# A Pen Scanner Based System for an Easy Access to Relevant WWW Hyperlinks

Caj Södergård [1], Helene Juhola[2], Christer Bäckström [1], Ilkka Vainikainen [2]

Key words: Hybrid media, integrated media, pen scanner, WWW hyperlinks, OCR, computer-aided teaching

## Abstract

Practical means are needed to integrate printed products with electronic media in the school environment. A new type of hybrid media system has been constructed for this purpose. The patented system uses a pen scanner to access WWW hyperlinks on the Internet. Thus, the system forms a convenient bridge between printed and net media. The link anchors in the printed presentation are specially marked. The marked words are scanned with a pen scanner attached to a PC. By applying powerful text recognition and string matching, the predetermined hyperlinks are automatically chosen from a list of possible candidates and shown by the WWW browser. In addition to these editorial links, the system also applies WWW search engines for retrieving documents containing the link anchor text. The retrieved documents are put in their order of relevance. Voice synthesis of the anchor text and page titles can be used as user feedback. The system has been tested by teachers in 5 comprehensive schools in the Helsinki region as a tool for preparing their lessons. These user tests show that the pen scanner based system was clearly easier to use than traditional keyboard entering of URLs and search words.

## 1. Background

Integrated communication and digital printing are current research topics at VTT Information Technology. The three-year project on digital printing as a part of

[1] VTT Information Technology, Multimedia, P.O. Box 1203, FIN-02044 VTT, Finland. E-mail: Caj.Sodergard@vtt.fi

[2] VTT Information Technology, Printed Communications, P.O. Box 1204, FIN-02044 VTT, Finland. E-mail: Helene.Juhola@vtt.fi

the business chains is one of the projects in this area, covering the following four main areas of technical interest

- cost/benefit analysis of book/textbook production and customer-driven commercial production

- Internet-based management and control of networked business chains

- methods to automate and integrate digital printing and postpress processes

- development of hybrid media systems

This paper focuses on the last mentioned area, yet derives fundamental knowledge from the market and technology surveys and calculations made in the first mentioned area.

## Development of information society

The Finnish government has set goals to the development of information society. According to these goals, Finland is striving to reach the world top in the management of information technology and data networks. Society should be able to function in a networked way and the services of the information society should be available to all citizens in the same way as electricity. Certain network and telecommunication parameters are already top class

*Table 1. Internet connections per 1,000 inhabitants in January 1997 (Anon,97).*

| Position | Country | Number | Number/1,000 inhabitants | RIPE's figure |
|---|---|---|---|---|
| 1 | Finland | 283,526 | 56 | 65 |
| 2 | Iceland | 11,667 | 45 | 46 |
| 3 | Norway | 171,686 | 40 | 42 |
| 4 | Norfolk Island | 73 | 36 | |
| 5 | USA | 7,491,421 | 30 | |
| 6 | Australia | 514,760 | 30 | |
| 7 | Sweden | 232,955 | 27 | 28 |
| 8 | New Zealand | 84,532 | 25 | |
| 9 | Canada | 603,325 | 22 | |
| 10 | Denmark | 106,476 | 21 | 21 |
| ... | | | | |
| 14 | Austria | 99,284 | 12 | 13 |
| .. | | | | |
| 16 | Great Britain | 591,624 | 10 | 13 |
| ... | | | | |
| 18 | Germany | 721,847 | 9 | 9 |
| . | | | | |
| 28 | Estonia | 9,148 | 6 | 6 |
| . | | | | |
| 30 | France | 245,501 | 4 | 4 |
| | World total | 16,146,360 | 3 | |

The number of Internet connections (Table 1) and mobile phones in relation to the number of inhabitants is in Finland the highest in the world.

The foundation for the efficient use of the services of the information society is laid in school. The objectives and the content of the education are based on constructive learning and life-long learning principles. This means that children have to learn to learn and to be active seekers of information. Children in the comprehensive school must be able to retrieve information independently and learn to use different media. This can only be achieved by increasing the use of information technology as a working tool for all subjects. The result is that a considerable amount of money is spent annually to increase the use of information technology in schools, to help the schools to purchase new equipment, to build data networks and to train teachers. Similar ideas and requirements have also been brought forward, for example, in the USA.

## Textbooks and new challenges

Textbooks are still essential educational tools. But the rapid development of information technology and the increased utilisation of data networks make new demands on the production of textbooks. It is difficult to estimate the rate of change in the educational sector, but it is quite evident that the publishers must find new ways to produce educational material. Some new opportunities are

- an information database allowing the teacher to select the required parts;

- a textbook and a complementing electronic part that contains e.g. updated information;

- a completely electronic textbook on-line or off-line.

## Textbook production and digital printing

Digital printing allows to produce textbooks on demand and to tailor books and exercise books. Figure 1 shows the alternatives that the publisher has to deliver textbooks or the information of textbooks to schools. There are three main alternatives: conventional textbooks, complete textbooks printed in small quantities on demand, integrated, i.e. hybrid media products, or on-line in the digital form.

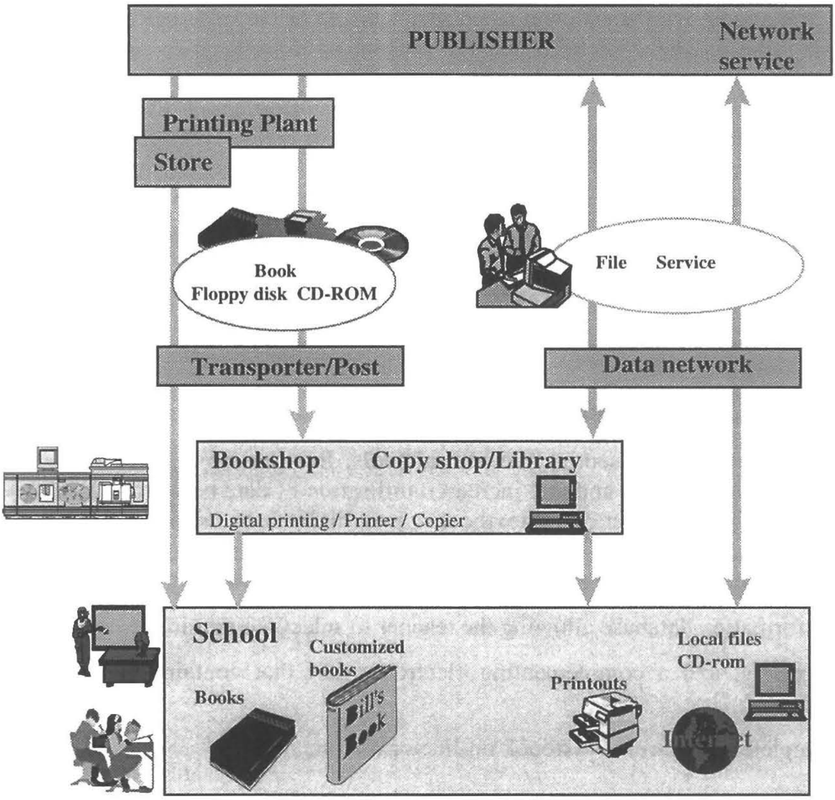


*Figure 1. Different logistic chains for textbooks*

We made calculations assuming that the textbook or some parts of it will be printed in some part of the chains. These calculations showed that the production of complete textbooks in small quantities (on demand), using digital printing, is today cost-effective only if cost savings are made in the other parts of the logistic chain (storing, selling, transport). Another opportunity is to customize books, especially if the same information can be used in several versions and for different purposes.

## Integrating traditional printed textbooks and electronic media

The cost calculations clearly showed that traditional textbooks produced in large quantities still have a strong competitive edge in cost efficiency. To be able to take full advantage of both traditional books and electronic media we have to find new ways to integrate them. The existing solution is to print the basic information in a textbook and give updates, relevant WWW links or other material on-line by the data network. This approach requires independent editing resources, which means extra costs. And in practice, the updates cannot be supplied in real time.

The question arises how to get updated information, relevant to a certain textbook and available in the Internet every day, into schools easily and in a controlled way without heavy arrangements at the publisher end. We began to explore this in 1995. Later on a study made in Great Britain showed that half of the interviewed teachers refused to use the Internet in the preparation of their lessons, because it is too complicated and takes too much time to filter the relevant information from the great number of references. This proves that methods must be developed to make the use of the Internet easier for teachers.

These were the basic facts that led to the development of the hybrid media system reported below.

# 2. Motivation for hybrid media

Hypertext and hypermedia are becoming more and more popular in electronic documents. These methods enable the reader to conveniently access information linked to the *link anchors* in the text. Especially the distributed hypermedia used in the World Wide Web are growing rapidly. WWW gives access to a practically infinite information base that could tapped, e.g. when preparing lessons. Teachers need above all *hybrid* solutions, where the printed course material is the basis, while further clarifications and illustrative cases are retrieved from the Internet. The retrieval must be straightforward and give relevant information - not hundreds of irrelevant references that many search engines produce today. Therefore should the publisher and the authors supply predetermined, i.e. editorial, WWW links together with the course material.

The existing printed communication cannot use hypertext, even if printed references, indexes and WWW addresses fulfill the same function in a more limited form. But to retrieve WWW pages on the basis of printed URLs demands careful entering of text strings, which is laborious especially for beginners, and if there are several addresses. Long http adresses occupy space and make the typography of the printed page more complicated. The pen scanner system described below aims at overcoming these problems.

A starting point for the work was the WWW-service set up in winter 1996 by the Finnish publisher Otava as a part of their Horisontti course material in social studies for upper level schools. This service contains a link list to interesting WWW sites like United Nations and European Union.

# 3. System description

Our system (Figure 2), called LINKER, uses a pen scanner to enter the printed anchor words linked to the URL addresses (see patent application Södergård, 1997). Pen scanners are used frequently to read bar codes. Some of these systems also use wireless transmission of data (Tremmel, 1983), (Kucken, 1996). Other bar code readers use a local display and a keyboard (Wakatsuki, 1990). In spite of their reliability, bar codes are not suited for our purposes, because their content is not intelligible to the human eye and because they do not fit into printed layouts. The first pen scanners employing Optical Character Recognition (OCR) of the scanned text images have recently appeared on the market (IRISPen, 1995). However, these data pens are used for entering alphanumeric strings into word processing programs - not for navigating on the Internet like in LINKER.

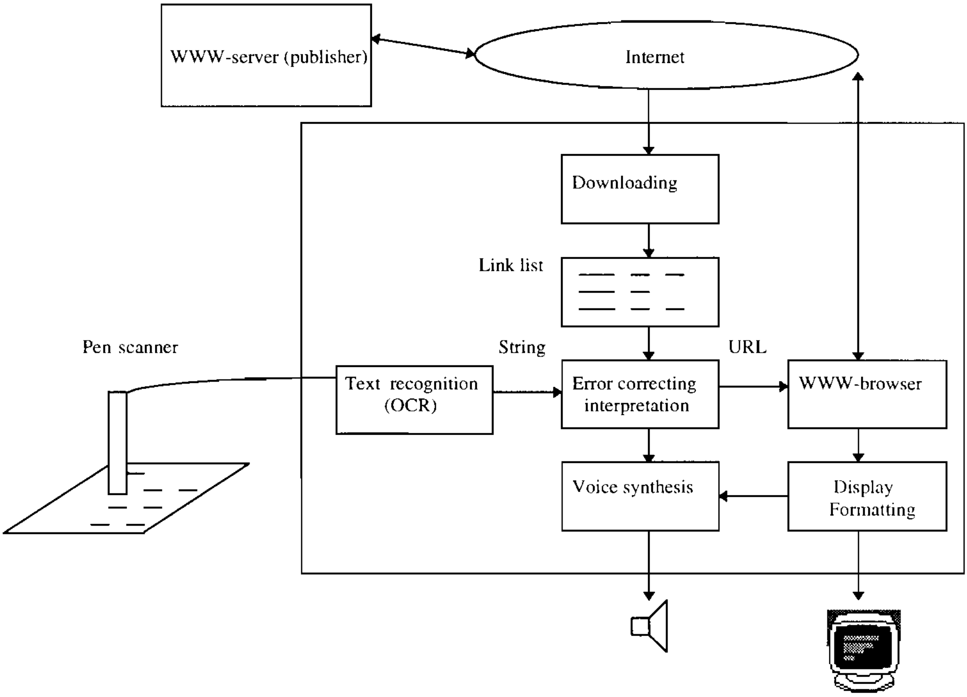


*Figure 2. The different parts of LINKER.*

The pen scanner is used to scan scanning link anchors that are marked in red in the text book. The scanned text is processed with an OCR software. Since the recognition is far from perfect (see below), the OCR result is processed further in an interpretation module . This error correcting interpretation module selects the correct link anchor from the link list that is stored locally on the hard disk. The link list is downloaded from the publisher´s WWW server. After selecting the link anchor, the corresponding URL adresses are determined from the link list and the WWW pages are retrieved with an Internet browser and displayed on the monitor. In addition to these "editorial" links, the link anchor and the words that are around it, - i.e. focusing terms - on the textbook are fed to a search engine, like e.g. Alta Vista, to retrieve a list of WWW documents, that contains the words. AltaVista arranges the references into their order of relevance by using the focusing terms. The retrieved editorial WWW pages and the search engine reference list are positioned as tiled windows on the monitor using a formatting program (see figure 3). The system provides audio feedback of the interpreted anchor word as well as of the titles of the retrieved WWW documents with a voice synthesis program.

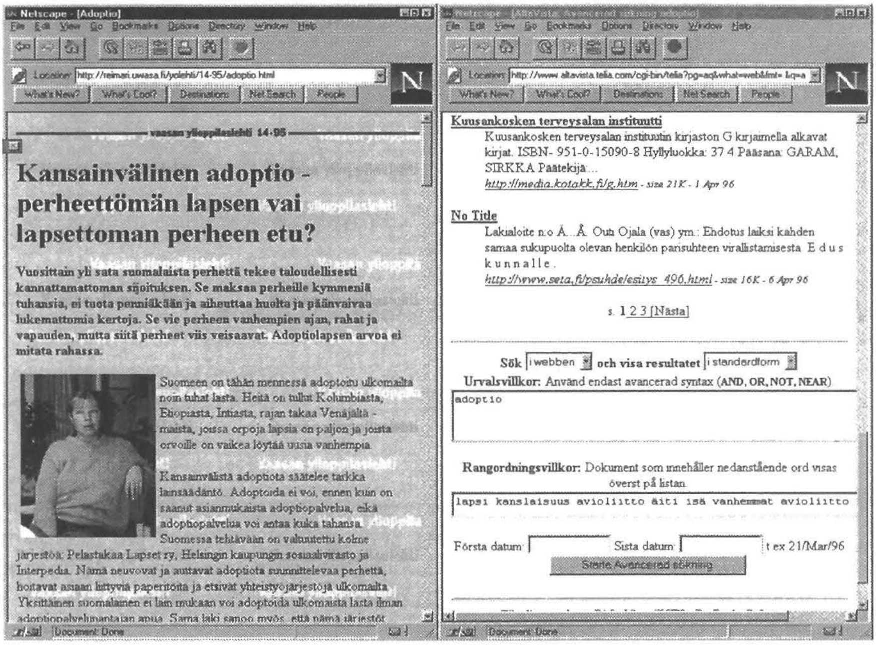


*Figure 3. LINKER presents this display after the word "adoption" has been scanned with the pen. The editorial predetermined link is at left, whereas the automatic search result from Alta Vista is at right. The anchor word and one specifying word (lapsi=child) from the text book context are fed into Alta Vista.*

The testing setup of LINKER in the schools is depicted in Figure 4.

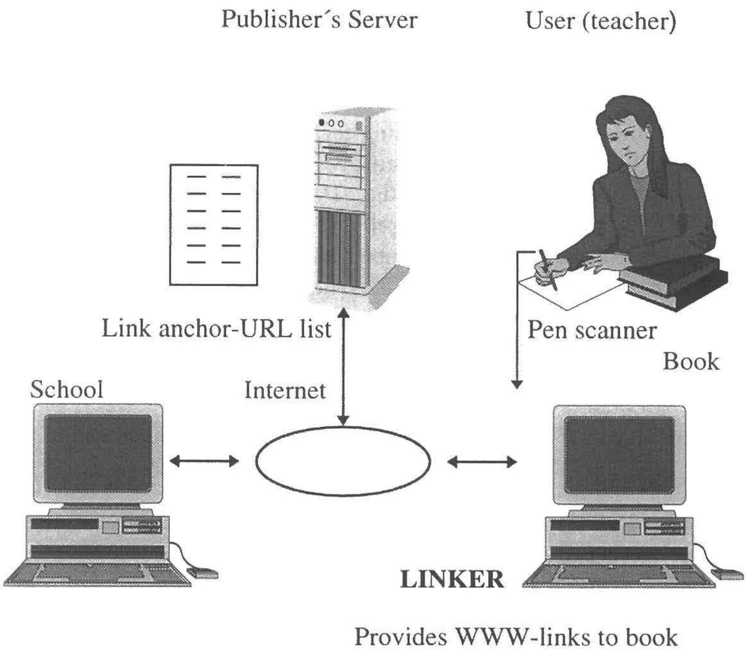


*Figure 4. The system used in schools for testing the LINKER.*

# 4. An overview of OCR

Optical Character Recognition and Document Understanding (DU) systems are now commonly available on the market and on fairly inexpensive platforms. These systems are used routinely for scanning and converting paper documents into the electronic format. Vendors routinely quote for them a character recognition accuracy of close to 100 %.

Experience has shown that such an accuracy is achievable only with clean, first-generation documents in standard formats and type styles. In a more realistic situation, with documents which are degraded to some extent, the performance drops very rapidly.

Character recognition typically proceeds by segmenting lines of text or words into individual characters that are then recognized by their shape. The common point of failure in many of these techniques is precisely this segmentation into individual characters. If characters break apart into multiple pieces because of poor image quality, or if multiple characters merge because of blurred or dark backgrounds between the characters, they cannot be recognized correctly. Thus the performance of traditional OCR approaches is highly dependent on the amount of degradation in the scanned image. Character segmentation is error-prone especially with degraded images.

Using a pen scanner, a non-uniform movement will accentuate the degradation. Below is a typical scanned character line. The original is laser-printed (600 dpi) on office paper.

*Figure 5a. The intermediate result of scanning the string 'A null terminated string of characters, unquoted.' with a commercial pen scanner.*

Furthermore the text recognition task is made harder by the high variability of character features, such as their dimension, thickness, font, background and position.

To overcome the problems with traditional OCR feature a step based recognition (Selander 1994) is applied to overcome. This approach is forward, but it is not enough. There are also expert systems for an automatic correction of errors (Pavlidis 1994) made by optical character recognition devices. This correction is based on an English dictionary.

The text image in Figure 5a is interpreted by a typical commercial feature extraction based software. The result is in Figure 5b. It is easy to predict that this interpretation does not qualify as a URL or search term for searching on the web.

i null te~llate~ ~[jml Dlt~aiacteIS, unqUDted.

*Figure 5b. The accuracy of the OCR recognition of 5a is below 50 %.*

The recognition process is sequential. It includes image acquisition, text and non-text separation, text segmentation into lines and characters, OCR, contextual analysis, and text reconstruction in the electronic format. The chain is as strong as its weakest link. An early error may compromise the whole recognition process.

An error correction module is applied in this work to recognize an erroneous word. This consists of minimizing a suitable distance measure between the input line and the words in a dictionary. The scanned text string is classified as the nearest link anchor in the dictionary, or rejected if the minimum distance measure is above a predetermined threshold.

## 5. Error correction

The scanned word (character string) constitutes a link anchor that points to one or several URLs, on the basis of which the WWW pages are retrieved. The link anchor is also used as selection criteria for web search engines. The search can be narrowed by using the text context to supply the ranking criteria. The nouns in the context also rank the search results of the search engines in their order of relevance.

OCR software is sensitive to the typography of the printed text. The scanner sweep may start too early, which causes part of the preceding word to be included in the scanned image. The scanner sweep may start too late, or finish too late or too early. Also the ergonomic design of pen scanners systematically produces unwanted results. The image in Figure 6a. represents a normal result with a high-grade offset-printed first-generation material.

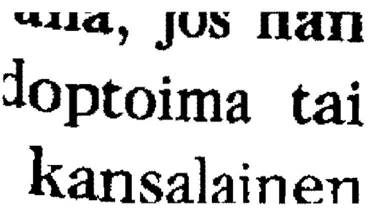


*Figure 6a. The word 'adoptoima' is scanned in its context. The text is from a Horisontti textbook used in comprehensive schools.*

The scanner software interprets the centre line in Figure 5a as a meaningless character string depicted in Figure 6b.

l0ptoima tal

*Figure 6b. The recognition accuracy is here close to 66%. In order to find the URL, the accuracy has to be 100%.*

In this example we wanted to grab the word 'adoptoima' (adopted) from the text, but after applying our *error correction* we get the association 'adoptio -- URL'. The link anchor in the URL list is in this case 'adoptio', the nominal form of adoptoima, which is sufficiently near to the garbled character string acquired from the scanner according to the distance measure in Appendix A2. The decision criteria have to be robust in contradictory situations. The *error correction* has to yield the correct result equally well under the following circumstances:

i) the scanned string consists of only a part of the link anchor

ii) the scanned string consists of the link anchor and of one or two other words or parts of them

iii) one or several letters of the link anchor are garbled

iv) any combination of the above

This has been achieved with our *error correction* method described in Appendices A and B.

# 6. Testing the LINKER in schools

Five comprehensive schools in the Helsinki area were selected to test the LINKER system. The selected users were teachers who all had used a PC (see Appendix C1). About half of the teachers had used the Internet before, on the average 1-3 hours a week. In one school also the students were able to use the LINKER. The PCs used in the testing were state-of-the art machines (Appendix C2).

The first installation was made at the end of November 1996 and by the beginning of January 1997 all installations were completed. Most of the bugs were fixed and the environments configured in December. The test ended at the beginning of April 1997.

Social studies were selected as the subject, because the teacher of this subject needs plenty of background material. The teaching material consisted of a study book and special material for teachers to prepare their lessons. The 411 words in the index of the study book were selected as link anchors and these words were underlined red in the text. Otherwise the books were the same as usual.

When the LINKER was installed in the school, the user was given basic training and written instructions for use. The LINKER was updated several times during the testing period and the new features were shown to the users.

Log files were used to collect objective information. They showed how often the LINKER was used, which link anchors were selected and how long the sessions took. Log files were collected several times during the testing period. Also questionnaires were filled in by the users C.

Table 2 shows, that LINKER was used on the average 2,3 times per week 25 minutes a time. The user´s own estimates come fairly close to these objective log numbers. Most of the time the LINKER was used 10 to 15 minutes between classes. A few long sessions of over 40 minutes increased the average.

*Table 2. The use of the LINKER in schools.*

| | User 1 | User 2 | User 3 | User 4 | User 5 | average |
|---|---|---|---|---|---|---|
| Number of sessions/week (user´s estimate) | 2 | 5 | several | 3 | 2 | 3 |
| Number of sessions/week (log) | 1,4 | 4 | 2,1 | 2 | 2 | 2,3 |
| length of the session (user´s estimate) | 43 | 24 | - | 15 | 15 | 24 |
| length of the session (log) | 34 | 18 | 20 | 26 | 26 | 25 |

The teachers scanned on the average 2,5 link anchors per session and followed 2,8 references on the Alta Vista result list (Appendix table C3). This indicates, that special information was searched for and that there was no need for web surfing.

The teachers used Internet without the LINKER approximately once a week and the estimated average duration was 30 minutes per session (see the appended table C4). In other words, they used the LINKER pen scanner three times more often than the keyboard to access WWW pages.

The teachers printed on paper in about half of the sessions as can be seen in the appended table C5. The short breaks between the classes do not allow time to read or take notes of the information on the WWW pages so the printouts are needed.

Teachers like to use the LINKER to prepare lessons. They also find it useful for the pupils in the school, but not so much at the pupil´s home (see the appended table C6).

Commercial pen scanners cost over USD 250 and hand-held bar scanners over USD 300. Teachers are not willing to pay more than USD 220 and would prefer a price under USD 170 for a pen scanner and LINKER software. For pupil use the price should be even lower, below USD 120 (see the appended table C7).

The biggest advantages to the users were the easy access to the Internet and the possibility to check information (see the Appendix table C7). The users also thought that they saved time, whereas the system only moderately created new ideas. The biggest drawback was missing or irrelevant links. Some WWW addresses changed during the testing and this caused problems, because some users thought that the LINKER was not running properly. In general, the users complained that the LINKER did not work properly all the time. At the beginning of the test there were some problems with reliability, but things were soon put right. Most of the Internet connections were modem connections and sometimes quite slow. If the PC and modem connections were slow and the users did not have the patience to wait, they judged the LINKER not to work properly. With a fast PC and the LAN there were no problems with the speed.

A main result was that the teachers found it much easier to use the LINKER to access WWW pages than to enter the URLs and search words in the traditional way by the keyboard (Table 3).

*Table 3. Easy of access to WWW pages on the scale of -5...0...+5 (-5 = keyboard much easier, 0 = equal, +5 = LINKER much easier)*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| LINKER vs. keyboard entering | +2,3 | +4 | +5 | +4 | +2 | +3,5 |

The following comments on the LINKER were collected from the questionnaires.

Positive:

- a good tool for individualized teaching
- helps to use and explore the Internet and the home pages
- the pages on community and government institutions are useful in social studies
- it is a good arrangement to have the editorial and Alta Vista links side by side on the screen
- an easy way to perform AltaVista searches
- when reliable, it may be used by pupils either in class or in the library

Negative:

- too many missing or irrelevant links

- the LINKER should be at the teacher´s home; not enough time between classes
- in the beginning the reliability of the LINKER and the pen scanner was poor, but it improved towards the end; rebooting system helped

# 7. Conclusion

The pen scanner based LINKER constructed and patented in this work was in the school tests found to be well suited for teachers preparing lessons in social studies. It increased the Internet usage threefold compared to traditional keyboard use. The teachers also found the LINKER to be significantly easier to use for accessing WWW than the keyboard. Similar benefits are achievable in many other hybrid media applications, where you need easy access to WWW pages that are linked to a printed presentation.

However, the system still need development before qualifying as a marketable product. Especially the price of the pen scanner has to be dropped to be attractive in schools. A problem is the significant amount of work that goes into the preparation of a relevant link list. This work can be lessened if the automatic search robots can be put to come up with more relevant search results by introducing language understanding software. However, a total automatic search does not seem to be possible. Some applications would benefit from a wireless pen.

# Acknowledgments

The authors want to thank Jukka Vahtola and Ilkka Nousiainen of Otava and the teachers Mervi Maijala, Markku Liuskari, Harri Rinta-aho, Risto Seppälä and Markku Vasander for fruitful cooperation.

# References

Anon.

1997 Central Statistical Office of Finland.1997.

Fischer M. J., and Wagner A.

1974 "The string-to-string correction problem", J. ACM 21 (1974), pp.168-173.

IRISPen

1995 Pen-sized scanner with text recognition for PC. Product guide. Image Recognition Integrated Systems. 1995.

Kucken, J.A.,
1996 U. S Patent 5,581,707. System for wireless collection of data from a plurality of remote data collection units such as portable bar code readers (December 3, 1996).

Pavlidis, T., Vincent, L.M.; (Eds).
1994, "Document Recognition.: Expert system for automatically correcting OCR output." Proc. SPIE Vol. 2181, pp. 270-278.

Pavlidis T. and Wang B. P.
1990 "Optimal correspondence of string subsequences", IEEE Trans. Pattern Anal. Mach. Intell. 12 (1990), pp. 1080-1087.

Sankoff., D. and Kruskal, J. R.
1983 "Time Warps, String Edits, and Macromolecules: The Theory and Practice of Sequence Comparison" (Addison Wesley, Reading, MA, 1983).

Selander J. M.; (Ed.)
1994 "Word recognition in a segmentation-free approach to OCR". 22nd AIPR Workshop: Interdisciplinary Computer Vision: Applications and Changing Needs. Proc. SPIE Vol. 2103, pp. 135-141.

Södergård, C., Bäckström, C.,
1997 Finnish patent application FI 970585. Mentelmä ja järjestelmä sähköisessä muodossa olevan tiedon liittämiseksi painettuun tietoon (In Finnish) (Filed February 11, 1997).

Tremmel, H., et al.
1983 U.S. Patent 4,418,277. Apparatus for collecting, transmitting and processing data stored in code, preferably in bar code (November 29,1983).

Wakatsuki, Y, et. al.,
1990 U.S. Patent 5,023,438. Portable data input apparatus with different display modes (June 11,1991).

# Appendix A. Error correction of pen scanner input

Whether the scanned input string is sufficiently near a link anchor in the URL list is determined by thresholding the distance measure (A1) between the link anchor (input) and the reference (link anchor in the URL list). The calculation of the string distance is in Appendix B.

The link anchor with the maximum acceptance value above the threshold is selected as a match for the input string.

$$\text{Ratio}_{\text{acceptance}} >= \text{Threshold} \quad \text{(A1)}$$

The acceptance ratio is defined as below, where $k_1$ and $k_2$ are constants.

$$\text{Ratio}_{\text{acceptance}} = k_1 * \text{Ratio}_{\text{input}} * \text{Ratio}_{\text{reference}} + k_2 * \text{Ratio}_{\text{distance}} \quad \text{(A2)}$$

where

$\text{Ratio}_{\text{input}}$ is the ratio of the spatially weighted sum of the input pattern substrings to the the character sum of the input pattern

$$\text{Ratio}_{\text{input}} = \text{weighted\_char\_sum} / \text{input\_pattern\_sum} \quad \text{(A3)}$$

$\text{Ratio}_{\text{reference}}$ is the ratio of the spatially weighted sum of the input pattern substrings to the character sum of the reference pattern

$$\text{Ratio}_{\text{reference}} = \text{weighted\_char\_sum} / \text{reference\_pattern\_sum} \quad \text{(A4)}$$

$\text{Ratio}_{\text{distance}}$ is the ratio of the character sum of the input pattern substrings to the string distance between the input and the reference patterns plus the substring character sum of the input pattern substring length. This ratio normalizes the string distance.

$$\text{Ratio}_{\text{distance}} = \text{input\_pattern\_substring\_sum} / (\text{string\_distance} / (\text{const} + \text{input\_pattern\_substring\_sum})) \quad \text{(A5)}$$

# Appendix B. Calculation of the string distance

The string distance between two strings is formed according to the following definitions. The distance between the two strings x and y is defined as the cost of the editing operations to transform x into y. With three different basic needed operations, it is possible to transform any string into another. The editing operations, i.e. substitution, insertion and deletion, are applied in the single characters of the string. Let $s = e_1 , e_2, .. e_k$ be a sequence of editing to transform string x into string y. The cost is then defined as

$$c(s) = \sum_{i=1}^{k} c(e_i) \qquad \text{(B1)}$$

The distance between the two strings x and y is defined as

$$d(x, y) = \min \{ c(s) \mid s \text{ is a sequence of editing to transform } x \text{ into } y \} \qquad \text{(B2)}$$

According to this definition (B2), the distance between x and y is the cost of the minimum cost sequence of editing to transform x into y (Fischer 1974, Sankoff 1983, Pavlidis 1990). As an example Figure B1 the computation of two hypothetical strings x and y. Let x = aba and y = aabc and the costs c(a->b) = c(e->a) =c(e->c)=1, c(a->b) =0. The optimum editing paths is shown in Figure B1. The optimum cost of the string transformation aba-> aabc is (0+1+0+1) = 2. In Figure B1. the cost of an inserting operation is from the left to the right, the cost of a deleting operation from direction of top to the bottom and the cost of a substituting operation diagonally down.

The probability of an error in observing of different letters in OCR-based recognition, provides a very convenient method for assigning costs to the editing operations. This, of course, increases the value of the acceptance measure (A5), which in turn increases the overall reliability of the recognition process (A1).

| x/y | | a | a | b | c |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| a | 1 | substitution cost: 0 acc. cost: 0 | insertion cost: 1 acc. cost: 1 | | |
| b | 2 | | | substitution cost: 0 acc. cost: 1 | |
| a | 3 | | | | substitution cost: 1 acc. cost: 2 |

Figure B1. The minimum cost of transforming string aba -> aabc.

# Appendix C. Test Results

*Table C1. User information*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| Teacher/student | teacher | teacher | teacher /pupil | teacher | teacher | |
| used a PC before | yes | yes | yes | yes | yes | |
| hours/week | 5-8 | 1-3 | 4 | 10 | 2-4 | 4,4-5,8 |
| Used WWW before | yes | no | yes | no | yes | |
| hours/week | 1-2 | - | 2-3 | - | - | 1,5-2,5 |

*Table C2. The PCs used in the schools by the teachers. Teachers 4 and 5 used the same PC*

| | Processor | RAM | Hard drive | Internet |
|---|---|---|---|---|
| User 1 | 66/486 | 20 MB | 250 MB | modem |
| User 2 | 133Pentim | 16 MB | 1,2 GB | LAN |
| User 3 | 100/486 | 16 MB | 2 GB | modem |
| User 4 | 90 Pentium | 16 MB | 2 GB | modem |
| User 5 | 90 Pentium | 16 MB | 2 GB | modem |

*Table C3. LINKER use during the test according the users´ estimate*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| LINKER used/week | 2 | 5 | severa l | 3 | 2 | 3 |
| minutes/session | 43 | 24 | - | 15 | 15 | 24 |
| scanned anchors/session | 3,6 | 1,5 | - | 4 | 0-1 | 2,5 |
| AltaVista links/session | 3 | 6 | 3 | 2 | 0 | 2,8 |

*Table C4. Internet use without the LINKER during the testing period (user´s estimate)*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| sessions/week | 1 | 1 | 2 | 1 | 0 | 1 |
| minutes/session | 40 | 20 | 45 | 15 | - | 30 |

*Table C5. Number of paper copies printed per week and copies per session (user´s estimate)*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| times/week | 2,5 | 1,75 | - | 1 | 0 | 1,3 |
| sheets/session | 1-10 | 2,25 | - | 3 | 0 | 1,7 -3,8 |

*Table C6. Applicability of the LINKER according to the teachers, on the scale of 0...5 (0 = not suitable, 5 = very suitable)*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| **Applicability** | | | | | | |
| teacher preparing lesson | 3,7 | 4,25 | - | 5 | 3,5 | 4,1 |
| pupils using at school | 3 | 4,25 | 4 | 3 | 5 | 3,9 |
| pupils using at home | 1 | 3,75 | - | 3 | 0 | 1,9 |

*Table C7. Estimated prices limits of the LINKER in different use in schools (US dollars)*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| teacher preparing lectures | 75 - 110 | 110-220 | - | 220 | 220 | 156-192 |
| pupils using LINKER in schools | 45 | 110-220 | - | 110 | 110 | 94-121 |

*Table C8. Advantages and disadvantages, on the scale of 0...5*

| | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|
| **Advantages** | | | | | | |
| easy access to the Internet | 3,3 | 5 | 4 | 5 | 3 | 4 |
| check information | 4 | 3,7 | 4 | 4 | 4 | 3,9 |
| saves time | 3 | 4,7 | 4 | 5 | 2 | 3,7 |
| new ideas | 2,7 | 3,7 | 3 | 3 | 0 | 2,5 |
| **Disadvantages** | | | | | | |
| bad or missing link anchors | 3,7 | 2,3 | -* | 3 | 3 | 3 |
| did not work properly | 2,7 | 2 | 5* | 2 | 3 | 2,9 |
| worked slowly | 2,7 | 0,7 | 5* | 2 | 2 | 2,5 |
| difficult to use | 1,3 | 0,5 | 5* | 2 | 0 | 1,8 |

** There were big network problems in the 3rd user's school during the testing. The modem line was difficult to use and it caused frustration. Problems were related to the network upgrade in the school and the new user profiles.*