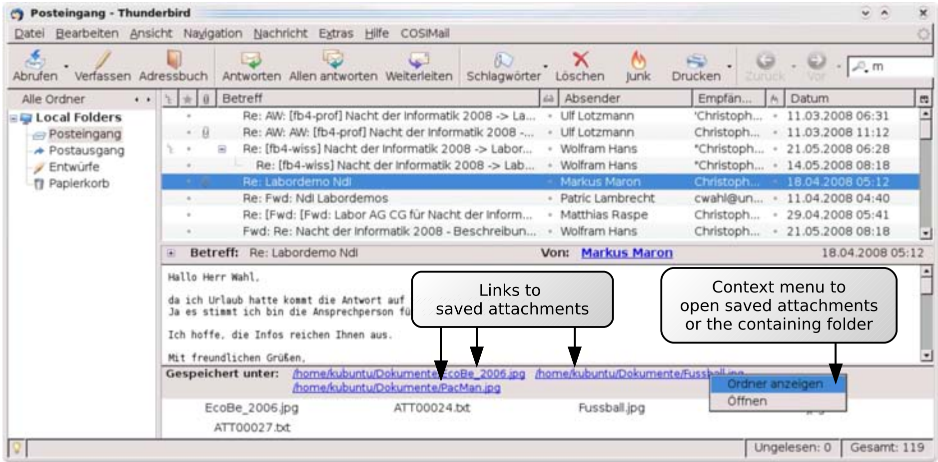

Figure 2. Screenshot of COSIMail showing Emails of the Evaluation Data Corpus

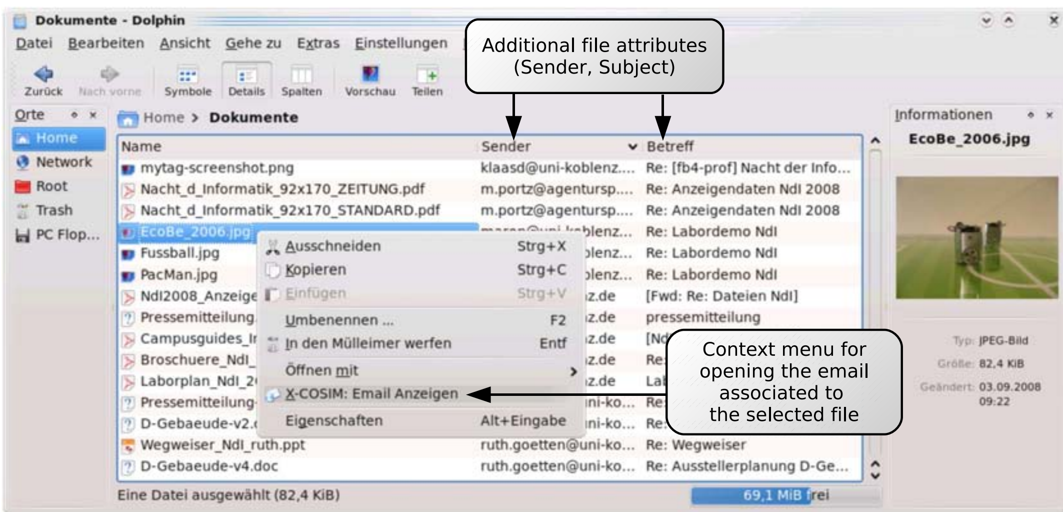

Figure 3. Screenshot of COSIFile showing files of the Evaluation Data Corpus

attributes providing supplementary contextual information such as sender, recipient, and subject of the email it was sent from. Like any other file attributes, they can be used for sorting files, a strategy that users commonly employ in manual search [5]. The context-menu for files contains an additional menu entry for opening the email associated to a file in COSIMail.

Summary

A presented above, COSIMail and COSIFile have been implemented as extensions that augment the functionalities and user interfaces of established applications for email and file management. We believe that the integration into known applications reduces the users' effort to familiarize with the added functionality as they do not need to familiarize with new user interfaces and interaction paradigms.

DESIGN OF THE EVALUATION

The goal of our evaluation of the presented COSIMail and COSIFile applications is to investigate whether PIM benefits from such semantic desktop tools. Specifically, we want to learn whether relations expressed by semantic meta data can be exploited by tools to result in more efficient PIM. Accordingly, we formulate the following hypothesis for our evaluation: *Does the utilization of the semantic desktop applications COSIMail and COSIFile result in a more efficient conduction of common PIM tasks compared to their counterparts in a conventional desktop?*

For answering this question, we choose a task-based evaluation of our tools. Conducting task-based evaluations was provoked as a means to foster research on human interaction [21]. They allow for summative evaluations and enable the comparison of evaluation results among researchers [11]. In this evaluation, test persons executed a set of typical PIM tasks on one of two systems. Whereas the first system featured the X-COSIM semantic desktop providing COSIMail and COSIFile as semantic PIM applications, the other system was designed as conventional desktop with the Thunderbird mail client and Dolphin file manager. Evaluations of PIM systems require desktop data on which tasks can be executed. Thus, we created different task types, i.e., generic abstractions of the actual tasks evaluated. Based on these task types, we created a set of concrete PIM tasks to be evaluated. Such task types in combination with a data corpus enable the comparison of desktop tools [6].

In the following, we introduce our evaluation process and methodology. Next, we characterize the participants of the evaluation. We then explain the data corpus, the tasks created, and introduce the test systems used in the evaluation. Subsequently, we present the conduction of the evaluation, before we conclude the section.

Evaluation Process and Methodology

The evaluation process consists of three phases, namely *introduction*, *observation*, and *feedback*. In the introduction phase, the test persons are introduced into the evaluation setting, the planning of a conference-like event at the University of Koblenz. This includes the documents and emails created and exchanged by the two organizers of the event, forming the data corpus of our evaluation. This introduction is conducted as a measure to familiarize a test person with the evaluation setting. In addition, the test persons are introduced into the PIM tools that are used for solving the different PIM tasks in the observation phase. Depending on whether they worked on the X-COSIM semantic desktop or using a conventional desktop, either COSIMail and COSIFile or Thunderbird and Dolphin are explained. Subsequently, in the observation phase, the actual evaluation of the tools is carried out by conducting a set of pre-defined tasks typical for PIM. Here, no further assistance to the test persons is given. Rather, we merely observe the test persons and track their behavior using screen recordings and taking notes. The observation phase is followed by a feedback phase, where test persons fill-in a questionnaire to gather subjective feedback. Subsequently, a short interview is conducted to collect further comments not captured by the questionnaire.

To complement this evaluation process, we defined an evaluation methodology that specifies the concrete measures to evaluate the hypothesis defined above. Following the goal-question-metrics approach [2], we defined the following questions considering user effectiveness, user efficiency, and user satisfaction when carrying out the tasks:

- With respect to *user effectiveness*, we measure how effective a test person are in completing the PIM tasks. Thus, we track how many and which tasks test persons can complete successfully using our semantic PIM system compared to a conventional one.

- Considering *user efficiency*, we measure how efficient test persons are in completing the PIM tasks. Thus, we are interested in the effort a test person is spending for completing the tasks using a semantic desktop compared to a conventional one.

- Considering *user satisfaction*, we evaluate which test system is preferred by the test persons and why. Are test persons satisfied with the usability and functionality of our extensions or do they hinder them in their work?

To answer the previous questions, we have employed objective and subjective evaluation methods [16, 11] during the observation phase and feedback phase. For measuring effectiveness and efficiency during the observation phase, we employed objective methods: We observed test persons while interacting with the test systems and recorded the computer screen for each test person and for each task. We measured the time a test person worked on each task (we stopped the time when a person successfully completed a task or indicated to give up) as well as the mouse movements, and the number of window switches. To gather feedback on user satisfaction in the feedback phase, we have applied subjective methods. Here, the users filled out a questionnaire. The questionnaire was developed by selecting questions from the IsoMetrics inventory [12]. To be more specific, we used the IsoMetrics^S version that supports a summative evaluation of software systems. Afterwards, we conducted a short interview with every test person to record further remarks and opinions. Table 1 summarizes the employed metrics and the corresponding evaluation question.

Table 1. Questions and Metrics

Phase	Question	Method	Metric
Observation	Effectiveness	Objective	Success Rate
”	Efficiency	”	Execution Time
”	Efficiency	”	Mouse Movements
”	Efficiency	”	Window Switches
Feedback	Satisfaction	Subjective	Questionnaire
”	Satisfaction	”	Interview

Data Corpus

Summative evaluations require comparable test systems including the evaluation data available on the compared systems. Thus, for our evaluation, we created a corpus that has been selected from a realistic scenario for PIM. The corpus was extracted from real emails and files from two organizers of the night of computer science[6] at the computer science department of the University of Koblenz. The event is dedicated to non-expert visitors and includes presentations of research labs and industrial partners, workshops, and invited talks on prominent topics in computer science. The corpus consists of 119 emails and 66 files on the file system, where 40 of the files are associated to emails. The data corpus contains emails and documents around the following activities that have been carried out by the organizers: *(i: Advertisement)*, Correspondence with media agencies and print shops, preparation of an advertisement poster and a newspaper advertisement, *(ii: Scheduling)* of guided tours to research labs, *(iii: Preparation)* of a leaflet that presents guided tours, research labs, workshops, and invited talks, and *(iv: Planning)* of booths for industrial partners. The data corpus was selected to ensure that the test persons of our evaluation will already have an understanding of the context in which the emails and files have been created.

[6] `http://nacht-der-informatik.uni-koblenz.de/`

Test Persons

In our evaluation of COSIMail and COSIFile, 18 test persons from our computer science department of the University of Koblenz took part, 15 PhD students and 3 graduate students. All of them have not been using the X-COSIM semantic desktop before, nor have they been acquainted with any other semantic desktop system. All test persons participated in the night of computer science as visitors. Thus, the context of the event is known to them. However, the test persons have not been involved in the planning of the event. In particular, they have not been familiar with the data corpus, i.e., the communication flow that happened between the organizers for preparing the events.

The participants have been divided into two groups, one used the X-COSIM semantic desktop and the other one using the conventional desktop. All participants have not been told that there is another group of people that evaluated with a different desktop system.

Designing the PIM Tasks

A set of different task types for PIM has been defined for our evaluation. Based on these task-types and the data corpus described above, different PIM tasks have been created for our evaluation. The task types have been defined based on findings in PIM research. In [1], four major PIM task types have been identified, namely tasks for acquisition, organization, maintenance, and retrieval. For our evaluation, we define concrete tasks for the types organization and retrieval. With respect to the task type retrieval, three specializations have been distinguished [9]: Lookup tasks are defined as tasks where a piece of information that is inside some document (e.g. an email, or spreadsheet) needs to be found (e.g. a phone number). The document itself may be exactly known or not. Known-item tasks are those where the document as a whole is required and the user knows exactly which one he or she is looking for. Multi-item tasks are tasks where information needs to be collected or processed from multiple items.

For designing the set of concrete tasks used in our evaluation, we define one organization task, two lookup tasks, and three multi-item tasks. In addition, we define further tasks for document-driven-collaboration and for information-collation. Table 2 lists the different task types, their quantity in the evaluation task set, ordered in the sequence of their occurrence. We start with an organization task where the users are asked to initially organize the emails and documents of the data corpus defined above. This task was specifically designed to ensure that test persons get acquainted with the data corpus and feel comfortable with it when performing the subsequent PIM tasks of our evaluation. In the lookup tasks, the test persons have to use search functionality to find an item sought after. As the functionality provided by the X-COSIM semantic desktop is not useful for these two lookup tasks, they serve as a baseline test to proof the comparability of the skills of the two different user groups in the evaluation. Consequently, measurements for these two tasks are expected not to vary significantly for both groups of test persons. The following tests are performed to investigate on the advantages of our semantic desktop tools compared to the conventional ones. Multi-item tasks require test persons to combine information contained in multiple documents, e.g. in a file and an email. The task set for the evaluation contains three multi-item tasks.

Based on the analysis of the corpus and related work on email utilization [3, 20], we created further tasks that are combinations of the lookup task type and multi-item task type mentioned before. They are intended to resemble common work practices related to email and file management. We defined three document-driven-collaboration tasks that resemble email utilization for collaborative work on documents, e.g., the collaborative editing of a document. Typical for such tasks is that different document versions are sent back and forth between its editors where the associated emails contain comments on the changes made or remarks on what should be changed. A further complex task type we created is that of *information-collation* standing for tasks where information contained in multiple documents needs to be collected, e.g. for reporting on work progress within a project.

Table 2. Evaluation Task Set

Task-ID	Task Type
1	Organization
2,3	Lookup
4,5,6	Multi-Item
7,8,9	Document-Driven-Collaboration
10	Information-Collation

Test Systems and Evaluation Wizard

As the test persons have no experience with semantic desktops and thus the tools are not installed on their computers, we had to set up two predefined test systems. Both test systems are running the KDE desktop. One test system has installed the X-COSIM semantic desktop including our PIM applications COSIMail and COSIFile and the other one is a conventional desktop with Thunderbird and Dolphin. The test systems have been created as virtual machine images and the computer used in the evaluation was equipped with 2GB RAM and a dual-core 2GHz processor. A standard keyboard, a 3-button wheel-mouse, and a display running a solution of 1280x1024 pixel was connected to the computer. Both systems were loaded with the data corpus described above. In addition, we have installed tools for tracking mouse movements. Furthermore, we capture the screen for additional analysis purposes and to review evaluations.

For capturing general information about the test persons such as demographical and prior experiences with PIM applications, for guiding the test persons through the set of tasks, and for gathering the subjective feedback, we developed a graphical tool depicted in Figure 4. The tool guides test persons in a wizard style form through the different tasks of the evaluation and presents a description and contextual information about the task. Once a test persons clicks on the Next task-button, the person's solution is stored and measures such as elapsed time are stored and reset for the next task. The tool does not allow to switch back and forth be-

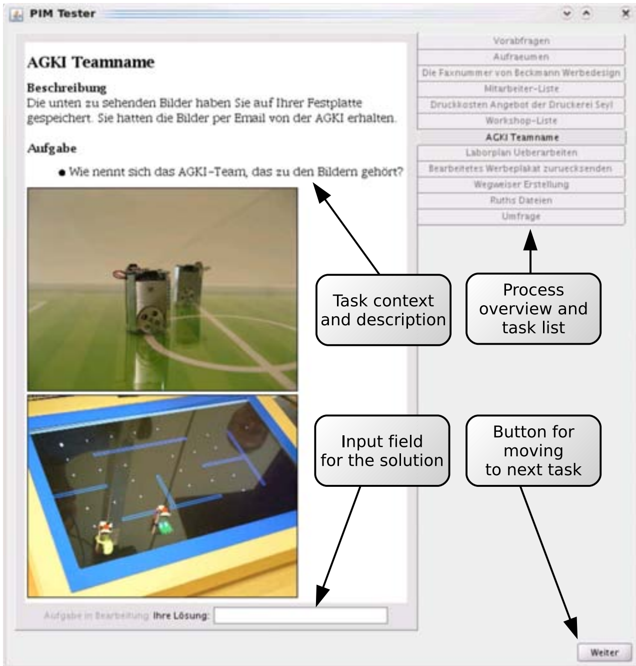

Figure 4. Screenshot of the Evaluation Wizard

tween tasks. The evaluation wizard spans over the entire observation phase and provides the questionnaire of the feedback phase.

Conducting the Evaluation

We conducted the evaluation at a standard work place in our research group following the three phases introduced above. Each test person was randomly assigned to one of the two groups to determine whether the semantic desktop system or the conventional desktop system was to be used. In the introduction phase, first each test person was presented a set of slides introducing the data corpus and the tasks of the organizers of the night of computer science. Then, the test system was introduced to the test person and the corresponding email and file management applications to be used during the evaluation were started. We presented their core functionalities, introduced them into the evaluation wizard, and asked whether the test persons had questions on specific tool functionalities. In the subsequent observation phase, test persons started to work on the pre-defined PIM task set. Here, no further help or guidance is given to the test persons. In a first step, the users initially organized their emails and files. Subsequently, the two baseline tests had been conducted. Finally, the more other PIM tasks had to be carried out. For the observation phase, the observer choose a place askew to the test person that would not distract the test persons attention and that does not interfere with their activities. When all tasks had been executed, the evaluation wizard presented the questionnaire for gathering subjective feedback. The questionnaire consists of statements that test persons were asked to rate based on a rating scale from 1 to 5, interpreted as strongly disagree, disagree, so-so[7], agree, strongly agree.

[7] 'So-so' is a standard answer defined by the IsoMetrics[8] questionnaire.

Persons evaluating on the X-COSIM semantic desktop were asked to rate the following eight statements that give insight on their perception of the usefulness and usability of the X-COSIM semantic desktop features:

S1: The extensions provide me all the support I need to conduct the tasks.
S2: The extensions are well tailored to the tasks.
S3: The additional information provided by the extensions are immediately comprehensible.
S4: The extensions hamper conducting the tasks by an inconsistent design.
S5: The use of the extensions is hard to learn.
S6: To leverage the extensions I need to memorize many details.
S7: The use of the extensions are good to memorize.
S8: The X-COSIM extensions ease conducting the tasks.

In addition, participants of both groups were asked to comment the following statements:

S9: Working on the tasks was tedious/cumbersome.
S10: The tasks correspond to task types that I also need to do for my work.
S11: Tasks were significantly harder to do, since I was required to work with unknown data.

Finally, we conducted a short interview where test persons commented on how they used the systems, how they solved certain tasks, and what they considered useful or distracting about the tools of the test system they used.

EVALUATION RESULTS

Following the evaluation process and the design of the evaluation presented above, we present the results of the observation phase. Subsequently, we present the results from the feedback phase.

Observation Phase

In the observation phase, we have analyzed the effectiveness and efficiency of the users performing the PIM tasks.

Effectiveness

All of the 18 test persons completed all tasks. The evaluation wizard logged answers that test persons entered into the input field presented for each task (cf. Figure 4). When test persons entered wrong answers they have not been informed about it and continued with the next task. By an analysis of the answer logs we recognized 3 wrong answers, 2 of them by test persons using the X-COSIM tools.

Efficiency Measurements

As indicators for efficiency, we present below, the execution times, distance of mouse movements, and number of windows switches we measured for each task.

Figure 5 presents the measurements for the task execution times for task 2-10. It includes the minimum, average, and

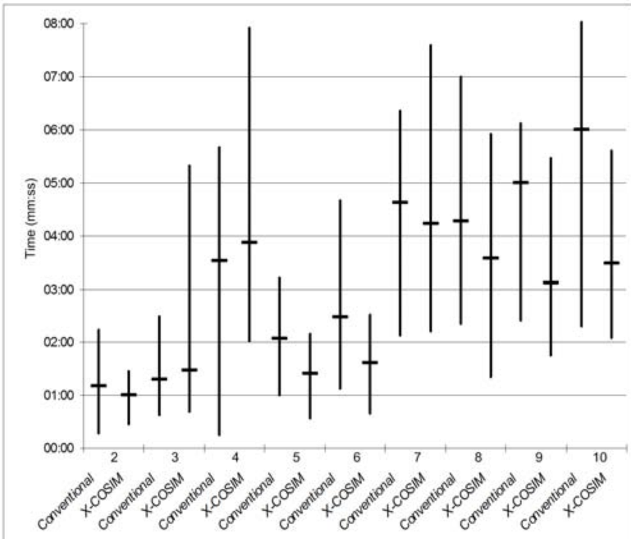

Figure 5. Min., Max., and Avg. Execution Times for Task 2-10

maximum times for each task separately for test persons using the X-COSIM tools and the conventional ones. Table 3 also presents the execution times of the task executions. The baseline tasks 2 and 3 are marked by a double-lined border. Additionally, the relative performance of test persons using the X-COSIM tools with respect to persons using the conventional tools is shown as percentage. For example, a value of 50% indicates that test persons on the X-COSIM desktop needed 50% of the time that test persons on the conventional desktop needed. For each task, we conducted t-tests to investigate on the statistical significance of the differences in execution times between persons using the conventional desktop and the X-COSIM desktop. The result for $P(T \leq t)$ using 0 as the hypothesis is shown in the last column. It represents the probability that the measured execution times for test persons of the two evaluation groups are part of the same distribution. Values where the probability is around or less than 5% are highlighted. Additionally, Table 4 shows the same statistics for the distance of mouse movements (measured in pixels). By an analysis of the screen recordings, we extracted the number of windows switches that occurred during the execution of each tasks. They are summarized in Table 5.

Table 3. Average and Median Execution Times

	Conventional		X-COSIM		Rel. Performance		T-Test
Task	Avg	Median	Avg	Median	Avg	Median	P(T<=t)
1	13:14	13:30	10:52	06:44	82%	50%	0,305
2	01:10	01:17	01:00	01:01	86%	79%	0,259
3	01:18	00:57	01:28	01:03	113%	111%	0,373
4	03:31	03:48	03:52	03:03	110%	80%	0,376
5	02:04	02:02	01:25	01:27	69%	71%	0,014
6	02:28	02:10	01:37	01:43	66%	79%	0,042
7	04:37	04:42	04:14	03:53	92%	83%	0,319
8	04:16	04:10	03:34	03:50	84%	92%	0,178
9	05:00	05:40	03:07	02:44	62%	48%	0,004
10	06:00	07:14	03:29	03:34	58%	49%	0,019

Table 4. Average and Median Mouse Movements

	Conventional		X-COSIM		Rel. Performance		T-Test
Task	Avg	Median	Avg	Median	Avg	Median	P(T<=t)
1	126260	106927	83647	44405	66%	42%	0,1489
2	16364	8490	12029	9957	74%	117%	0,2237
3	14146	13786	13733	11808	97%	86%	0,4325
4	34937	39113	40957	30395	117%	78%	0,3268
5	30408	29627	16582	15749	55%	53%	0,0167
6	23922	17052	16862	15989	70%	94%	0,1299
7	67536	61083	42236	40032	63%	66%	0,0640
8	52042	56344	39477	39521	76%	70%	0,1426
9	70852	70673	45448	38505	64%	54%	0,0180
10	82991	74892	47745	45190	58%	60%	0,0406

Table 5. Average and Median Window Switches

	Conventional		X-COSIM		Rel. Performance		T-Test
Task	Avg	Median	Avg	Median	Avg	Median	P(T<=t)
1	27,13	14,00	12,75	7,00	47,0%	50,0%	0,306
2	5,50	4,00	4,63	4,00	84,1%	100,0%	0,228
3	6,63	6,50	5,88	6,00	88,7%	92,3%	0,266
4	14,75	13,00	18,63	14,50	126,3%	111,5%	0,191
5	13,38	13,00	10,88	9,00	81,3%	69,2%	0,159
6	7,86	7,00	5,63	5,00	71,6%	71,4%	0,114
7	18,00	15,00	13,00	10,50	72,2%	70,0%	0,187
8	14,75	14,50	10,88	13,00	73,7%	89,7%	0,113
9	18,14	18,00	10,71	11,00	59,1%	61,1%	0,003
10	26,67	27,00	5,29	4,00	19,8%	14,8%	<0,001

All test person spent most of their efforts on the initial organization task (cf. Table 2). However, 2 test persons (one using the X-COSIM desktop, one using the conventional desktop) decided not to organize files and emails at all.

For the lookup tasks (2,3) in the task set, test persons of both groups required the least execution times (cf. Table 3). While test persons using the X-COSIM tools needed less time to execute task 2, they needed more time to execute task 3 compared to test persons working with the conventional tools.

For both groups of test persons, we notice that among the multi-item tasks, the first task (4) required the most time, mouse movements, and window switches (cf. Table 3, 4, 5). We also recognize that the average performance of test persons using the X-COSIM tools is behind that of the other group with respect to time, movements, and switches. Instead for the other two multi-item tasks 5 and 6, the average and median execution times, mouse movements, and number of window switches are lower for the group testing the X-COSIM tools. Moreover, for task 5 and 6, test persons using COSIMail and COSIFile needed significantly[8] less time. For task 5, we also measured that they had required significantly less mouse movements.

For the document-driven-collaboration tasks 7,8,9 and the final task 10 on information-collation, test persons using X-COSIM tools required less time, mouse movements and window switches, considering both the average and median values (cf. Table 3, 4, 5). Their reduction in mouse movements has been significant for task 7, 9, and 10, while significant

[8] at the 5% level

reductions in the execution times and the number of window switches have been measured for task 9 and 10.

Feedback Phase

Besides indicators for user efficiency in the observation phase, also subjective feedback was gathered during the feedback phase. The subjective feedback considered information about users' opinion and satisfaction with COSIMail and COSIFile (S1-S8) as well as their satisfaction and impression about the conducted tasks (S9-S11). Rating values could range from 1 (predominantly disagree) to 5 (predominantly agree). The statements to be rated had been formulated as positive and negative statements so that the same rating value may have different interpretations, e.g. S5 states that the features of COSIFile and COSIMail are hard to learn while S7 states that they are easy to memorize. Table 6 presents normalized rating aggregations (average and median) for statement S1 to S8 where a value of 1 corresponds to the most negative feedback about COSIFile and COSIMail while a value of 5 corresponds to the most positive. The results show that average and median ratings range from 3.7 to 4.5 (cf. Table 6).

Table 6. Subjective Feedback for X-COSIM Tools (S1-S8)

Statement	S1	S2	S3	S4	S5	S6	S7	S8
Average	4,2	4,4	4,3	3,6	3,8	3,7	4,0	4,1
Median	4,0	4,0	4,5	4,0	4,0	4,0	4,5	4,0

While the statements S1-S8 could only be rated by test persons that used the X-COSIM tools, all test persons have been asked to rate S9-S11. Table 7 shows the average and median ratings given by test persons of both groups. The average and median ratings on the statement about the originality of the task set (S10) are identical among the groups (cf. Table 7). For statement S9 and S11, however, the groups differ. Test persons that worked with X-COSIM tools tended to disagree to S9 and S11 (average and median ratings from 2.0 to 2.3). Instead, test persons of the conventional tools had been undecided about S9 (average and median rating 3.0) while showing a tendency to agree with S11 (cf. Table 7).

Table 7. Subjective Feedback Comparison (S9-S11)

	Conventional		X-COSIM		Difference	
Statement	Avg	Median	Avg	Median	Avg	Median
S9	3,0	3,0	2,3	2,0	0,7	1,0
S10	3,4	4,0	3,4	4,0	0,0	0,0
S11	3,5	3,5	2,2	2,0	1,3	1,5

INTERPRETATION OF RESULTS

In the following, we start with a discussion of the results from the observation phase and then continue with an interpretation of the subjective feedback given by test persons in the feedback phase.

Observation Phase

None of the 18 test persons indicated to be unable to solve the presented tasks and only 3 wrong answers have been measured. Accordingly, we cannot conclude that the X-COSIM tools result in increased effectiveness for their users. However, the evaluation wizard only supports the tracking of wrong task executions for tasks where some textual information was to be returned from test persons. Sometimes, minor mistakes were made by the test persons such as the wrong version of a file was edited or returned by email. Those cases could not be tracked by the evaluation wizard so that we have to assume that the number of wrong executions is higher than we measured. In a future work, we like to extend our evaluation to further investigate the effects of such mistakes and their occurrence while conducting and accomplishing PIM tasks with the X-COSIM tools and conventional ones.

Concerning the efficiency of test persons, we observed that test persons working with the semantic desktop put less effort into the organization of files. Our evaluation was not targeted to analyse users' organization strategies. However, comments we gathered during the interview pointed towards the hypothesis that the additional features of the X-COSIM semantic desktop resulted in the impression by test persons that less organizational effort is needed. For instance, one test persons explained that *" ... such features reduce the need for organization ... "*. Another test persons stated that *"... having more of such features, I would not organize at all ..."*. However, further studies are needed to investigate on the changes of users' organization strategies and behaviors when using a semantic desktop to verify this interpretation.

Task 2 and 3 have been included in the task set as baseline tasks for which our semantic desktop tools do not provide any additional support. Less efficient executions in task 2 and 3 from test persons using the X-COSIM tools suggest that both groups have been balanced with respect to the PIM efficiency of included test persons.

Although task 4 is not a baseline task, test persons using conventional desktops have been more efficient on this task with respect to all considered efficiency indicators (see task 4, Table 3, 4, 5). Instead for task 5, which is similar to task 4, test persons using the X-COSIM tools have been significantly more efficient (see task 5, Table 3 and 4). While both groups of test persons increased their efficiency from task 4 to task 5, test persons using X-COSIM tools needed less than half the time and half the mouse movements they needed to accomplish task 4 (see task 5, Table 3 and 4). Due to the similarity between task 4 and 5, we interpret the increased efficiency of both groups as a learning effect. We attribute the larger improvement we measured for test persons working with the X-COSIM tools to two points: First, these persons not only had to face an unknown desktop system, but additionally the concepts of a semantic desktop. Second, once they have been able to exploit the features of the X-COSIM tools, they experienced a larger benefit compared to persons that had familiarized with the conventional tools. We found these assumptions supported by our observations of the test persons. Most of them were initially unsure about the functionality provided by COSIMail that is useful to solve multi-item tasks like task 4 and 5. They were initially confused about the utilization and meaning of the link to saved attachments (cf. Figure 2). For instance, they expected that clicking on the link opens the saved attachment, however, it opens the file system folder where the file is saved. Throughout the whole observation phase we recognized this error made by test persons, however, once they had found out how to open the file, they immediately recognized the error in subsequent situations so that we believe that it had less impact on their efficiency.

We consider multi-item task 6 as a strong indicator for the intuitiveness of relations as established by the X-COSIM tools. Task 6 has been presented as shown in Figure 4. It is about finding the name of a research team working with robots as depicted on two images (cf. Figure 4). The name of the team is given in an email message to which the files have been attached. Although it is mentioned in the task description that the images of the robots have been retrieved by email, test persons of both groups commonly started to search for the images on the file system, exploiting the image-preview feature of the file manager. However, test persons using the conventional file manager got stuck once when they had found the images. Realizing that the identification of the images does not lead to a solution for the task, they changed their strategy and switched to the email client, searching for emails about robots to find the email that contains the images. Persons using COSIFile also identified the files on the file system first. Having found the images, some test persons remembered the context menu to open the associated email. Others used the additional document attributes sender, recipient, and subject as search criteria in the email client to find the email that contains the information they are looking for. Accordingly, we presume that the information linkage provided by the X-COSIM tools is the reason for the significant efficiency improvement (cf. Table 3) in task 6 as it enabled test persons to employ the most intuitive strategy for solving the task.

The tasks on document-driven-collaboration give further indications for the hypothesis that the X-COSIM tools improve support for PIM compared to the conventional tools. Significant improvements on execution times have been measured for task 9 (cf. Table 3) while significant improvements with respect to mouse movements have been also measured for task 7 (cf. Table 4). Among the document-driven-collaboration tasks 7,8,9, we further recognize that the execution times of test persons using the X-COSIM tools constantly decrease throughout these tasks (cf. Table 3) which may be due to further learning effects. However, we also observed that test persons got more acquainted to the additional features of the X-COSIM tools and started to invent there own strategies of using them. For instance, we observed a test person that used the link to saved attachments as displayed by COSIFile (cf. Figure 2) to support the selection of the file in the attach-file-dialog of the email client.

On the final task 10, test persons using the X-COSIM tools also worked significantly more efficient with respect to execution time, mouse movements, and window switches than test persons using the conventional tools (cf. Table 3, 4, 5). We explain the highly significant[9] reduction of window switches by the fact that test persons using X-COSIM tools could solve this task using COSIFile exclusively. Instead, the only strategy for solving the task with conventional tools is to switch back and forth between the email client and the file manager.

Feedback Phase

The questionnaire for subjective feedback included statement S9-S11 to learn about the impression that test persons had. As shown in Table 7, test persons of the conventional desktop rated S11 with 3.5 on average. This indicates that they recognized slight difficulties they attributed to the lack of knowledge about the data corpus. Test persons of the X-COSIM desktop expressed a tendency to disagree with the statement (Avg 2.2, Median 2.0), indicating that they considered their limited knowledge on the data corpus as less problematic. We consider these statements as support for the success of the measures we took to conduct a laboratory experiment where test persons are familiar with the test setting. The same trend among both groups of test persons can be observed from the ratings for statement S9. Persons working with the X-COSIM tools considered the tasks in the task set less tedious (Avg 2.3, Median 2.0) than persons working with the conventional PIM tools (Avg 3.0, Median 3.0). We take these ratings of test persons working with the X-COSIM tools as hints for increased satisfaction in doing PIM compared to test persons doing PIM with conventional tools. We see further hints in the subjective feedback gathered from the ratings of statement S1 to S8 (cf. Table 6) where test persons rated the usefullness and usability of the X-COSIM tools as positive. However, in the feedback interview, test persons also remarked the slow response times of the test system and commented on the initial confusion of the COSIMail functionality that provokes changes for its user interface and interaction design.

For statement S10, on the originality of the tasks in the task set, both user groups expressed the same tendency (average rating 3.4, median rating 4.0) towards an agreement that the task types resemble common PIM tasks for them (cf. Table 7). We notice the identical ratings as a further indication for the balance of both groups. We also attribute the tendency towards an agreement as the outcome of our methodology for the creation of the evaluation task set. Nevertheless, we expect an higher agreement for less versed computer users and users that have a different work background. This notion is confirmed by the statement of one test person, stating that he rarely does document-driven-collaboration as "... for such things, there is SVN ...".

Summary

Based on i) measured results on user efficiency in combination with ii) user observations and iii) the collection of subjective feedback, we discussed the utilization of our semantic desktop tools COSIMail and COSIFile by test persons of the evaluation. We pointed out for which task types and for which specific task instances we found significant efficiency improvements over the utilization of conventional PIM tools.

[9] at the 1% level

RELATED WORK

Above, we presented the summative evaluation we conducted to investigate on the benefits of our semantic desktop X-COSIM and its end-user applications COSIMail and COSIFile. In the following, we give a brief overview on existing related work.

Haystack [14] is an approach to a semantic desktop that provides a monolithic application for personal information management such as email management and calendaring. It provides a graphical user interface for enabling users of the system to deal with the information that can be manipulated with Haystack. Unlike Haystack, IRIS [7] integrates existing applications, e.g., the Mozilla suite for web browsing and email management, into one user interface. It was developed within the CALO research project[10] [7] and serves there as knowledge store. To the best of our knowledge, an evaluation of Haystack or IRIS towards user effectiveness, user efficiency, and user satisfaction has not been published.

The Gnowsis semantic desktop provides a user frontend for the editing and association of meta data to files, contacts and further PIM assets. A study reporting about the long-term utilization of Gnowsis by two users has recently been published [18]. While the study gives insight into the specific utilization by those users, it does not reveal any information about the benefits of Gnowsis compared to conventional desktop systems.

Finally, UMEA [13] is PIM application built around the metaphor of a *project*. A project can be considered a high-level task. The UMEA user interface supports the association of documents, folders, URLs, and contacts to a project. The associations are exploited to provide access to associated resources, motivated by the need to support “higher-level user activities” where users deal with multiple resources in the context of a task or project. A formative evaluation of UMEA was conducted by eight users over a period of two to six weeks. Seven users responded positively about the general idea behind UMEA. However, the automatic association of resources to projects was seen as major drawback of UMEA as that feature lacked precision and added too many and irrelevant resources to projects.

With respect to the semantic desktops mentioned above, none or formative evaluations have been carried out. Such formative evaluations provide insight into the use of semantic desktops in general. However, to the best of our knowledge a summative evaluation allowing to compare the use of semantic desktop applications with conventional counterparts has not been published.

CONCLUSION

In this paper, we have presented a reproducible summative evaluation of the two PIM tools COSIMail and COSIFile of our semantic desktop X-COSIM. In the evaluation, we have considered typical email and file management tasks in a semantic desktop environment and have compared it with a conventional desktop. This research is a contribute to fill the gap of summative evaluations of semantic desktops that are missing so far. As result, we have found out that the utilization of the X-COSIM semantic desktop results in significant improvements for typical PIM tasks compared to the utilization of a conventional desktop environment.

[10] `http://caloproject.sri.com/`

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