

# A WEB-BASED INFORMATION SYSTEM FOR DIAGNOSING, SERVICING AND OPERATING HEATING SYSTEMS

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**SUMMARY:** Diagnosing a heating system may turn out to be necessary even for an ordinary customer, like a residential building owner or a facility manager. The need is usually triggered by a technical problem in the system. The customer wants to know how to solve or handle the problem. This paper presents a Web-based information system, called WebDia, which is designed to assist customers with such heating problems. WebDia is a prototype system, constructed for district heating substations and oil heating systems. WebDia incorporates a Web server integrated with a back-end database, accessible from a browser of a PC, a Personal Digital Assistant (PDA) or a Wireless Application Protocol (WAP) mobile phone. The general idea behind the development is that the server computer shares its resources and knowledge with the user. Besides fault diagnosis, instructions for servicing and operating the heating system are also essential topics. The information content is gathered from various publications, material provided by manufacturers and interviews with experts. A great deal of the professional information also comes from the fourteen co-operating companies assisting in the system development. WebDia is a collection of dynamic HyperText Markup Language (HTML) pages, but it also includes pictures, photographs, video and audio recordings, and animations. Most of the pages are created using server-side scripting based on Active Server Pages (ASP) technology, but Java applets are also used. Building a system like WebDia turns out to be a tedious process, which requires knowledge and expertise from several disciplines in addition to modern Web authoring and multimedia tools.

**KEYWORDS:** Web engineering, multimedia, database systems, WAP, PDA, diagnostic methods, heating systems

## 1. BACKGROUND

Developments in communication technology will gradually change methods of maintaining buildings and their technical systems. This is partly due to the Internet, which provides us with broadband data transmission and huge computing capacity not tied to any geographical location. In addition, new wireless technology enables users to utilize this information almost anywhere. The transferred information will soon be not only plain text,

but also any kind of multimedia, such as hypertext, pictures, photographs, video and audio recordings, and animations. How could all this be used to help ordinary service personnel or residential building owners in the maintenance of their heating systems? This was the primary question at the beginning of the project. The resulting solution is a Web-based information system that helps the new wireless generation to diagnose, service and operate their heating systems. The following is a description of the design and implementation of the prototype, referred to as WebDia. The project was started in the beginning of 1998. At that time no other corresponding Web-based tools for HVAC systems were available.

## 2. APPLIED CRITERIA FOR THE DESIGN

Designing a Web site, which consists of a large number of Web pages, requires systematic techniques and a careful plan of the layout. Web-based information systems are no longer manageable with *ad hoc* methods (Paynter and Pearson, 1999). Besides the requirements for comprehensive representation, ease of navigation, usability, interoperability and accessibility, the collected data must be easy to maintain (Nielsen, 2000). Developers should also focus on the security and reliability of the Web system.

In addition to these general design rules, the authors put stress on the following criteria:

- Instead of using conventional static Web pages, the team members were advised to use dynamic HTML (DHTML) techniques. DHTML pages make the presentation versatile and they are also supported by modern database techniques.
- Plain written text should be avoided as the only source of information for the user. If such sections or pages had to be applied, they should be short, distinct and clearly focused on the subject. Multimedia presentation was preferred instead: by using pictures, photographs, video and audio recordings, and animations, the required information can be illustrated in a short and comprehensive form. One multimedia page easily replaces several conventional, static Web pages.
- All the collected information should be used efficiently. This means diversified linking from all pieces of information. Good linking practice also provides the user with additional details on the main subjects on the Web page and relates the presented information to larger entities.
- Wireless technology clearly has an influence on the design of the system. A standard Web browser cannot be used in WAP mobile phones and PDAs, they require specific user agents and a specific layout from the Web pages. However, the contents should still be compatible with ordinary PCs and their browsers.
- Finally, the contents of the Web pages should be relevant, updated information and presented according to the requirements of ordinary customers, such as residential building owners, facility managers and service personnel.

## 3. OUTLINE OF THE SOLUTION

WebDia consists of a Web server on the Internet, and PCs, WAP mobile phones, and/or PDAs equipped with a communication capability, as illustrated in Fig. 1. The following items give a more detailed description of the contents of WebDia.

- WebDia is a help desk, which is a basic type of diagnostic network (Möttönen and Pakanen, 1997), but it can also be categorized as an informational and/or interactive Web application (Ginige and Murugesan, 2001). In addition to fault diagnosis, the help desk delivers essential, updated information about servicing and operating a heating site.
- In all the presented information, user safety and prevention of large (costly) site failures are highlighted. Service procedures and repairs not permissible for the consumer are clearly pointed out and he/she is advised to contact a professional service person.
- WebDia is accessible from a PC with Internet connectivity or from a WAP mobile phone, a laptop computer or a PDA with a wireless link to the Internet. So, WebDia even advises the user at the heating process site.

- The system is not electrically interfaced to any building or plant. If observations, like reading of instruments, are needed, the user enters them when required according to instructions given by the server. Thus, the results are based on interactive communication (Pakanen, 1994).
- The information concerning heating systems is gathered from various publications, material provided by manufacturers and interviews with experts. A great deal of the professional information comes from the fourteen co-operating companies involved in the project. A complete list of publications and other referenced material is presented by Pakanen et al, (2001).

WebDia can be found at the URL: <http://webdia.vtt.fi>. The URL for WAP mobile phones is: <http://www.rte.vtt.fi/wapdia>. The Web pages target Finnish customers, and they are therefore implemented only in Finnish. English equivalents of important terminology are superimposed on the figures in this article.

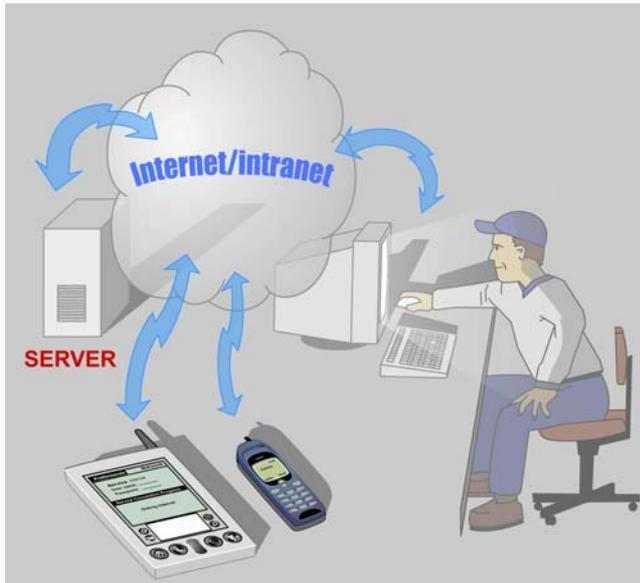


FIG.1: System schemata of WebDia.

#### 4. TECHNICAL APPROACH

WebDia is a collection of dynamic HTML pages. Most of them are created using server-side scripting. This is based on Active Server Pages (ASP) technology, built directly into Microsoft Web servers. Active Server Pages make it possible to combine HTML code, script languages and a server-side database. The script is automatically compiled when the page is loaded, then the HTML document is created including information gathered from the database. Finally, the finished HTML file or Wireless Markup Language (WML) deck is sent to the client machine (Fig. 2). All server-side scripts were programmed using Visual Basic Scripting (VBScript). The database, supported by ASP technology, has become an essential part of WebDia. The number of page documents in WebDia is growing all the time. Maintaining the collected information would soon be difficult without the database solution.

Java applets are another way that was used to create dynamic HTML pages. Fault tree applications did not easily meet the requirements of server-side database implementation, and they were therefore designed using Java applets. Now, fault trees emerge by executing embedded scripts in the client's browser. Animations also need a Java-enabled browser or a suitable plug-in. They were designed using Macromedia's Flash animation tool. The Web pages also include audio and video recordings, which are saved as WAV and AVI files and played on standard Windows players.

A wireless link to the Internet can be accomplished by means of a WAP mobile phone (Fig. 3) or a PDA with mobile Internet connectivity. Although both technologies have access to WebDia, their technical solution on the server side is handled differently. A WAP mobile phone gets the loaded Web documents through WML pages inherently tied to ASP files and the database. However, all the information in WebDia is not available to WAP

mobile phones. This includes the fault tree procedures, which are based on Java applets in the client browser. The Web browsers on PDA computers are similar to those of PCs, transferring the page file to the PDA and presenting it on its screen. But some PDAs may have problems getting a clear and organized view of the Web page. This is especially true for PDAs that are not able to present an ordinary-sized Web page on their screen. Some models are equipped with a screen magnifier, and they do not suffer from the problem.

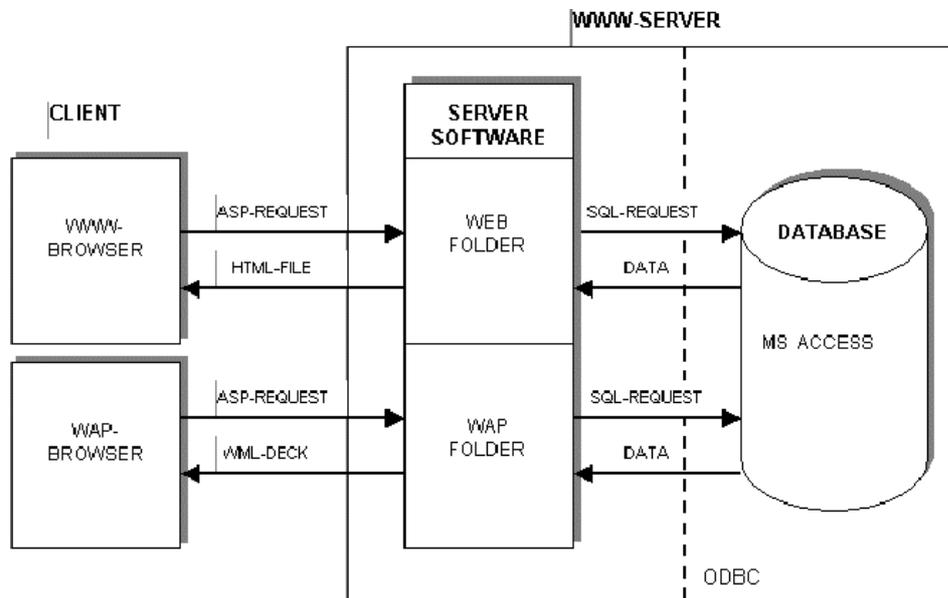


FIG. 2: Data transfer between client browsers and a Web server back-ended with a database.



FIG. 3: Accessing WebDia from a WAP mobile phone.

## 5. SERVICING AND OPERATING A HEATING SYSTEM

One part of WebDia deals with servicing and operating heating systems. The information is presented using several techniques, mostly text, hypertext, drawings and photos, but video and audio (Fig. 5) recordings, and animations (Fig. 4) are also used to promote comprehension.

The service and operation pages concern either the whole heating site or concentrate on specific instruments. They give guidelines for annual service procedures, but also include some detailed instructions. The pages are designed for ordinary customers, residential building owners, facility managers or professional service personnel. However, service procedures and repairs requiring professionals are clearly pointed out to the user.

A consumer who is interested in finding out more information about his/her heating system may take a closer look at the process animations to learn more about the heating system, or to locate certain process equipment. If

the user is not sure of the terminology, he or she can consult a directory describing most professional terms related to heating systems. Questions concerning servicing and operating commercial process equipment, like controllers, pumps, heat exchangers, boilers, etc., are linked directly to the Web pages of the manufacturers. In order to avoid frequent updating of Web links, only the manufacturers' home page URLs are used.

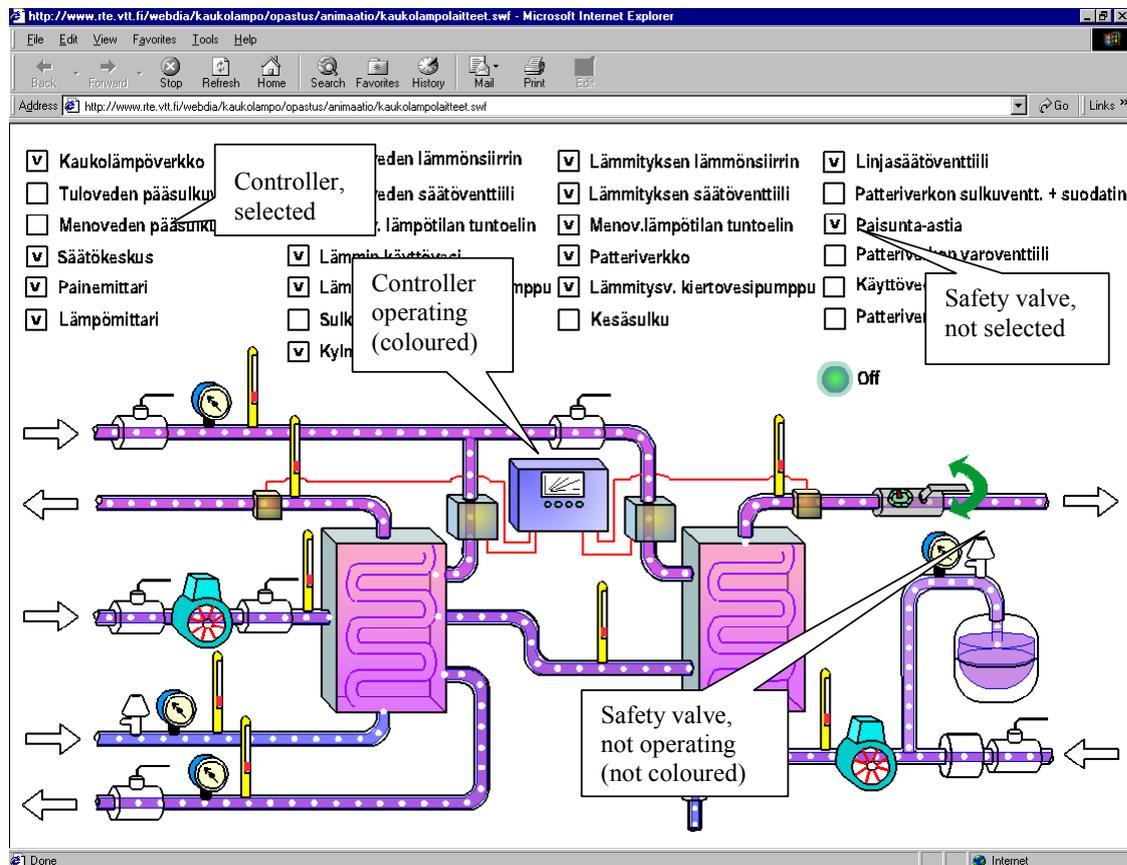


FIG. 4: Animated district-heating substation. The upper part of the page contains a list of common devices of a substation. When the user enters the page the figure is first black and white. By selecting a device from the list the animation is started by highlighting the device in colors and showing its operation. By clicking the off (on) button the whole process animation is stopped (started), as presented.

- Laakerit ovat kuluneet.
- Tarvittaessa varmistu kuuntelemalla laakerin käyntiääntä joko ruuvimeisselillä tai erillisellä kuuntelulaitteella.

[Ehyt laakeri](#)

[Vaurioitunut laakeri](#)

Instruction of the procedure

Audio link of a bearing in good condition

Audio link of a damaged bearing

FIG. 5: A procedure for checking the condition of pump bearings using audio recordings.

## 6. DIAGNOSTIC TOOLS

WebDia contains several diagnostic methods: a look-up table, frequently asked questions (FAQs) and a fault tree. If the symptoms offered by the user are clear and specific, the look-up table gives immediate answers to heating problems. FAQs are answers to common questions concerning fault diagnosis, service and operation of heating systems. The fault tree procedure takes more time to navigate than the others, but it is the most thorough tool for fault diagnosis. The category of diagnosed faults includes all the typical faults of district heating substations and oil heating systems.

### 6.1 Look-up table

The look-up table (Fig. 6) is designed for those who don't want to waste their time exploring lengthy diagnostic methods. For them, a look-up table containing the most common symptoms and possible faults is a good choice. Besides displaying symptoms and faults, the table simply gives advice and suggests actions to be taken to solve the problem. Although the common advice is to contact a service person or energy company, the look-up table also provides the user with many useful hints. If understanding the operation of a site, its equipment and instrumentation poses a problem, the user can consult the FAQs, the process animation page or the term directory.

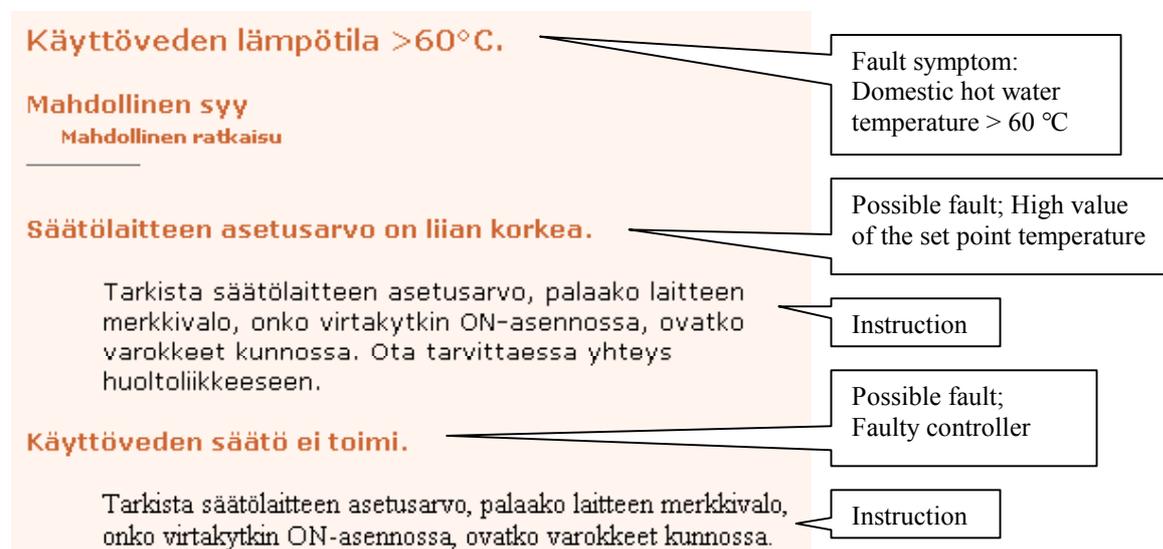


FIG. 6: Part of a look-up table page, giving instructions for a fault case.

### 6.2 FAQs

FAQs, well known to Web users, are also a practical tool for users and one choice in solving diagnostic problems in WebDia. The user can choose from over 200 questions, categorized according to heating systems and their process equipment. FAQs not only solve diagnostic problems, but they also give technical information regarding the whole site, its equipment and instrumentation. The user can find many useful answers and hints related to all these areas on the FAQ pages (Fig. 7). Most FAQs incorporate a short, focused text dealing with the problem, in addition to drawings and photos illustrating technical details. Links to closely related subjects are included on the same page.

WebDia is designed together with HVAC companies. Therefore, many of the FAQs are further linked to their Web pages. By choosing the proper link, the user is directed to a manufacturer's Web page, where he/she will find detailed information about product types in his/her own process. More general product information, like drawings, photos, and service and diagnosis information provided by the manufacturers are widely applied in WebDia.

The screenshot shows a web browser window with the WebDia logo in the top left. The page title is 'KAUKOLÄMPÖ'. A navigation menu on the left lists categories like 'Ajankohtaista', 'Yhteystiedot', 'Käyttö ja opastus', 'Yleistietoa (FAQ)', 'Toiminta-animaatio', 'Sanasto', 'Huolto ja kunnossapito', 'Yleiset', 'Laittekohtaiset', 'Vian etsintä', 'Top 25', 'FAQ', and 'Vikapuu'. The main content area is titled '>> Käyttö ja opastus'. It contains a question 'Mikä on säätökäyrä?' and an answer explaining that the heating water temperature is adjusted based on outdoor temperature. Below the text is a graph titled 'säätökäyrä' with 'menoveden lämpötila °C' on the y-axis (ranging from 20 to 90) and 'ulkolämpötila °C' on the x-axis (ranging from 20 to -30). A line graph shows a positive linear relationship. Callout boxes point to 'Main menu', 'Selected heating system', 'Question', 'Answer', and 'Links to related FAQs'.

FIG. 7: WWW FAQ page, which explains the operation of a controller as a function of outdoor temperature. The layout is typical for WebDia. The left side provides the user with the main menu. Selection of a heating system is made using the graphical buttons on the upper part of the page.

### 6.3 Fault tree

The third fault diagnostic technique used in WebDia is a conventional fault tree. The procedure starts from the assumption that the heating process or the domestic hot water process has a failure. In every node of the tree the server gives advice on what to do next until the fault is isolated. When the user follows these instructions, he/she has to make observations from the process, such as reading the instruments or checking if a fuse has blown. The user must also implement the necessary control actions according to the server's instructions; that is, manually shutting or opening a valve or switching a pump on or off, etc.

While exploring the fault tree, an unskilled user also needs clear advice to be able to follow the instructions and to recognize the symptoms of the faulty process operation. Fig. 8 shows how the screen is divided into two frames; the left side presents the fault tree and the right side provides information, instructions, advice, and warnings. Multimedia, like audio (Fig. 5) and video recordings (Fig. 9), etc., simplify the presented information. The fault tree is always visible to the user. So, the user can see the current location and the forward path in the tree. Small icons, each with a special meaning, make the tree illustrative.

**WebDia - Vikapuu - Microsoft Internet Explorer**

Address: <http://www.rte.vtt.fi/webdia/kaukolampo/vika/yleinervikapuu/index.asp>

**Ikonien selitykset**

Valinta Dhje Tarkista Vaara Vika

**Painemittarit**

Node of the tree

Link to the process animation page [Toiminta-animaatio]

Check or read an instrument

A special instruction

End of the branch; Fault has been found

Other branches

Tarkista ovatko painemittarit kunnossa (näyttävätkö mittarit oikein). Tarkistuksen voit tehdä seuraavasti:

- Sulje kaukolämmön meno- tai paluuventtiili
- Avaa mittareiden oma sulkuventtiili
- Meno- ja paluupuolen painemittareiden tulisi nyt osoittaa samaa painetta

**Älä irroita painemittareita.** Warning

Instructions

Jos mittarit näyttävät eri painetta, merkitse mittareiden osoittamien paine ero muistiin.

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FIG. 8: WWW fault tree page. The left side presents one branch of the fault tree. The right side is a separate window that advises the user how to proceed. The illustrated page asks the user to check the condition of the pressure gauge. The short red text is a warning not to loosen or remove the gauge.

**Jatkotoimepiteet**

- Tarkista [pyörimissuunta](#) (video).
- Vaihda 2 vaihdetta keskenään.

Link to the video clip

Procedure to be followed if the direction of rotation is not right

First frame of the video clip

Video: Pumpun pyörimissuunnan määrittäminen

FIG. 9: A detail from the fault tree pages showing how to check the direction of rotation a pump. The instruction is given using a video clip. The procedure is designed for professional service personnel.

## 7. BENEFITS

WebDia has been available to Web users since 1998. The first small-scale version has been later amended to the current prototype. According to the feedback received, WebDia has turned out to be a handy tool for servicing, operating and diagnosing heating systems. Three major uses of WebDia have emerged:

- 1) It has been demonstrated in practice that a residential building owner or an unskilled person can learn how to use and maintain their own heating system, or how to proceed if some problems appear. In the case of technical problems, he or she can first consult WebDia and then call a service person, if necessary. After visiting the Web site, the user probably knows more about the system and can better describe the problem to the service person.
- 2) A professional service person can use WebDia to check how to perform a rarely-applied service procedure. WebDia also offers easy and updated links to the Web pages of HVAC manufacturers.
- 3) WebDia has been found to be valuable for the participating HVAC manufacturers. Their benefits are twofold. In the case of faulty HVAC systems, many users make a direct phone call to the equipment manufacturer. Answering such phone calls usually loads customer service. However, many of the phone calls are not relevant. It may happen that after a long discussion both sides realize that the reason for the fault is not in the manufacturer's equipment. Thus, such discussions may become shorter or even unnecessary if the customer is advised to consult WebDia first. Secondly, the participating companies have an opportunity to promote their HVAC products on WebDia pages. Information, like photos of products manufactured by the companies are commonly applied in WebDia.

## 8. DISCUSSION

Owing to financial and time restrictions in the project, all the requirements set in the beginning of the project could not be fulfilled. For example:

- More multimedia pages should be included. The current Web pages contain several types of multimedia, but they are not extensively applied. However, adding such features also increases the complexity of the system and the amount of work needed in design and implementation.
- The information content should be even more comprehensive. The user should be provided with links to more detailed information on the main subject on each Web page and links showing how the presented information relates to larger entities.
- Deficiencies can also be found in the Web content accessibility and other Web design criteria. For example, users with disabilities were not taken into account in the design.

WebDia is a prototype. If it is developed into a commercial product, certainly these shortcomings must be addressed. Commercialization of WebDia would also raise the question of adding information about other heating systems, like electric heating and heat pumps.

The following points illustrate the difficulty in producing a workable, useful tool:

- 1) Designing, developing and finalizing WebDia was a tedious process. Actually, the work and time required to design and develop a Web application is difficult to estimate with reasonable accuracy, and appropriate tools are just being developed (Mendes et al, 2001). Although the main part of the WebDia system relies on a database solution, the whole system still remains complicated. Links from page to page are a good way to utilize the collected information efficiently, but they also increase the complexity of the system. The multimedia presentations have the same effect because they make Web page design more demanding by increasing programmed scripts and details of the file. So, finishing the system is comparable to testing a computer program. Removing one fault may cause several other faults, but in the long run the number of faults will decrease.
- 2) Connecting to WebDia through a WAP mobile phone or a PDA computer is not a problem, unless the slow data communication speed bothers the user. An ordinary speed for Global System for Mobile Communications (GSM) data is 9600 bps. Some phone models achieve 30 - 50 kbps, but they use General Packet Radio Service (GPRS) techniques. This also concerns PDAs equipped

with a wireless link. But, speed should not be a problem when Universal Mobile Telecommunication System (UMTS) technology and high-speed wireless links become available. A comparison of the user agents gives the feeling that a WAP browser is a bit insufficient for a great part of the information. In this respect, a PDA is a more suitable user agent, but it may set additional requirements on the layout of the Web pages. However, both solutions are still necessary because some customers carry only a mobile phone.

- 3) Collecting the information content posed two problems. First, the technical terminology of the WebDia pages is not yet consistent, and secondly, the instructions provided contain details not agreed on by all experts. Both are due to the varying backgrounds and experiences of the interviewed experts, most of them being representatives of the participating companies. The inconsistency of the terminology can be solved, but the second problem is not so easy. Fortunately, the advice given for service, operation and fault diagnostics was carefully selected. Procedures and repairs not permissible for a consumer are clearly pointed out and he/she is advised to contact a professional service person.
- 4) Development in multimedia techniques, authoring tools and technical solutions for presenting dynamic Web pages has been rapid during the last few years. During that time Web-based applications have grown from simple information dissemination to online transaction systems. Evidently, rapidly changing technology and tools make Web designing and engineering a demanding task. This especially concerns Web applications designed for long-term use. Chosen tools and techniques should have technical support and updated versions available several years afterwards. This is not always true in practice.

## 9. CONCLUSIONS

Building a Web-based information system like WebDia requires considerable knowledge and expertise from several disciplines. Designing the site, collecting salient information, developing the contents and finishing the site is a slow, tedious process, even when using modern Web authoring and multimedia tools and the best Web engineering practices.

WebDia is a prototype that demonstrates the potential capabilities of a Web-based multimedia system for diagnosing, servicing and operating heating systems. However, feedback from users has been positive and shows that Web-based techniques enable the creation of practical, comprehensive and helpful services. Due to the limited project resources, the number of multimedia pages had to be restricted, but WebDia still contains valuable information and knowledge on heating systems that cannot be found in any other source book or paper. Already now, ordinary customers, such as residential building owners, facility managers and even professional service personnel benefit from the Web pages in diagnosing, servicing and operating their heating systems.

In addition to serving the PC world, WebDia is accessible from WAP mobile phones and PDAs. A WAP browser seems to be a slightly insufficient user agent for presenting the contents, but it probably satisfies customers who carry only a mobile phone. A PDA browser is a handy tool even for multimedia type information, but it sets additional requirements on the page layout. In the near future when high-speed wireless links become commonplace, systems like WebDia may prove to be a necessity in the every day life of ordinary customers.

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