Creation of user-friendly mobile services personalised for tourism

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Abstract: CRUMPET has realized a personalized, location-aware tourism service, implemented using a multi-agent system that supports seamless roaming, service mediation and interaction facilitation. As a last stage in the project, the CRUMPET approach and system have been validated in terms of technical and user-perceived qualities at two European trial sites, and validated in terms of user-perceived qualities at four European trial sites. This Deliverable 4.4 gives a detailed and comprehensive report on the user validation, summarizing the findings from all CRUMPET trials, and drawing conclusions concerning the CRUMPET System and mobile tourism services in general.

Two brief reports on the technical evaluation are included, concerning the seamless roaming in CRUMPET with a detailed discussion of performance related to QoS, and agent messaging between platforms and conclusions concerning scalability.

Keyword List: Mobile Tourism Service, CRUMPET, Trials, User Validation, seamless raoming, QoS, agent platforms

EXECUTIVE SUMMARY

The goal of the European IST project CRUMPET has been the "Creation of User-friendly Mobile Services Personalised for Tourism". As a last stage in the project, the CRUMPET approach and system have been validated in terms of technical and user-perceived qualities at two European trial sites, and validated in terms of user-perceived qualities at four European trial sites. This Deliverable 4.4 gives a detailed and comprehensive report on the user validation, summarizing the findings from all CRUMPET trials, and drawing conclusions concerning the CRUMPET System and mobile tourism services in general.

Full user trials have been performed in Heidelberg and Helsinki. In London an early prototype has been subject to a formative usability validation. A supplementary survey on mobile tourism support has been conducted in London, Aveiro, and Sankt Augustin.

The findings reported in this Deliverable rely on a sample total of 88 people; a total of 71 people have so far tested CRUMPET.

The full user trials have been conducted as a field test. Testing users have tried the CRUMPET system, down-town Heidelberg and in Helsinki, performing typical tourist activities supported by the CRUMPET services. The test users answered a questionnaire about tourist information needs, expectations in a mobile tourism support, and their assessment of the CRUMPET prototype. Part of the test users also answered a standardized questionnaire about usability (SUMI).

The outcome of the trial and survey has clearly confirmed the approach taken in CRUMPET.

The user assessment of the usability of the prototype was above average, according to the Software Usability Measurement Inventory (SUMI). The majority of users liked the system as well as the content provided. Performance has not always been satisfactory for the users. For Heidelberg, the reason of eventual user dissatisfaction with performance was more probably to be explained by various other reasons, which users perceived as efficiency. In the Helsinki trial this may have been caused by roaming between networking conditions, for which the most critical factor was seamless roaming from WLAN to GPRS and vice versa.

The importance of location-based services, based on user localisation, locally available services, and personalized recommendations, has been corroborated. Interactive maps, especially when enhanced by highlighting the current position of the user, sites of personal interest or tours, rank high in a mobile tourist support. Recommendations about places of interest, restaurants, events, and accommodation are indispensable in a mobile tourism support. Unexpectedly, information about transportation, culture and nature rank also very high among the information needs of travelling people.

A convincing majority of users approved of the added values of the system compared to other tourism support available today. A surprisingly high percentage of users seem to be prepared to pay for such a mobile tourism service. Preferred mode of payment would be subscription, i.e. paying once for a period of usage.

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1. INTRODUCTION

The vision of nomadic users having seamless, worldwide access to a range of tourist services seems within reach, within only a few years from now. Much of the underlying technology is already available, such as public networks, GPS-positioning, agent technology, handheld devices (PDAs). But there are still challenges with respect to, both, technology and usability that need intelligent solutions, which then have to be tested for viability and quality, including user-perceived qualities.

The goal of the European IST project CRUMPET has been the "Creation of User-friendly Mobile Services Personalised for Tourism". CRUMPET has had two main objectives:

- To implement and trial tourism-related value-added services for nomadic users across mobile and fixed networks
- To evaluate agent technology in terms of user-acceptability, performance and best-practice as a suitable approach for fast creation of robust, scalable, seamlessly accessible nomadic services

CRUMPET has realized a personalized, location-aware tourism service, implemented as a multi-agent system with a concept of seamless roaming, service mediation and interaction facilitation[1]. The client device is a handheld computer (e.g. an iPAQ), the user location is determined by GPS sensor data or alternatively by GSM triangulation. Modern handheld computers offer a screen size and resolution that is adequate to display maps and simple HTML pages. The system has not been realized for extremely limited displays such as WAP enabled mobile phones.

The system offers a simple user interface and handling of services. The main functionality is:

- Recommendation of services, e.g. tourist attractions (based on the user's personal interests and the current location).
- Interactive maps (overview maps of the area, highlighting the current position of the user; maps highlighting sites of interest and tours; maps can be panned and zoomed).
- Information about tourist attractions, both short text, more detailed information, pictures, maps, and directions.
- Proactive tips, giving an unobtrusive tip when the user gets near a site that might interest him or her.
- Roaming in a changing communication network, i.e. the system adapts in a user-friendly way to quality of networking service (QoS) and type of wireless connection that is available (WLAN vs. GSM).

As a last stage in the project, the CRUMPET approach and system have been validated in terms of technical and user-perceived qualities at two European trial sites, and validated in terms of user-perceived qualities at four European trial sites. This Deliverable 4.4 gives a detailed and comprehensive report on the user validation, summarizing the findings at all CRUMPET trials, and drawing conclusions concerning the CRUMPET System and mobile tourism services in general.

The trial in Heidelberg has been the main trial concerning user validation of the CRUMPET projects. In Heidelberg, the project has had access to the best-suited content base, well structured and extensive.

The focus of the Heidelberg trial was on location-based services, e.g. maps and directions. This trial site was the first to be available and had the longest period of time for trialling, i.e. from the first week of September to 1st of October 2002. This allowed for several days of user trial. During that period of

[1] For a more technical description and design rationale, we refer to deliverable D1.8. Details of the technical realization and local prototype versions of CRUMPET are documented in Deliverables 4.3(Heidelberg) and 4.3(Helsinki).

time 23 test users have tried and validated the system[2]. For more technical details about the Heidelberg trial we refer to Deliverable 4.3(Heidelberg).

The trial in Helsinki mainly concentrated on data communication issues, such as the QoS of data transmission, seamless mobility in the case of roaming between different network technologies. Accordingly, the scenarios of use in the Helsinki trial focussed on related use cases. In addition, in the Helsinki trial, we used Helsinki specific content, content adaptation (CASA), and GSM based positioning. For more details of the technical conditions and outcome in the Helsinki trial, see Deliverable 4.3(Helsinki). The Helsinki trial took place early in October 2002. 10 test users tried and validated the Helsinki CRUMPET services.

The London trial focussed on the campus of Queen Mary and the London East End. It aimed at giving recommendations about attractions, places to eat, rendering maps. A working prototype was not able to be realized within the time scale of the project, this work is being continued. Especially the effort of preparing suitable content, including GIS-based services and map rendering had been underestimated. However, a mock-up and early prototype has been subject to a formative usability evaluation. An additional 23 persons have taken part in the mobile tourism support survey, the outcome of which is included in this report. The prototype is subject to ongoing development exploitation at Queen Mary, mainly for research purposes.

In Aveiro also a fully functional prototype was not realized, for similar reasons as London. However, Aveiro has also taken part in the survey with 14 persons, covering the first part of the questionnarie.

The findings reported in this Deliverable rely on a sample total of 88 people; a total of 71 people have so far tested CRUMPET.

The remainder of this report is structured in the following way: Section 2 describes the methods applied for user validation. Sections 3 to 5 summarize and discuss the findings for the three central validation topics, i.e. CRUMPET usability (section 3), Tourism information needs (section 4), and Users overall assessment of mobile tourism services (section 5). Section 6 contains our main conclusions from the user validation of CRUMPET. The CRUMPET questionnaire and its statistical analysis are documented in the Appendix A. Appendix B reports on the technical evaluation of the seamless roaming in CRUMPET, with a detailed discussion of performance related to QoS. Appendix C reports on burst performance tests of agent messaging between different platforms, and interprets the outcome with respect to scalability.

[2] In October 2002, another 38 students have tested CRUMPET.

2. USER VALIDATION IN CRUMPET

In this chapter we describe how the user validation of the CRUMPET system has actually been conducted and what methods have been applied. The methods have already been described in the trial plan, see Deliverable 4.1, chapter 4. We could realize the validation process as planned, with a few adaptations only.

Validation criteria

The system has been validated mainly under the aspects Functionality, Usability, and Overall assessment, as outlined in the following.

Functionality – Information needs of Tourists

The trial included a survey among prospective users about their current information needs and habits concerning travelling. We asked about information content needed (such as accommodation, attractions). We also asked from which sources users currently get their travel-related information. And we asked these questions separately for both the travel planning needs and the needs while already on tour. The latter indicates the information needs to be supplied by a mobile tourism service. Additionally, we especially asked for information deficits while on tour, i.e. which information did they miss so far.

This cluster of questions about functionality is also tackled by two other questions. One is asking CRUMPET users to rank a variety of functions such as provided by CRUMPET. The other one asks for missing features in the CRUMPET system.

So, by several questions, we investigated the usefulness and importance of functionality of mobile tourism services. This allowed, firstly, to clarify whether CRUMPET provides the functionality required by travelling people, and, secondly, to identify crucial features of mobile tourism support. In other words, it allowed us to identify possible "killer applications" of such a service.

Usability

Usability is a prominent factor in the overall quality of a system. Usability is defined (ISO 9241-11) as Effectiveness + Efficiency + User Satisfaction. **Effectiveness** means that the intended task can in fact be accomplished using the system. For a tourist this would mean, for instance, that he or she can in fact get the required information or map, find a destination by using the system's directions, get recommendations of sights or restaurants nearby and according to his or her taste. **Efficiency** considers the resources needed for completion of a task. In the case of this system, resources would be time (is the system output given in reasonably short time, how efficient is browsing or searching for an information). Another example of a resource would be the monetary costs of using the service. **User Satisfaction**, finally, is the question to which degree the user likes (or dislikes) using the system. There are various other definitions of usability, which more or less map to these three or can be considered to contribute to these [NIEL93][SHNEID98][KIRAK02]

Effectiveness as part of usability is closely related to the **functionality of a system** and in how far it is appropriate to support the tasks in the application domain. We have already discussed functionality in the previous section.

From a user's point of view the system's functionality and the **content** it supplies upon request are hard to distinguish. A user cannot judge whether a poor list of recommendations is caused by an insufficient retrieval mechanism or because there were actually no better information available. The validation strives to explicitly cover both aspects, and to get the users' distinct assessment of both, content and functionality. Later on, it is part of the analysis of the user feedback to further separate the influence of both aspects on the overall assessment.

Overall assessment of CRUMPET

In the end, the crucial question for the project is whether the CRUMPET system would be a success on the market. We investigated this by several questions, tackling the assumed factors of a market success. In detail, we wanted to know how users liked the CRUMPET system, do they see the added benefits of CRUMPET (or, in general, mobile tourism services), and would they be willing to pay for such services. These questions have been asked by the CRUMPET questionnaire. We also wanted to know what are the most important features of a mobile tourism support, in other words which features would be crucial for a success of the CRUMPET system. The users have been asked to rank a variety of functions such as provided by CRUMPET.

Field experiment

As CRUMPET is a tourist support system with outdoor positioning and presenting data about spatial objects, the system has been tested in a field test, where users had to perform some typical tourist tasks, while using the services of the CRUMPET system. The methods have been chosen with a strong component of qualitative and formative validation, which is appropriate for such an innovative technology.

The validation experiments have been organized as follows:

1. Test person is informed about purpose of validation session.
2. Test person fills in part 1 of questionnaire.
3. Brief introduction of system and hands-on for user. This is to make sure the user manages the basics of handling the system.
4. Handout of instructions to test person. The instruction contains the tasks the user should perform, supported by the CRUMPET system, e.g., get a map of this area, ask for interesting sights/restaurants nearby, get directions to one of these sights.
5. The user starts on a tour, where he/she tries to accomplish these tasks.
6. An experimenter accompanies the user. (Role of experimenter is described below.)
7. After all tasks had been accomplished, the test person filled in part 2 of the questionnaire.
8. Some of the users also filled in the SUMI questionnaire[3].
9. Debriefing of user.

The instructions for the user were to fit the locally available system and content. The instructions ensured that

- the test person is focussed on tourist goals (not technical features of the system),
- all users perform similar tasks,
- the essential support of the system is recognized and tried out.

In Heidelberg the experimenter took the opportunity to take notes while observing the user. Observation has been focussed on what the user tried in order to achieve a goal, what he/she expected and which issues came up. This allowed a deeper insight in the experiences of users with the CRUMPET prototype. The observations of the early trial could already be used to improve the prototype before the end of the trial.

Test Users

The leading question here is: which type of users is to use a CRUMPET system? As CRUMPET is meant to support travelling people in general, all people who travel at least sometimes can use it. So, in principle, everybody who has travelled sometimes could take part in the validation of CRUMPET.

[3] SUMI consists of 50 questions, and we did not want to impose that on every user. 19 users underwent this additonal effort.

The application scenario foresees that a travelling person uses a personal digital assistant or similar handheld device. We also assume that such devices will become a common and familiar tool of future travellers, who will use PDAs in everyday situations as well as when travelling. We therefore can assume that users have a certain familiarity with computers in general, with the World Wide Web, and with the device. In this respect CRUMPET is quite different from a kiosk solution or a museum guide, which are meant for a short period of use by untrained users. The future CRUMPET user is more likely to be a mobile knowledge worker at a raised level of computer literacy. The percentage of such travelling people will increase considerably over the next years.

The selection of test users has not been confined to persons with advanced computer skills. The familiarity with some crucial computer usage has been documented for each test person but not made a criterion in selecting test persons.

Data collection and analysis

Though the four trials (Heidelberg, Helsinki, London and Aveiro) each have a different focus, we had to collect comparable data. We used two questionnaires for this purpose.

SUMI Questionnaire

The SUMI questionnaire measures user satisfaction in a standardized way, and is applicable for almost every application.

The Software Usability Measurement Inventory (SUMI) is a rigorously tested and proven method of measuring software quality from the end user's point of view. SUMI is a consistent method for assessing the quality of use of a software product or prototype, which is backed by an extensive reference database embedded in an effective analysis and report generation tool. SUMI is the only commercially available questionnaire for the assessment of the usability of software that has been developed, validated, and standardised on an international basis. SUMI is mentioned in the ISO 9241 standard as a recognised method of testing user satisfaction.

SUMI is a commercial product. It includes the software to analyse the answers and write a commented report. The essential result from SUMI has been included in this deliverable.

CRUMPET Questionnaire

In addition to SUMI, we devised a CRUMPET-specific questionnaire, which has been used at all trial sites, independently of the special focus or local content of the trialled prototype. The questionnaire, together with the statistical result of every question, is included as Appendix. The CRUMPET questionnaire has two parts, Part 1 is to be answered before the test, and part 2 after the user has tried out CRUMPET. Part 1 serves to document the characteristics of the sample[4] in terms of a few demographic facts (gender and age) and pre-skills such as familiarity with using the WWW. It also investigates the user's information needs and habits to get tourism-related information services, the user's expectations, and personal interests in a destination.

Questionnaire Part 1 covers:

- Demographic data such as gender and age.
- Familiarity of user with computers, WWW, iPAQ, and PDA.
- Travelling frequency of user, purpose of travelling.
- Information needs and habits concerning travelling, both before the trip and while on tour, both content required and source of information.
- Information deficits experienced while on tour, so far. Both content and source of information considered separately.

[4] The sample in a trial cannot be representative for tourists in general. But it aims at being representative for the prospective market of a CRUMPET system in the near future. It has covered both genders equally and all ages (but not including young people).

- Personal interests in various aspects of a destination.

The part 2 serves to get the users' assessment, after they have had the experience of using the system.

Questionnaire Part 2 covers:

- User satisfaction/affection. Not usability in detail, but one general assessment of user satisfaction, which is one dimension of usability.
- Usefulness of the information supplied so as to distinguish features and content by explicitly asking the user.
- User's rating of the features of a mobile tourism service. This includes a few services not covered by CRUMPET but discussed for mobile tourist support.
- Features the user was missing - open question
- Aspects of the system the user liked – for the aspects GUI, Performance, Usability, and content, plus an additional open question
- Aspects of the system the user did not like - or the aspects GUI, Performance, Usability, and content, plus an additional open question
- Added value of CRUMPET compared to other tourist information media - yes/no answer and open question.
- User's willingness to pay for this kind of service - yes/no answer and the preferred mode of payment as an open question.
- Any other comments on the system - open question.

The questionnaire contained predefined answers[5], which have been analysed by statistical methods. The answers to the open questions served to further elaborate a user's opinion, to add ideas to the predefined answers, to outline users' reasons for an assessment. The analysis of the open questions has been included here, wherever useful.

[5] So-called "closed questions".

3. USABILITY OF CRUMPET

The usability of CRUMPET has been measured by applying SUMI for 19 test users (12 users in Heidelberg and 7 users in Helsinki). The SUMI measurement is well tested and standardized by dozens of projects. It is supposed to have stable results already when applied to 10-12 test users only, per user group. The sample in the CRUMPET user validation consisted of one user group (tourists, as end users) and was rather homogeneous with respect to computer skills. So the result from 19 test users is probably reliable. The result of the SUMI analysis shows the status of the CRUMPET prototype with respect to the 5 usability dimensions Efficiency, Affect, Helpfulness, Control, and Learnability.

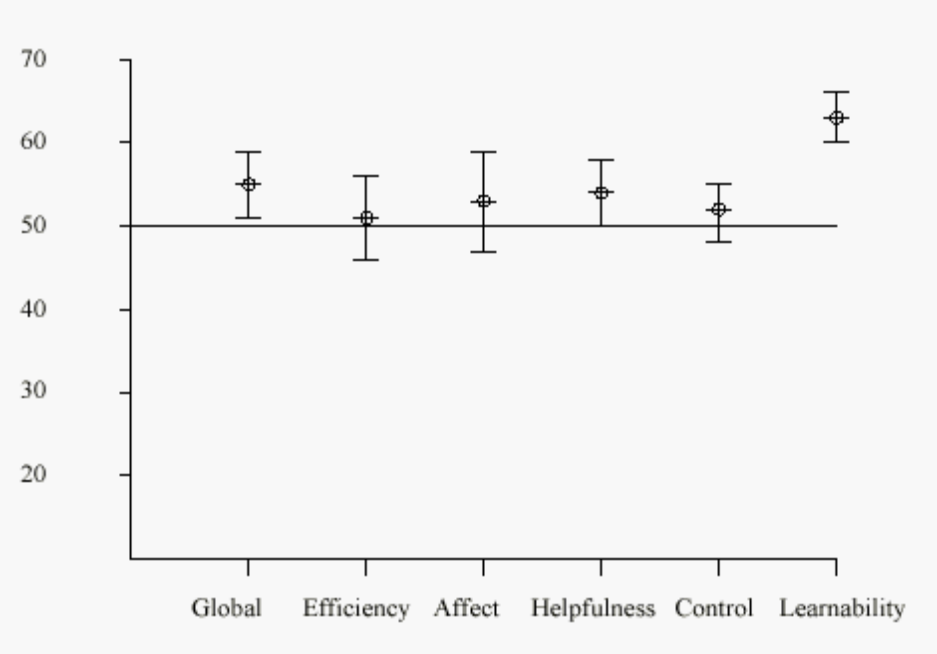

Figure 1 Results from the SUMI inventory

The global value for all 5 dimensions combined shows that CRUMPET is slightly above average. Also, every single dimension is above average, with a weakness perhaps in Efficiency[6]. The good result for Learnability allows an optimistic outlook that the system would also be suitable for users who are at a lower level of computer skills. It is also a corroboration of our approach, i.e. to keep the interface and interaction as simple as possible.

In addition to SUMI, the special CRUMPET-tailored questionnaire also included several questions to investigate users' assessment of usability. The questionnaire includes the questions "Did you like CRUMPET?" and "Did you find the content helpful?", which resulted in an overall assessment of affection for the system and affection/helpfulness of the content. The results for both are rather positive and quite encouraging, see Figures 2 and 3.

[6] See discussion in section 3 about performance.

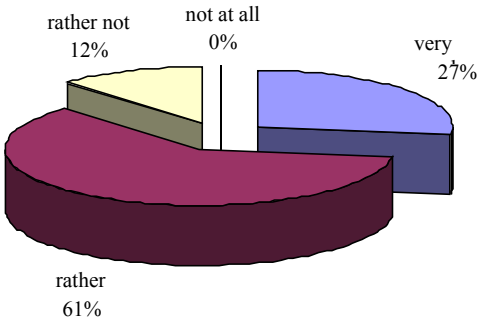

Figure 2 Did users like CRUMPET?

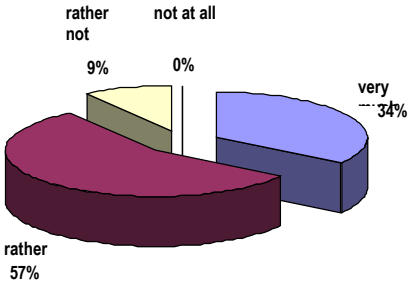

Figure 3 Did users like the content?

By two additional questions we wanted to find out if users especially liked or disliked one of the aspects GUI (graphical user interface), Usability, Content, and Performance. The results are shown in Figure 4.

The user answers about the likes and dislikes need careful interpretation. For the aspects GUI, Usability, and Content, the percentage of users who disliked these aspects is always counterbalanced by a higher percentage of users who especially liked the same aspect. Only for the aspect Performance more users especially did not like it than like it.

Performance seems to have been a weaker point in the CRUMPET prototypes. Still, when opinions are diverging like this, this needs further discussion. It has to be pointed out, that the user assessment here is an overall assessment of performance, i.e., if the users felt they could accomplish their tasks using the system "without becoming impatient". Possible reasons if users are not satisfied with respect to performance are manifold. For Heidelberg, we found a variety of possible reasons some of which we amended in the course of the trials. For instance, in the first trial sessions the zoom factor of map display was quite low, resulting in the need to click the zoom function many times in order to get the desired effect. This is only a parameter in a function, and after adjusting it, users got the desired map scale much faster. This certainly has annoyed our first users and probably contributed to low scores for performance. Another example, in a few cases it happened that a GPS signal was missing[7] and the system failed to deliver a result. From a technical point of view, this is more related to robustness than to performance, which is rather a matter of immaturity of the prototype than of technical qualities of the approach. For the users who encountered this, this resulted in low performance and got low scores accordingly. Also, missing content or inappropriate keywords for a search may result in a user feeling inefficient in search for information. Many such deficiencies could be amended easily and have in fact been amended later.

One aspect of performance is concerning seamless roaming and reaction to moving in varying networking conditions. As this was one major technical goal of CRUMPET, this is discussed in detail in Appendix B. This concerns trials in Helsinki, where it may have affected user satisfaction about performance.

[7] This happened in very narrow streets, e.g., and when battery of the GPS device was low.

The observations made in Heidelberg gave more insight in possible reasons for user assessment. This has already been used to improve the system in some features[8], in the course of the trials. However, observation findings are on a level of detail that shall not be discussed here.

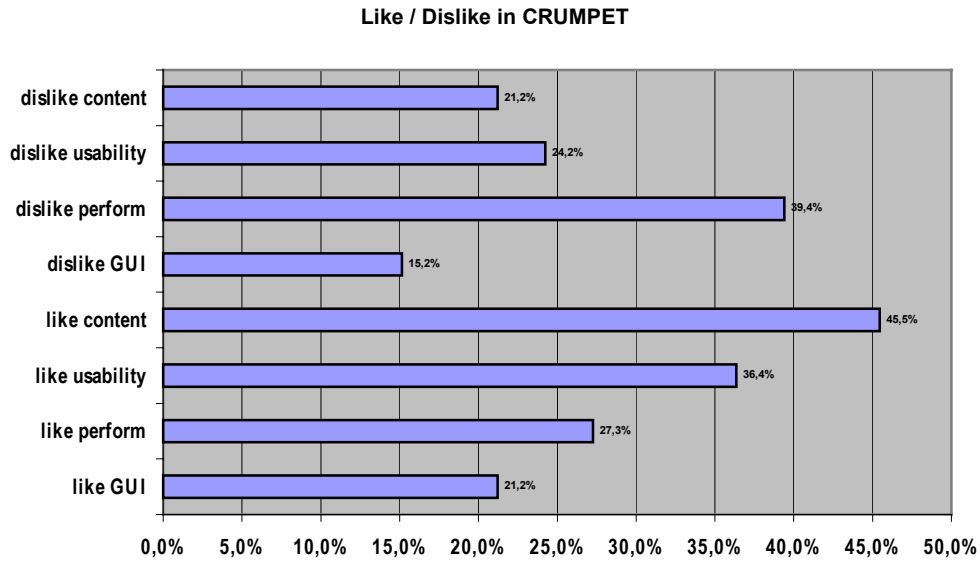

Figure 4 Usability of CRUMPET

Another question, concerning usability, asked "Did you miss features in CRUMPET?". A rather high percentage of users did in fact miss features: almost 70%. This might indicate a negative view on the CRUMPET service. Indeed, a mobile tourism service should include more service types than have been realized in CRUMPET. On the other hand, when users ask for more features, the concept is corroborated in principle: users have developed an appetite.

This question also had room for free statements, and users made ample use of this. We include the most prominent ones here:

- Search function (the prototype had the interest-based way of content retrieval; some users said they need a straight-forward search as well)
- Direct interaction on maps (directly manipulate zoom/pan by clicking on the map instead of a button)
- Maps should show more details, such as bus stops, facilities, accessibility for disabled, distinct outline of single buildings.[9]
- Maps should indicate their orientation, or even be adaptive to the user's orientation. User position should be updated on the map.
- Content about public transportation, facilities including doctors, hospitals, car parking.
- Textual description of tours, in addition to display the route on a map.
- Voice control (user speaks commands) and audio output (system gives spoken information).

[8] For instance, the above mentioned issue of map zooming.

[9] It is up to the system designers to carefully consider the tradeoff between details needed under circumstances and by individuals, and, on the other hand, not to clutter the small screen with unneccessary details.

Most of these ideas would certainly improve a mobile tourist guide. Some are quite a challenge and would need more research and development efforts, also more investigation in the related HCI (Human Computer Interaction) issues.

4. TOURIST INFORMATION NEEDS

Several questions in the questionnaire have been dedicated to investigate what information tourists currently need and from which sources they get tourism related information. This has been distinguished for information needs before travelling and while travelling. An additional question asked for the individual interest (importance) of various aspects of a destination.

As can be seen in the Appendix A, a high percentage of participants travelled several times a year, and also stated a high percentage of business trips. Therefore, their answers to tourism-related information needs are of interest.

The first question was about information needs and sources when preparing a journey. Figure 5 shows the results.

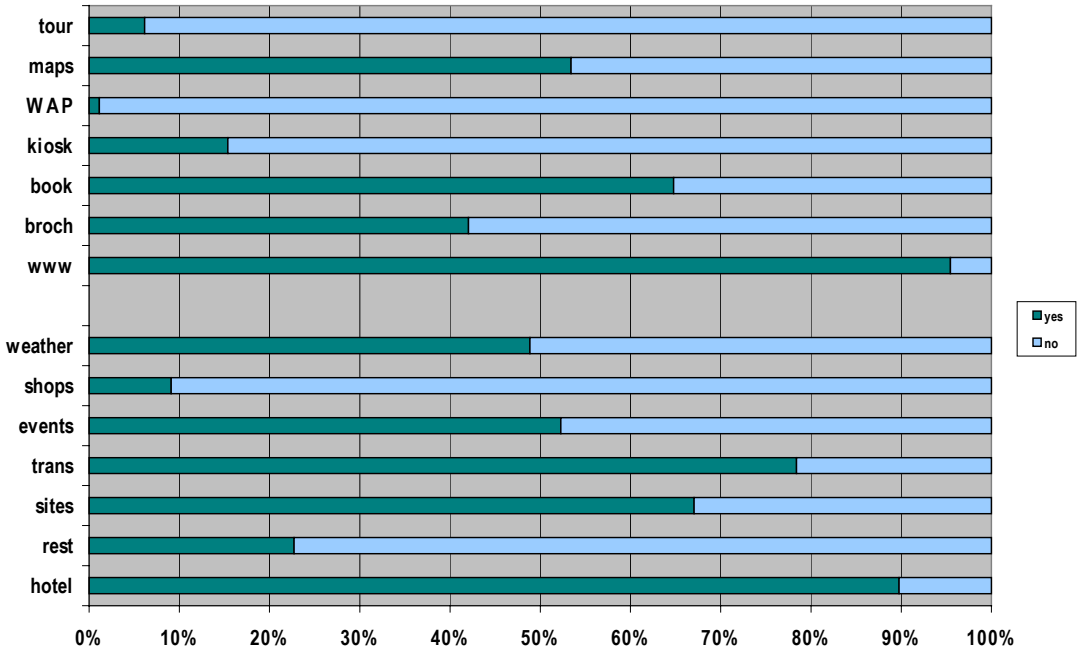

Figure 5 Tourist information needs before travelling

Concerning the content, the information about hotels, transportation, sites, and events rank highest. This is not especially surprising. But we want to point out the high importance of sites (tourist attractions), as this seems not to be in the focus of current discussion and investigation. Currently, the focus of tourist information needs analysis is more on tourism products and commercial interests. Still, sites seem to be important for travellers and contribute to the attractiveness of a destination.

Concerning the sources of information when preparing a journey, the high percentage of WWW usage is striking. This was to be expected of highly computer literate people. More interesting is the fact that a high percentage of the same people use additional sources of information, especially books, maps on paper and brochures. We conclude that the co-existence of information sources will continue and needs to be taken into account.

A similar question has been asked about the information needs while on tour, i.e. while travelling or at a destination. Figure 6 shows the results.

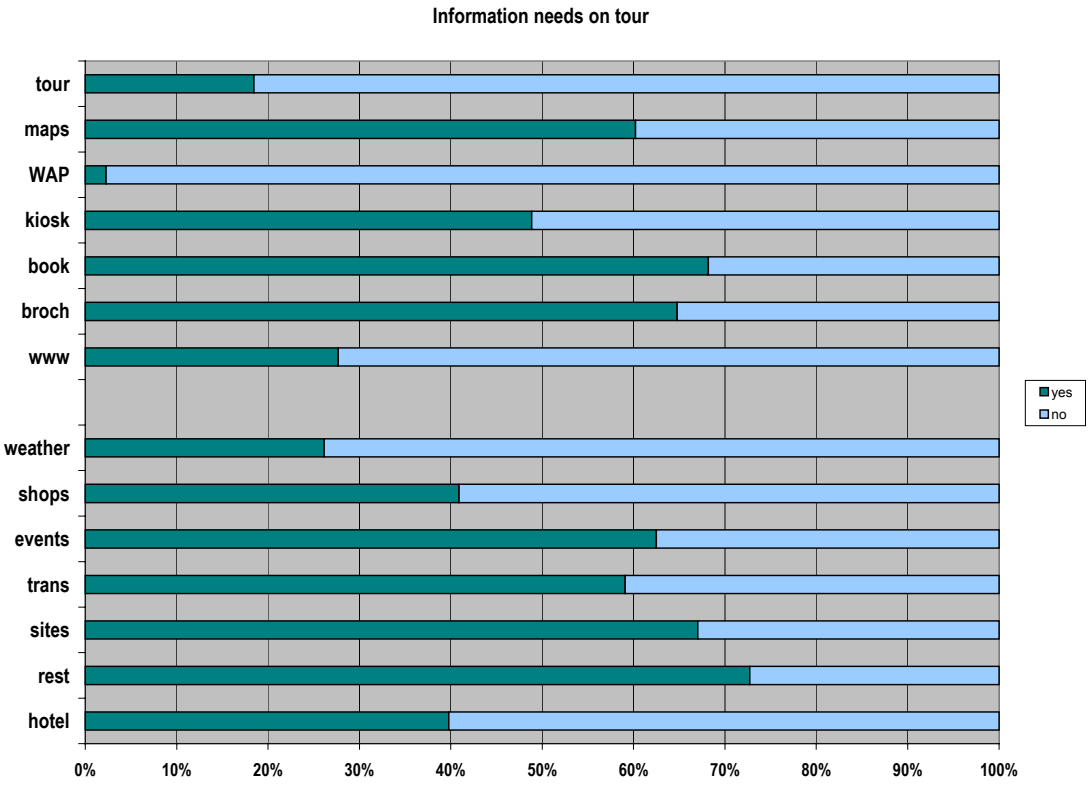

Figure 6 Tourist information needs while on tour

Concerning the content, the information about restaurants, sites, transportation, and events rank highest. Not surprisingly, hotels are no longer of dominant importance, as they are booked in advance in most cases. Again, sites are quite important. We also want to point out the high importance of transportation information both when planning and when travelling.

Concerning the sources of information when on tour, the highest percentages are for books, maps on paper and brochures. The rather low percentage of WWW usage is probably to explain with the still limited accessibility of the Internet for travelling people. Again, a high percentage of the same people use several sources of information in parallel.

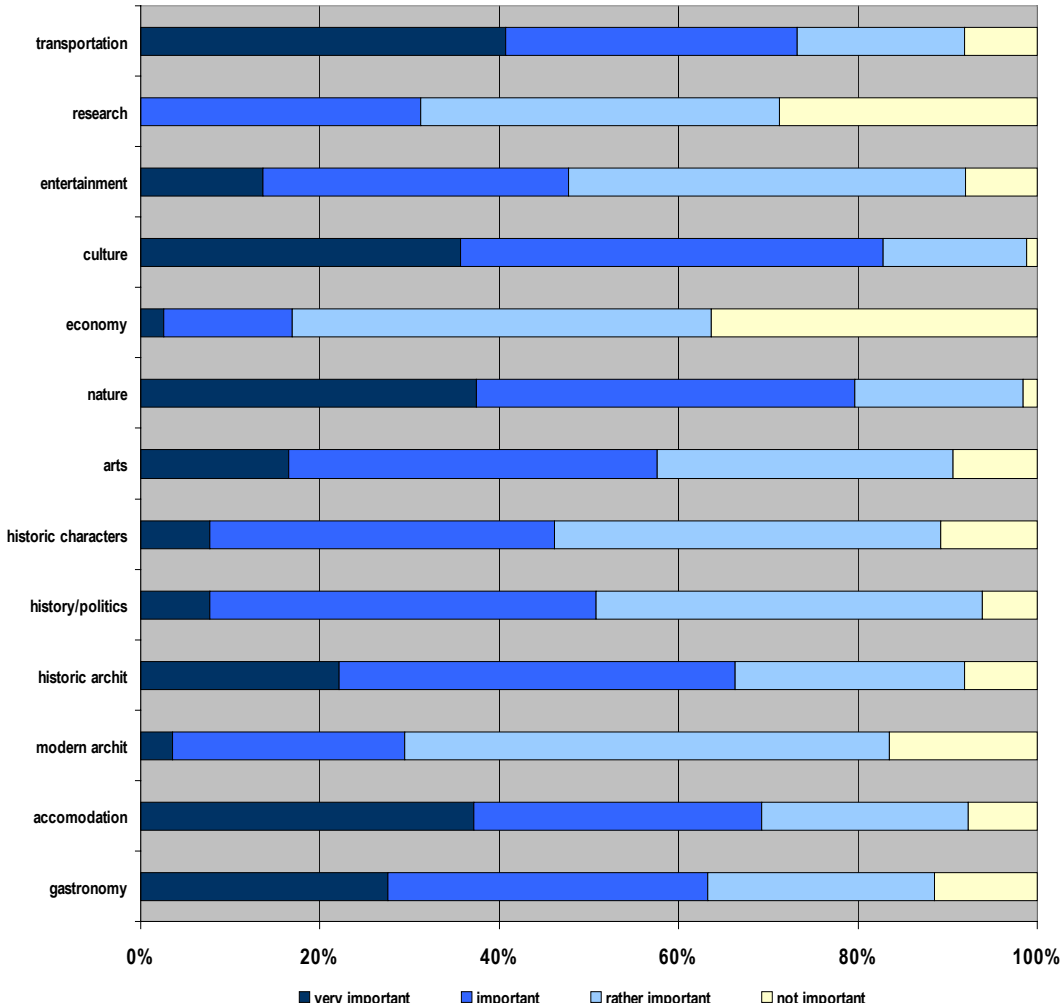

Figure 7 Importance of Aspects of a destination

Another question focussed on the personal interest of people in various aspects of a destination. The outcome is shown in Figure 7.

It is striking, that both culture and nature rank very high as aspects of a destination. This is in compliance with findings of other tourism surveys, but often neglected when discussions are dominated by commercial aspects and the tourism industry.

Then, the next highest level of importance was found for Transportation. We assume, that this does not mean that transportation is an interesting aspect, but rather that it is a crucial issue for travelling people and very often a problem.

Next to this, the aspects accommodation, gastronomy, historic architecture, and entertainment seem to be important aspects of a destination.

We finally wanted to know how the users would rank various features of a mobile tourism service. The outcome is shown in Figure 8.

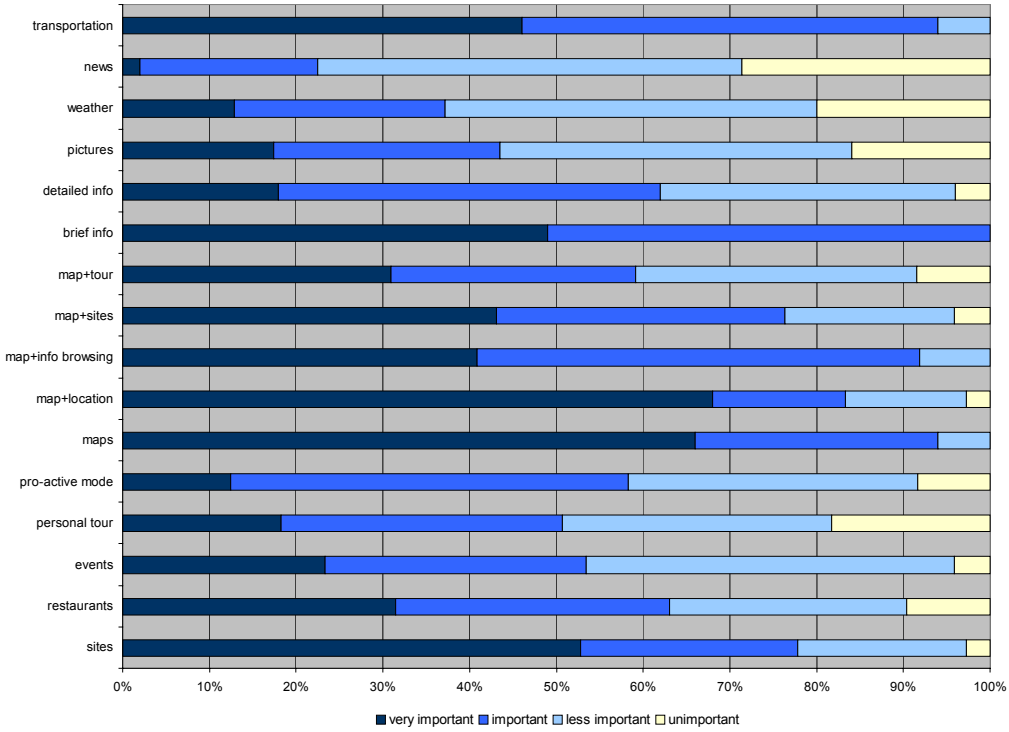

Figure 8 Ranking the features of a mobile tourist guide

Maps rank very high, and even higher when they indicate the current position of the user. The rendering of maps, enhanced by context-sensitive information is probably a core feature for mobile tourism support.

Then, recommendations of sites rank high. In addition, information about transportation is considered to be important or very important by almost all users.

Also, users were unanimous in that brief information is important or very important. Some interviews confirmed that brief information is indispensable, but whenever a user finds something that interests him or her personally, they want to find more detailed information upon request. Therefore a supply of more detailed information is not to be neglected.

5. OVERALL ASSESSMENT OF MOBILE TOURISM SERVICES

We mainly asked two questions to investigate the general attitude of users towards mobile tourism services.

- "Compared to information and sources you have used so far when travelling, would a mobile support on a handheld device have added values for you?"
- "Would you be willing to pay for a mobile tourism service?"

The high percentage of users (over 78%) who see the added benefits of a mobile tourism service is a corroboration of the CRUMPET project (and, of course, similar projects funded in the tourism cluster of the IST 5th framework).

A surprisingly high percentage of users (over 60%) also would pay for such a service. Considered that the use of WWW is usually for free, this was not a safe bet.

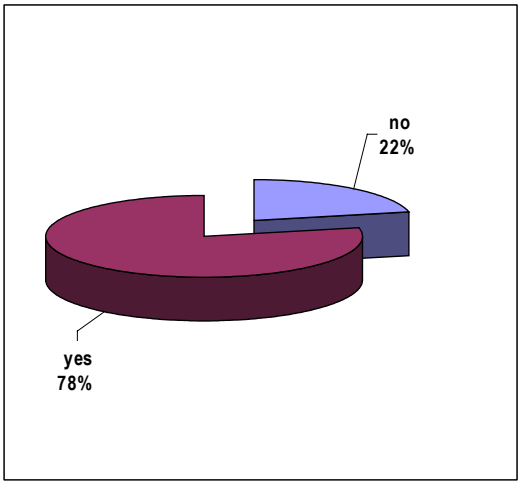

Figure 9 Would CRUMPET have added values?

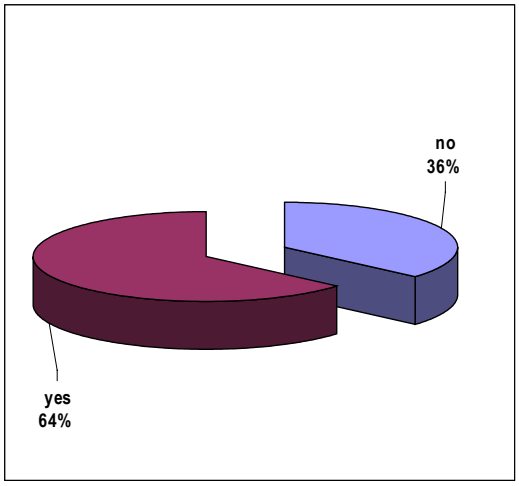

Figure 10 Would users pay for it?

There is one interesting analysis that shows that among people who have actually tried CRUMPET the acceptance and willingness to pay is even higher, as shown in Figures 11 and 12.

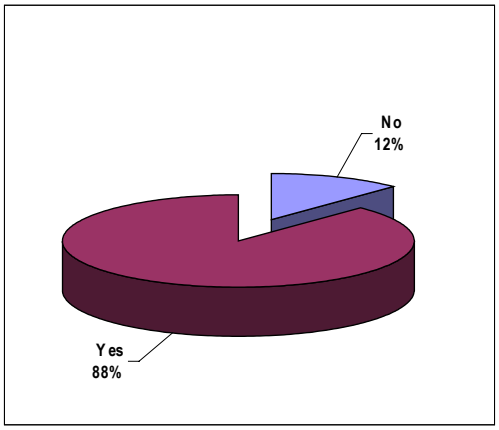

Figure 11 CRUMPET users acceptance

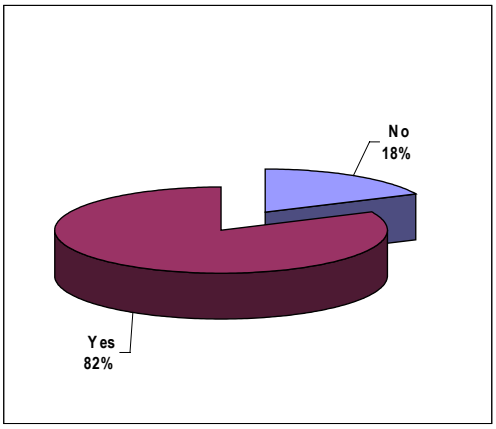

Figure 12 CRUMPET willingness to pay

For both questions we had additional open questions to collect user's comments and reasons in more detail.

The answers about what exactly would be the added benefits of a mobile tourism service included many of the points that have already been made for other questions, such as the importance of location-based information. Overall, tourists imagine they are more flexible with such a device (no need to collect printed information, no need to collect information well in advance), they expect information dynamically adapted to context (location) and personal interests, and they hope for reliably updated information (e.g. concerning events, opening times, transportation).

Concerning their preferred mode of payment we got a variety of answers. With a few exceptions only, the preferred mode was described as "subscription", "fee for renting", "prepaid". Two users also named sort of micro payment, i.e. they would be willing to pay per recommendation. Users want to know in advance the maximum price to which a service can amount in the end. About the amount of money they would be willing to pay, we got answers ranging between "1 EUR per afternoon" to "Same price as for a guide book, i.e.10-20 EUR". Most users answered "rent including the device for 10 EUR per day". The users who would prefer micro payment said "10-20 cent per information". The current practice to charge mobile, i.e. wireless, access to information by time of being online is apparently not favoured by users.

This issue about paying mode and acceptable prices would need further investigation.

We have tested all variables concerning interests and assessments for correlations with demographic variables. It is tempting to expect correlations between gender/age, on the one hand, and interests in a destination, ranking of features, or overall assessment of CRUMPET, on the other hand. Or to expect a correlation between travel frequency and any of the other variables. However, we did not find convincing, significant correlations. There seems a slight tendency that male users would more easily see the added value of the system; there seems a tendency that people who travel more are more ready to see the added value and also to pay for such a service. Overall, correlations of gender or age with other variables were usually rather low. In other words, within our rather homogeneous sample, these variables played no significant role in determining the other variables.

6. CONCLUSIONS

The outcome of the trial and survey have clearly confirmed the approach taken in CRUMPET.

The user assessment of the usability of the prototype was above average, according to the Software Usability Measurement Inventory (SUMI). The majority of users liked the system as well as the content provided.

The importance of location-based services, based on user localisation, locally available services, and personalized recommendations, has been corroborated. Interactive maps, especially when enhanced by highlighting the current position of the user, sites of personal interest or tours, rank high in a mobile tourist support. Recommendations about places of interest, restaurants, events, and accommodation are indispensable in a mobile tourism support. Unexpectedly, information about transportation, culture and nature rank also very high among the information needs of travelling people.

A convincing majority of users approved of the added values of the CRUMPET system compared to other tourism support available today. A surprisingly high percentage of users said they would pay for such a mobile tourism service. Preferred mode of payment would be subscription, i.e. paying once for a period of usage.

All in all, the mobile tourism service can be expected to become one of the dominant information sources for travelling people in the near future. It may well reach an importance for on-tour information supply that equals the importance of the WWW for travel planning today.

7. REFERENCES

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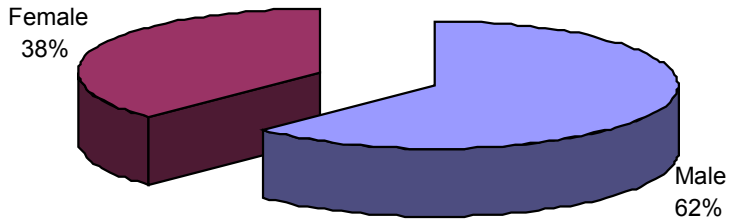
APPENDIX A: CRUMPET questionnaire and results

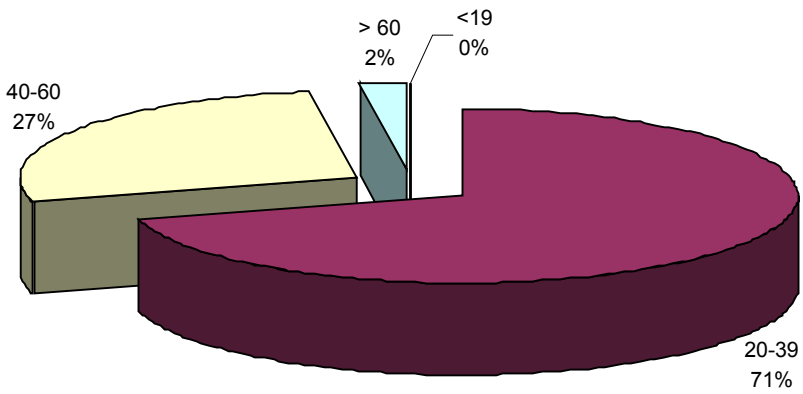
Part 1

1) Please answer a few general questions about yourself

Gender: ☐ male ☐ female

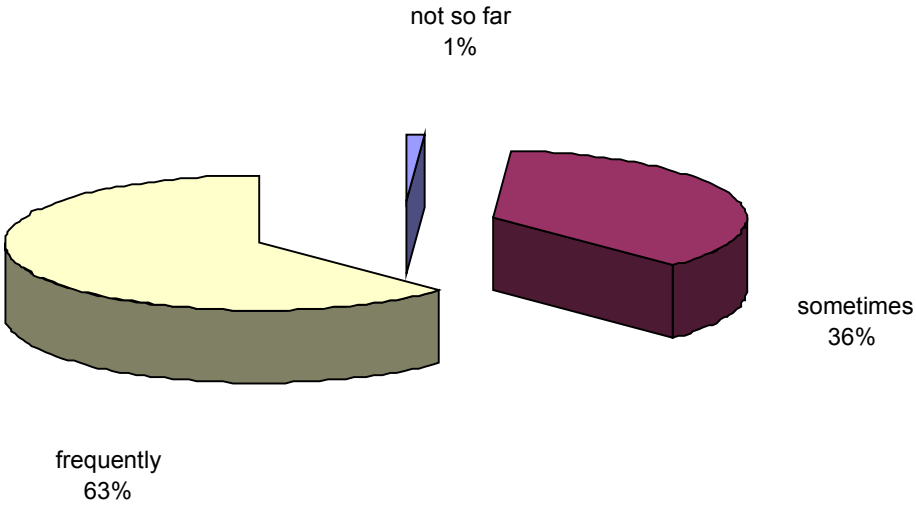


Age: ☐ -19 ☐ 20-39 ☐ 40-59 ☐ over 60



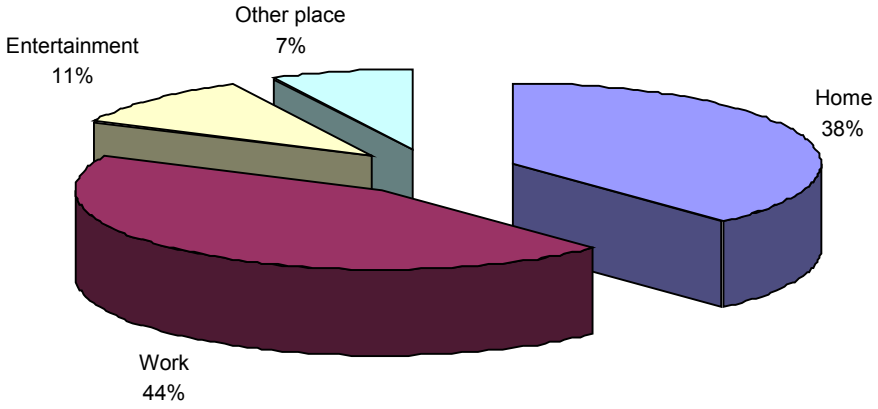
2) Do you use computers?

☐ not used so far ☐ use sometimes ☐ used frequently



if yes: where (multiple choices allowed)[10]

☐ Home ☐ Work ☐ Entertainment ☐ Other place

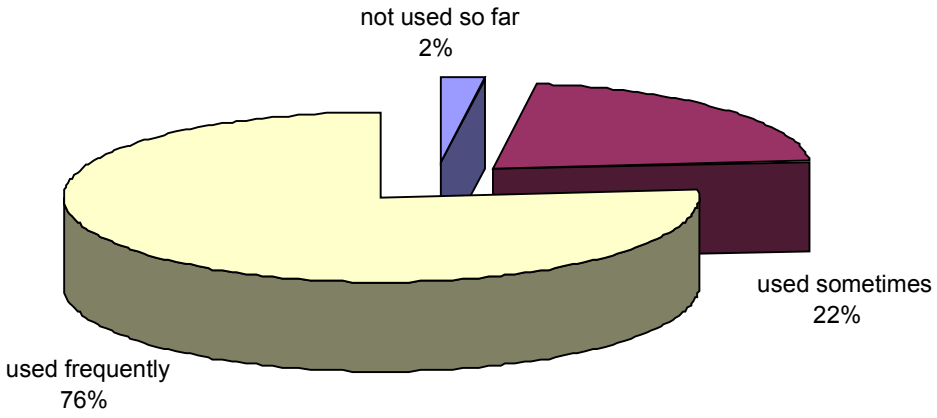


[10] As multiple choices were allowed, the percentages shown in this diagram refer to the total of "ticks", not to the sample size.

3) How familiar are you with the following

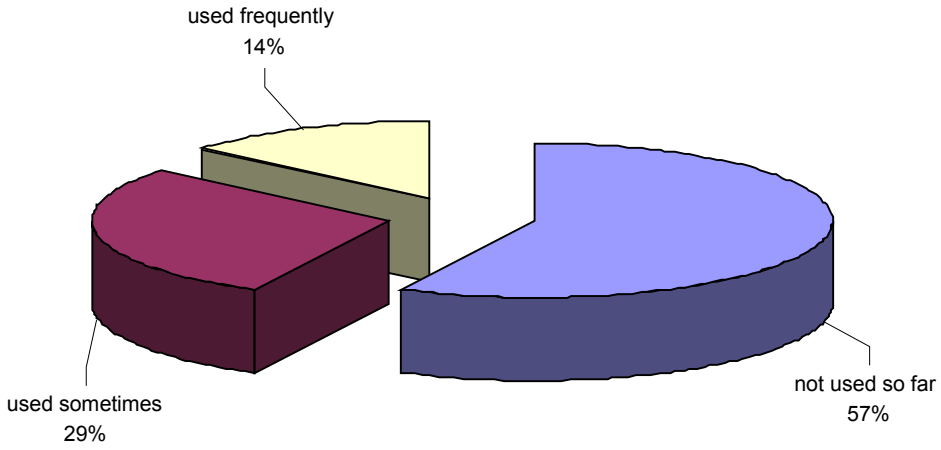
World-Wide Web

☐ not used so far ☐ used sometimes ☐ used frequently



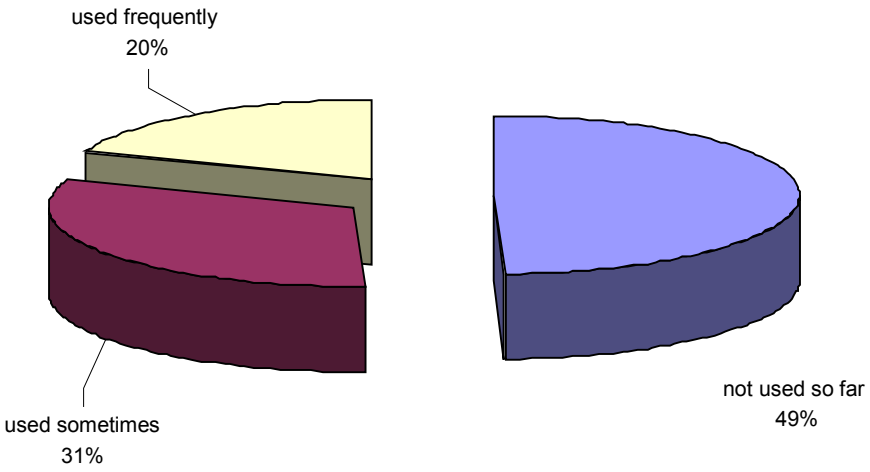
WAP phones

☐ not used so far ☐ used sometimes ☐ used frequently



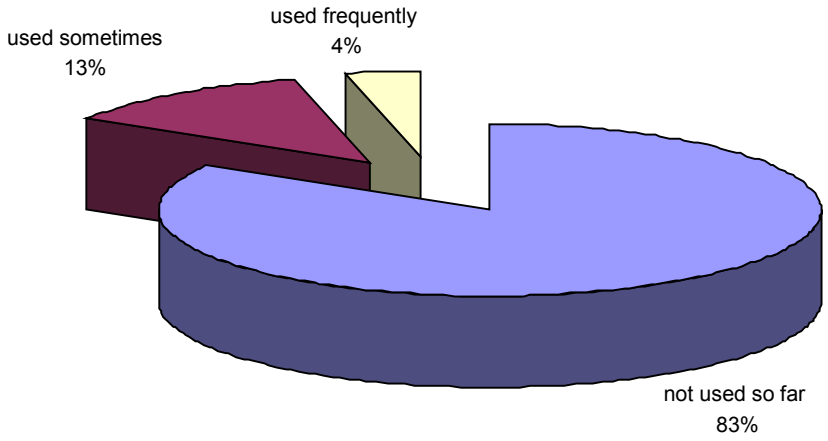
iPAQ (or other handheld)

☐ not used so far ☐ used sometimes ☐ used frequently



CRUMPET like system

☐ not used so far ☐ used sometimes ☐ used frequently



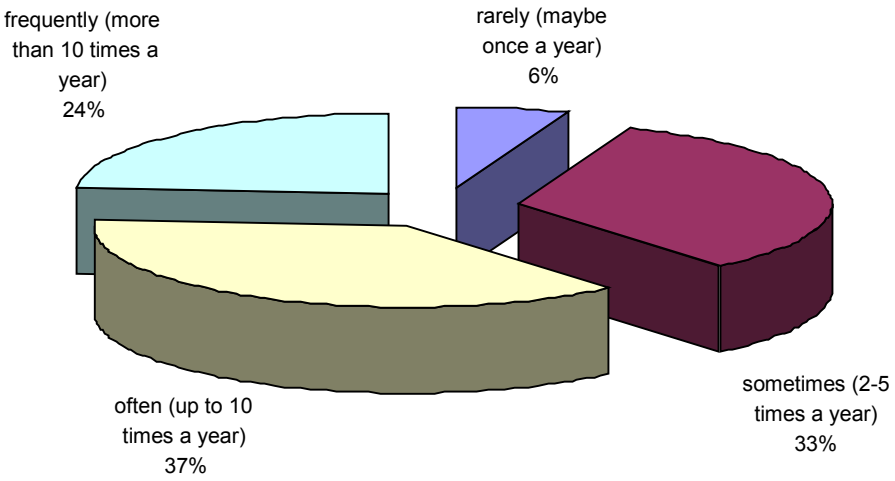
4) How often do you travel?

☐ Rarely (may be once a year)

☐ Sometimes (2-5 times a year)

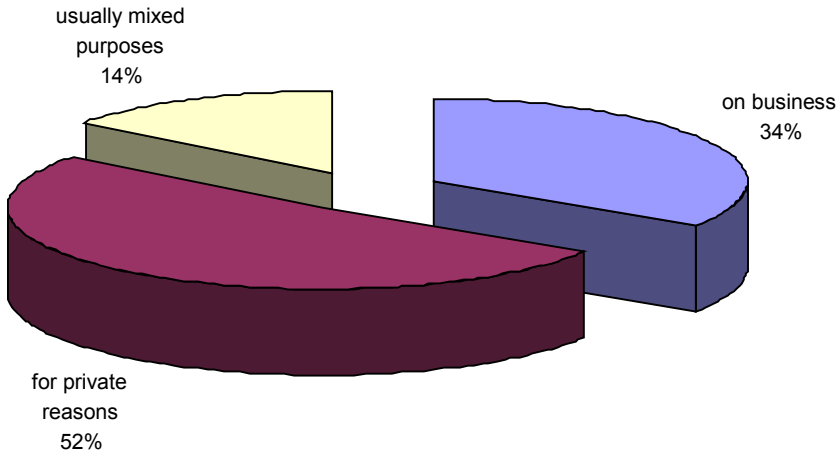
☐ Often (up tp 10 times a year)

☐ Frequently (more than 10 times a year)



For wich purpose? (multiple choices allowed)[11]

☐ On business ☐ For private reasons ☐ Usualy mixed purposes

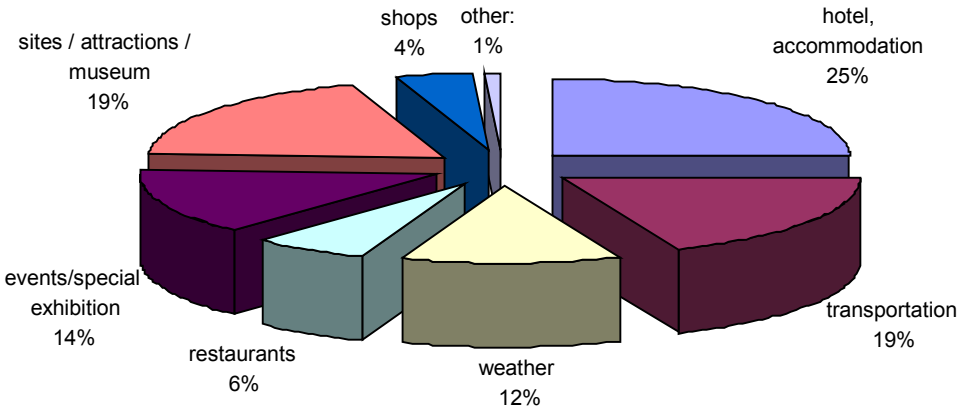


[11] As multiple choices were allowed, the percentages shown in this diagram refer to the total of "ticks", not to the sample size.

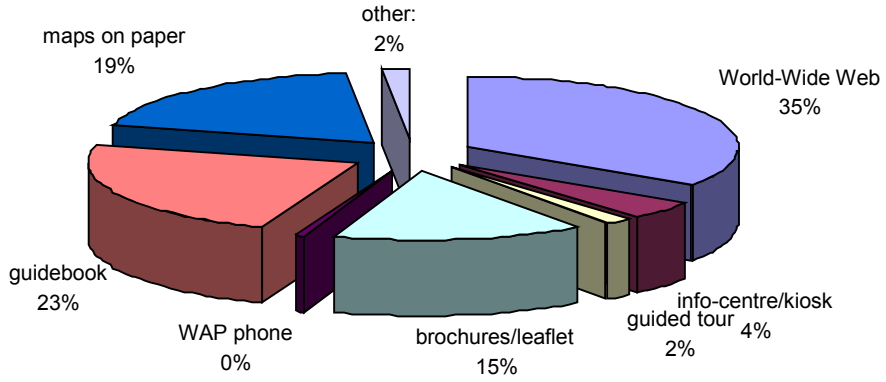
4) What information do you usually get *before travelling*, and from witch *sources* do you get it?[12]

☐ hotel, accomodation	☐ restaurants	☐ sites / attractions / museum
☐ transportation	☐ Events/special exhibition	☐ shops
☐ weather	☐ World-Wide Web	☐ brochures/leaflet
☐ guide-book	☐ info-centre/kiosk	☐ WAP phone
☐ maps on paper	☐ guided tour	

other: _____



What information do you usually get *before travelling?*



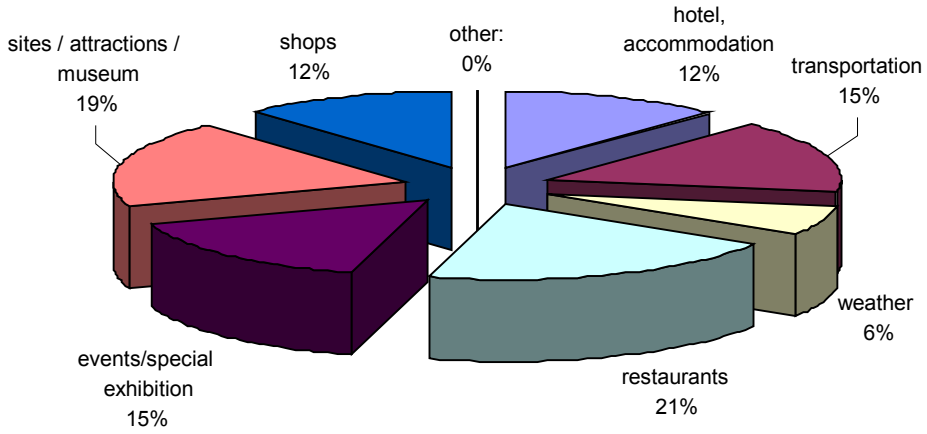
From witch *sources* do you get it?

[12] As multiple choices were allowed, the percentages shown in this diagram refer to the total of "ticks", not to the sample size. For a different visualization, see Figure 5.

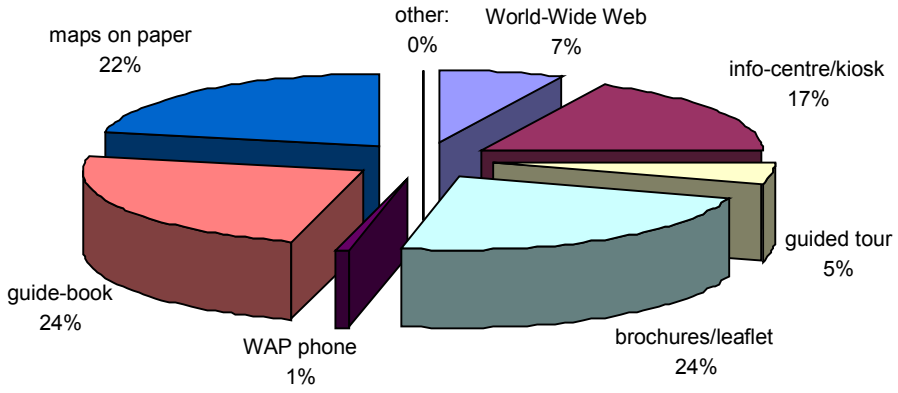
6) What information do you usually get *on tour*, and which *medium* did you use?[13]

☐ hotel	☐ restaurants	☐ sites / attractions / museum
☐ transportation	☐ Events/special exhibition	☐ shops
☐ weather	☐ World-Wide Web	☐ brochures/leaflet
☐ guide-book	☐ info-centre/kiosk	☐ WAP phone
☐ maps on paper	☐ guided tour	

other: _____



Wath information do you usually get *on tour?*



Which *medium* did you use?

[13] As multiple choices were allowed, the percentages shown in this diagram refer to the total of "ticks", not to the sample size. For a different visualization, see Figure 6.

7) What information do you *miss* on tour, and how would you like to get it?

_____

_____

8) What kind of support would you like to get, when using a mobile handheld computer on tour?

_____

_____

9) In general, how important are the following aspects of a city? [14]

ratings scale: 1 = very important 2 = important 3 = less important 4 = unimportant

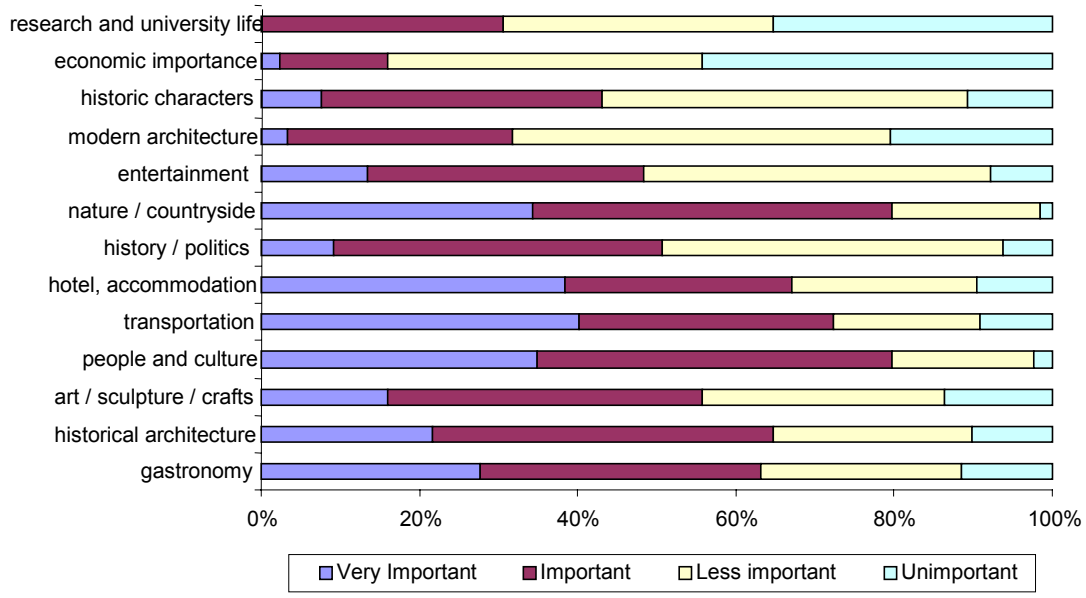
__ gastronomy __ modern architecture __ historical architecture

__ history / politics __ historic characters __ art / sculpture / handicrafts

__ nature and countryside __ economic importance __ research and university life

__ transportation __ people and cuture __ entertainment

__ others:_____



[14] As multiple choices were allowed, the percentages shown in this diagram refer to the total of "ticks", not to the sample size. For a different visualization, see Figure 7.

Part 2

1) Did you like the CRUMPET system?[15]

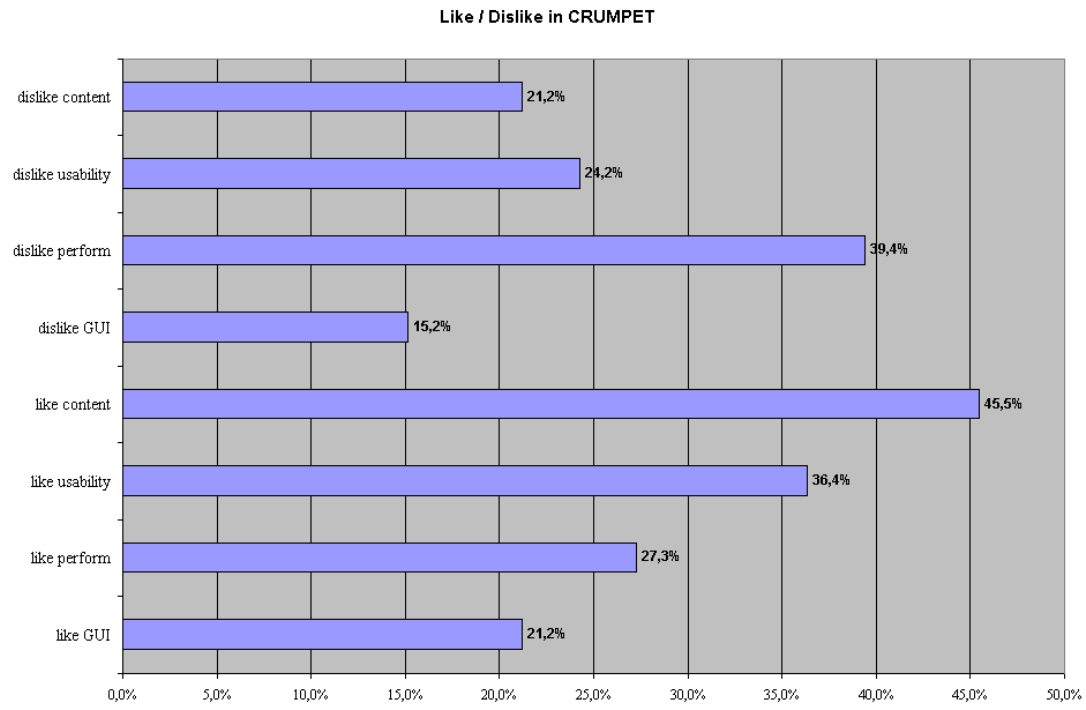
☐ very much ☐ rather ☐ not really ☐ not at all

2) What did you especially *like* in the CRUMPET system?

☐ GUI ☐ Performance ☐ Usability ☐ Information content
Other:_____
_____

3) What did you *not like* in the CRUMPET system?

☐ GUI ☐ Performance ☐ Usability ☐ Information content
Other:_____
_____



[15] Results see in Figure 2.

4) Did you find the information supplied by the CRUMPET system useful?[16]

☐ very much ☐ rather ☐ not really ☐ not at all

5) Please rate the features of a mobile tourism support system (write down number)[17]

ratings scale: 1 = very important 2 = important 3 = less important 4 = unimportant

__ recommendation of sites and attractions
__ recommendation of places to eat
__ recommendation of events (eg show, cinema, party)
__ personal siteseeing tour
__ recommendations in a pro-active mode
__ maps in general
__ map with current location
__ maps to browse for information
__ maps, highlighted sites
__ maps, highlighted tour
__ brief information
__ detailed information
__ pictures of places
__ weather
__ News
__ transportation

[16] Results see in Figure 3.

[17] Results see in Figure 7.

6) Did you *miss* features in the CRUMPET system?

☐ No ☐ Yes If yes, please specify

_____

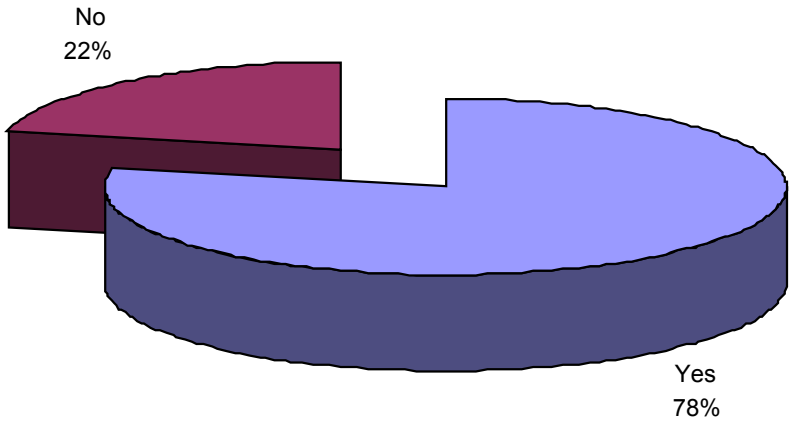
_____

7) Compared to information and media you have used so far when travelling, would a CRUMPET system have added values for you?

☐ No ☐ Yes If yes, please specify

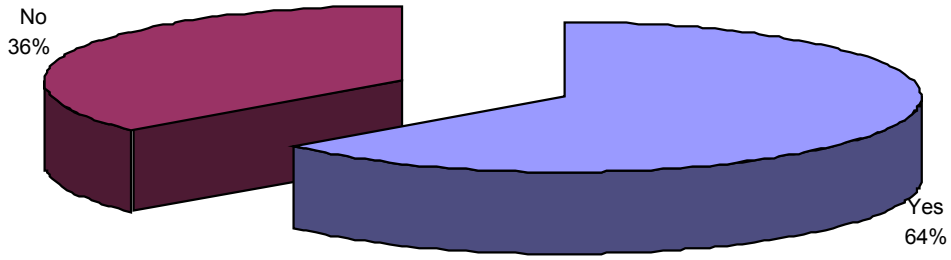
_____

_____



8) Would you be willing to pay for a CRUMPET tourism service?

☐ No ☐ Yes



9)Do you have any other comments on the CRUMPET system?

_____

_____

_____

APPENDIX B: Seamless Roaming and QoS Issues

Executive summary

This appendix is a report of the QoS issues of the CRUMPET trial in Helsinki. The most critical factor related to QoS is seamless mobility between different network technologies. Seamless mobility created delays those trial users experienced too long and thus not satisfactory. This was clearly seen in the questionnaires.

The basic technology used in the CRUMPET trial (operating systems, drivers for communication controllers–WLAN, GPRS, etc.–) were implemented in a way that made it very difficult to obtain accurate and just-on-time information of sudden disconnections in a reasonable timeframe. Therefore, the delay in seamless mobility was in some cases too long.

Introduction

The trial in Helsinki mainly concentrated on data communications issues, such as the QoS of data transmission, seamless mobility between different network technologies. Seamless mobility between different network technologies (i.e. WLAN, GPRS, GSM) turned out to be the most critical factor affecting trial users' acceptance of QoS of the CRUMPET service in Helsinki trial. The basic technology used in the CRUMPET trial (operating systems, drivers for communication controllers–WLAN, GPRS, etc.) were implemented in a way that made it very difficult to obtain accurate and just-on-time information of sudden disconnections in a reasonable timeframe. Therefore, the delay in seamless mobility was in some cases too long. This appendix discusses the QoS related to seamless mobility.

The issue was considered so important from the viewpoint of providing services to nomadic users that Sonera has started a new research activity to further study the QoS issues in seamless mobility. This appendix discusses the QoS issues related to seamless mobility in the environment of CRUMPET tourist services.

QoS Issues in Seamless mobility at Crumpet Project

Seamless mobility between different network technologies (hereinafter vertical handover) in tourist services is more than just IP-based seamless mobility and multi access protocols and technologies. The whole area contains several related smaller entities that together prepare the ground for vertical handover in nomadic users networking environments.

Seamless Roaming refers to a collection of network and Mobile Node (MN) side techniques and networking protocol design techniques, which together aim to provide uninterrupted service and network connectivity regardless of handovers between different (wireless) access networks. An example from the CRUMPET project is to provide an uninterrupted audiovisual streaming media service in GPRS-UMTS-WLAN networks environment allowing both vertical and horizontal handovers between these access technologies. There are several components affecting the delay created by the seamless mobility. The low level components are as follows:

Data communication controller: The delay depends on the capability of a controller (WLAN, GPRS, GSM, etc.) to detect the quality of radio signals, especially when the quality is low enough to cause handover, and to inform associated software components.

Drivers of data communication controllers: The delay depends on the capability of a driver to act in an appropriate way when informing associated software components about the QoS.

Operating systems: The delay depends on the capability of the operating system to support simultaneous data connections. In the case, where the operating system does not support simultaneous connections (e.g. Windows CE), the delay can be significant, as the old connection must shut down before the new one can be established.

The middle level components comprise data communication protocols, such as MIP, TCP, and UDP.

The upper level components consist of the following:

- Application level: In the case of CRUMPET, the delay depends on the application level session (re-)establishment. This delay comprisesthe opening a TCP socket, and roughly one round-trip for the session establishment messaging.

We did not have the tools for accurate measurements and differentiation of these issues, but based on our experiences, we can say that the cases of worst delay were caused by the components of operating systems and application level, and especially when roaming to GSM or GPRS. The reason is that the setup time for GSM and GPRS are in the magnitude of seconds, whereas in the case of WLAN, the delay is in the range of some hundreds of milliseconds.

In the CRUMPET system the WLAN data communication controller was polled for the signal strength with an interval of one second. If the signal strength was below our predefined threshold-value, the WLAN connection was shut down, and GSM or GPRS connection was set up. Correspondigly, when the user roamed to the WLAN coverage, and the signal strength raised above our predefined threshold, the GSM or GPRS connection was shut down, and a new WLAN connection was set up.

In the Table 1 the delays in the roaming cases are collected. The numbers are in milliseconds.

Table 1: Delays in different roaming situations

From	To	Controller	Shutdown	Setup	Session	Total
WLAN	GSM	1000	300	9000	3000	13300
WLAN	GPRS	1000	300	3000	3000	7300
GSM	WLAN	1000	600	200	200	2000
GPRS	WLAN	1000	600	200	200	2000

Legend:

From	– the originating network
To	– the destination network
Controller	– the delay caused by the polling of the network controller

Shutdown	– the delay caused by the shutdown from the originating network
Setup	– the delay cuase by the set up of the connection to the destination network
Session	– the delay for application level session re-establishement

In addition to the factors mentioned above, middle level components, such as the data communication protocols (e.g. TCP and UDP), affected the delays of seamless mobility. These issues are discussed in more detail below.

Current transport protocols such as TCP, UDP, and RTP have not been designed with mobility in mind. Thus transport protocols usually have performance and behaviour implications during handovers. These implications are mostly caused by significant changes in underlying network characteristics such as roundtrip time, bit error rate, transfer speed, and increased amount of required signalling. Seamless mobility procedures shall incorporate several techniques in order to enhance the handover procedure. Handovers might be based on network QoS, service media requirements, and user or network provided profiles and characteristics. These handover selection mechanisms and enhancement techniques are currently unsolved issues, which require further research.

Multi-access is closely related to seamless mobility and means that a mobile computer can be connected to a network using multiple active network interfaces. For example, the mobile computer can have both GPRS and WLAN interfaces activated and connected to networks. Multi-access has a key role in enabling smooth vertical handovers for seamless mobility. Multi-access is a relatively new issue due to restrictions on the capabilities of mobile computers to manage multiple network interfaces and is an area for research.

An intersystem handover is challenging with respect to end-to-end transport protocols because packets often get lost, delayed or reordered in the network. Furthermore, path characteristics such as bandwidth, latency and the amount of buffering can change suddenly, often by more than one order of magnitude. Estimators used by the end-to-end transport protocols to control the amount of outstanding data in the network and the rate of transmission are likely to be significantly off after a handover. As a result, overshooting or underutilization of the available bandwidth becomes likely.

Sonera has carried out research on the following issues:

- How severe are problems that an handover cause to transport protocols; how long it takes to adapt; and
- What kind of optimizations in the network and protocol can aid the adaptation.

TCP is a reliable transport protocol still responsible for over 90% of all traffic in the Internet. TCP invokes slow start in the beginning of connection and after a retransmission timeout. In slow start, the Multiplicative Increase Multiplicative Decrease (MIMD) is used roughly doubling the transmission rate every round-trip time (RTT) in the absence of congestion. In steady state, known as congestion avoidance, TCP invokes Additive Increase Multiplicative Decrease (AIMD) congestion control. In this phase, the rate is slowly increased by one packet per RTT in the absence of congestion and halved when a packet loss is detected. TCP has an important property of self-clocking also known as the packet conservation principle. For loss recovery, TCP invokes go-back-N behaviour after a retransmit timeout and the fast retransmit on duplicate acknowledgments.

TCP congestion control behaves in a strange way, as in fact the bottleneck buffer size is estimated, not the link bandwidth. It makes the size of the buffer an important factor affecting TCP performance, and not the actual throughput. In general, window-based protocols are more sensitive to the change of bandwidth-delay product of the link than of the link bandwidth. A striking example is that the TCP congestion control estimators (congestion window, slow start threshold) for two links (4 kbps, 10 ms and 100 kbps, 100 ms) are the same assuming the same link buffer size. Therefore, after a handover without packet losses between two such links, the TCP sender instantly begins sending at the new rate because the transmission rate is defined by the rate of returning acknowledments (ACKs). This may have significant effects on the delay.

The most significant factor contributing to lengthy TCP recovery from handovers was found to be in exponential backoff of the TCP retransmit timer. Self-clocking is seen as the key feature of TCP congestion control that contributes to the stability of the Internet. Main characteristics of a congestion control algorithm are fairness, aggressiveness, responsiveness, and smoothness. Fairness reflects the ability of a flow to share bandwidth in a compatible way with a TCP flow running in similar

conditions. Aggressiveness describes how rapidly the algorithm increases the transmission rate in the absence of congestion. Responsiveness reflects how fast the rate is decreased in the presence of persistent congestion. Finally, smoothness defines how variable is the rate when packet losses are relatively rare.

The main problem with implementing an intersystem handover is that transport connections in the standard TCP/IP stack are bound to use the same IP address throughout their lifetime. Several mechanisms were proposed to solve this problem. Mobile IP assumes that the mobile host uses its permanent IP address from the home network at all times. Packets destined to this IP address are tunneled from the router in the home network (called home agent) to the router in the visiting network (called foreign agent). Several studies evaluated performance of Mobile IP handover in overlay networks. A common conclusion appears to be that while Mobile IP can provide sufficiently quick handovers for nonreal-time applications, the disruption is too high to be tolerated by real-time applications. Other approaches to implementing intersystem mobility can be classified into application-based e.g. using the Domain Name System (DNS), multicast-based, and micro mobility protocols with context transfers. Common goals are to minimize the delay and packet loss during a vertical handover.

Most connection-oriented transport protocols such as TCP include negotiation of protocol options during connection establishment. In case of TCP, the options cannot be adjusted later during connection lifetime. Optimal options negotiated at connection establishment may not be valid after a handover to a network with considerably different characteristics.

Based on the specific measurements, a GPRS to LAN handover may cause a break in a TCP flow for 15 seconds. The underlying reason is an excessively high retransmission timeout value at the TCP sender in GPRS. The RTT in GPRS during a bulk data transfer is about 7 sec due to a high link-latency and a significant amount of buffering. During a vertical handover, all outstanding packets get lost; and it takes a long time before the TCP sender retransmits any data. Even if the handover itself causes a much shorter disruption, the TCP sender would not start using the new link quickly unless fast retransmit is triggered. In that case, the break experienced by a TCP flow is about 0.1 sec. A LAN to GPRS handover took about 3 seconds. The TCP sender timed out and performed retransmissions using exponential back-off. The retransmission timeout value is much lower in LAN than in GPRS due to much lower RTT.

A GPRS to WLAN handover took about 100 ms. Although all data segments were lost, DUPACKs arriving after handover resume the connection quickly.

Conclusions

The studies showed that with current technologies (e.g. operating systems, device drivers, and communication controllers) the delay in seamless roaming can be quite long, i.e. up to 13 seconds, which is not satisfactory to tourists. Future research activities should address this issue.

APPENDIX C: Agent platform testing

Executive summary

QMUL has carried out some burst performance tests of exchanging messages with another agent platform in the London area – this represents a typical message exchange between agents on the access-node connected via a wireline Internet connection to another agent platform containing the service agents within the same metropolitan area. It can be seen that the round-trip for typical request-reply message exchanges takes of the order of about 400 ms. If these measurements are compared to the wireless access and wireless roaming, they are of the order of a factor of 10 less. The main bottleneck in exchanging agent messages across wireless-wireline environments is the performance of the wireless network. The dynamic nature of agent directories and service discovery can support reconfiguration to solve agent performance bottleneck problems.

Method and results of Performance tests

The following burst tests were carried out by QMUL to determine the performance of its agent platform

- Ping messages were sent in bursts 1000 and the average response time was measured
- AMS query messages were sent in bursts of 1000 to different agent platforms and the average response time was measured
- DF query messages were sent in bursts of 1000 to different agent platforms and the average response time was measured.

The results are shown in Table 2 below. The way the bursts are generated are that a test agent fires a sequence of messages: it waits for the return message in each case before sending the next message. Each message is sent to a different agent platform in sequence (up to 15 different platforms). Once the QMUL agent platform receives the response from the 15th agent platform, it then goes back to the first agent platform again repeating until it has sent the 1000th message.

Results and conclusions

Message test	no_iterations	total_duration (ms)	total_duration / no_iterations
Ping	1000	260147	260.15
AMS Query	1000	400551	400.55
DF Query	1000	370944	370.94

Table 2. Performance measurements for message exchange between two agent platforms distributed across a metropolitan area.

The dynamic nature of the agent mediation services

The project's approach to scalability is threefold: firstly to leverage the inherent scalability of the MAS paradigm; secondly, to review, monitor and measure the performance of the existing Agentcities network; thirdly, to analyse, design and implement enhancements to the current network to improve scalability.

In terms of the inherent scalability of the on-line Agent processing and task-handling - in many MAS implementations, agents can be run locally in a single computational container on a single host or in multiple agent platforms on the same host or on multiple agent platforms in multiple hosts. Currently, it is envisaged that in the case of bottlenecks it may be necessary that agents and agent platforms stopped, state saved and restarted in a new configuration. Agents can dynamically register in a local directory service and also each local directory can be registered, federated, with other agent directories. Thus,

one can search via a local directory to access information in a remote directory. Note also that FIPA and Agentcities does not require all services to be agents – directory services can be offered using robust non-agent designs such as those based on LDAP.

The dynamic nature in which FIPA directory service agents can register service providers and register with each other can help alleviate performance problems when one directory service gets overloaded.