Authors: G. Ghinea[1] D. Gill[1] A. Frank[2] and L.H. de Souza[3]

[1]Department of Information Systems and Computing, Brunel University, Uxbridge, Middlesex

[2]Department of Rehabilitation Medicine and Rheumatology, Northwick Park Hospital, Middlesex

[3]Department of Health and Social Care, Brunel University, Osterley, Middlesex

USING GEOGRAPHICAL INFORMATION SYSTEMS FOR MANAGEMENT OF BACKPAIN DATA

Abstract

In the medical world, statistical visualisation has largely been confined to the realm of relatively simple geographical applications, such as locating of patients' beds in a hospital, or the monitoring of the spread of a disease. This remains the case even though hospitals have been collecting spatial data relating to patients. In particular, hospitals have a wealth of backpain information which includes, besides questionnaire data, *pain drawings*, usually detailing the spatial distribution and type of pain suffered by backpain patients. In this paper, we propose several technological solutions which permit data within backpain datasets to be digitally linked to the pain drawings in order to provide methods of computer-based data management and analysis. In particular, we propose the use of Geographical Information Systems (GIS), up till now a tool used mainly in geographic and cartographic domains, to provide novel and powerful ways of visualising and managing backpain data. A comparative evaluation of the proposed solutions shows that, although adding complexity and cost, the GIS-based one is the most appropriate for visualisation and analysis of backpain datasets.

INTRODUCTION

According to a Department of Health survey, in Britain backpain affects 40% of the adult population, 5% of which have to take time off to recover (Boucher, 1999). This causes a large strain on the health system, with some 40% of backpain sufferers consulting a GP for help and 10% seeking alternative medicine therapy (Boucher, 1999). Due to the large number of people affected, backpain alone cost industry £9090 million in 1997/8 (Frank and De Souza, 2000), with between 90 and 100 million days of sickness and invalidity benefit paid out per year for backpain complaints (Frank and De Souza, 2000; Main, 1983; Papageorgiou *et al.*, 1995). Backpain is not confined to the UK alone, but is a worldwide problem: in the US, for instance, 19% of all workers' compensation claims are made with regard to backpain. Although this is a lot less than the percentage of people affected by backpain in the UK, it should be noted that not all workers are covered by insurance and not all workers will make a claim for backpain (Jefferson and McGrath, 1996). Moreover, backpain does not affect solely the adult population: studies across Europe (Balague, Troussier and Salminen, 1999) show that back pain is very common in children, with around 50% experiencing back pain at some time. Any improvement in the way that patients with backpain can be analysed (and subsequently treated) should therefore be viewed as one potentially capable of significantly saving both benefit expenditure and lost man-hours.

The problem with backpain is that "*there exist no standardised clinical tests or investigations by which all people with low backpain can be evaluated*" (Papageorgiou *et al.*, 1995). Nor will there ever be, as different people have different pain thresholds and will be affected differently. It is also difficult for medical personnel to know what has caused the backpain, as there are potentially many different causes behind it (Frank and De Souza, 2000; Matsen, 2001).

Not only is evaluation difficult, but, unfortunately, like most types of pain, backpain is also difficult to analyse, as the only information that can be used is suggestive descriptions from the patient. Usually, the backpain that a patient is suffering from can be categorised in one of three groups: chronic, sub-acute and acute. Chronic backpain is described as pain that lasts for longer than three months and affects between 10% and 15% of the population (Matsen, 2001). The majority of people affected by this type of backpain fall into the over-65 age group, where 28% of this age group suffer from this type of pain (Boucher, 1999). Sub-acute pain lasts between seven days and seven weeks and is normally mild. Acute backpain, however, lasts a short time, is usually characterised by severe pain and affects some 80% of backpain sufferers (Matsen, 2001).

Backpain Questionnaires

The main medical work that is undertaken to resolve backpain tends to be with patients that have chronic backpain. However, these patients may have developed psychological and emotional problems, due to having to deal with the pain. Because of these problems, patients can have difficulty describing their pain, which can lead to problems during the treatment. In some patients, the psychological problems may have aided the cause of the backpain, by adding stress to the body, or the stress of the backpain may have caused psychological problems (Von Baeyer *et al.*, 1983; Ginzburg, Merskey and Lau, 1988; Hildebrandt *et al.*, 1988; Man III *et al.*, 1992; Main, 1983; Parker, Wood and Main, 1995; Ransford, Cairns and Mooney, 1976; Uden, Astrom and Bergenudd, 1988). It is because of this factor that patients suffering from backpain are usually asked to fill out questionnaires of different types in order to help the medical staff, not only to know where the pain is located, but also to identify the patient's mental state before treatment begins. The main questionnaires used for this purpose are:

- The Modified Somatic Perception Questionnaire (MSPQ) which assesses somatic anxiety (Main, 1983);

- The Roland and Morris (1983) questionnaire, which is used to measure the patient's backpain-caused disability, and
- The Zung (1965) questionnaire, which assesses depression via the respondent giving answers to 20 questions using a self-rating scale.

In addition, the patient is usually required to mark on a diagram, usually of a human body, where the pain is located, and the type of pain. This type of diagram is known as a 'pain drawing' and forms the primary focus of our paper. Accordingly, the structure of the paper is as follows: the next section looks at pain drawings in more detail, examining the different types used in practice and their scoring methods, and finishes by highlighting limitations of current approaches. The subsequent section examines the feasibility of various technological solutions to overcome these limitations, and this is followed by a description of the implementation of these solutions in practice. Finally, the developed solutions are then compared with respect to one another and the set of requirements they set out to fulfil, and conclusions are then drawn.

THE PAIN DRAWING

Pain drawings, as depicted in figure 1, have been successfully used in pain centres for over 45 years (Palmer, 1949) and act as a simple self-assessment technique, originally designed to enable the recording of the spatial location and type of pain that a patient is suffering from (Ohlund *et al.*, 1996; Parker, Wood and Main, 1995; Rankine *et al.*, 1998). They have a number of advantages including being economic and simple to complete, and can also be used to monitor the change in a patient's pain situation (Ohnmeiss, Vanharanta and Guyer, 1995). Over the years, different ways of evaluating and using pain drawings have been suggested.

Take in Figure 1.

Ransford, Cairns and Mooney (1976) concluded that the pain drawings could be used not only as a location and pain recorder, but also as an economical psychological screening instrument to see if a patient would react well to backpain treatment. As previously mentioned, backpain can be caused by psychological and emotional problems, as well as occupational factors, and hence medical treatment may not remove the cause of the pain, making the patient no better (Chan *et al.*, 1993; Hildebrandt *et al.*, 1988; Uden, Astrom and Bergenudd, 1988). In order to evaluate the patient's psychological state the Minnesota Multiphasic Personality Inventory (MMPI), a standard American psychological questionnaire, can be used (Wadell *et al.*, 1980). This has been proven in a double blind study to indicate hypochondriasis (Hs) and hysteria (Hy) scores for patients, factors which have both been linked to treatment outcomes (Wiltse and Racchio, 1975). However, the MMPI is expensive and takes on average around one and a half hours to complete, and requires the respondent to understand English to a high school level in order to be able to complete the questionnaire (Von Baeyer *et al.*, 1983). In order to obtain a simpler screening device, capable of filtering those in need of further psychological evaluation, Ransford, Cairns and Mooney (1976) subsequently linked the pain drawing with the MMPI. Their solution worked by using a scoring system for the pain drawing, which gave points for abnormalities in the pain drawings (drawings that did not match accepted patterns of pain). If this score was greater than three, the patient could be psychologically distressed. Ransford, Cairns and Mooney (1976) found that they could predict 93% of the patients that needed further psychological evaluation just by looking at the patient's pain drawing, a conclusion later corroborated by Chan *et al.* (1993), and, to a lesser extent by Von Baeyer *et al.* (1983). The latter concluded that while relationships between the pain drawing score and the Hs and Hy scores in the MMPI were present, the magnitude of this relationships were much smaller than published in (Ransford, Cairns and Mooney, 1976).

Pain Drawings - Conclusions

The overall consensus of the literature seems to be that, while the pain diagram is a powerful tool in the role that it was originally designed, namely to record the spatial location and pain type, it is not as useful when it comes to acting as a psychometric test (Von Baeyer *et al.*, 1983). This is due to the fact that there are a number of problems with the way that patients behave towards the test when filling them out, especially regarding the way that they like to present themselves to medical staff (Hildebrandt *et al.*, 1988).

Whilst the literature on pain drawings is substantial, there is nonetheless confusion with what the pain drawing is actually to be used for, with little research into what it actually measures. It has been used by different organisations and at different times to measure psychological distress, type of pain, and disability (Ohlund *et al.*, 1996; Parker, Wood and Main, 1995). Most of the methods which are investigated are not able to be used on their own (Ohlund *et al.*, 1996; Parker, Wood and Main, 1995) or need further evaluation (Ginzburg, Merskey and Lau, 1988; Hildebrandt *et al.*, 1988; Margolis, Tait and Krause, 1986).

There also seems to be no standard way of scoring pain drawings, nor a standard way of filling them in. Whilst Chan *et al.* (1993) use the descriptors *pins and needles, burning, stabbing* and *deep ache* in their pain drawings, Hilderbrandt *et al.* (1988) state that they omit the pain qualities because they are not part of the standard pain drawings that they use. On the other hand, Uden, Astrom and Bergenudd (1988) use *dull, burning, numb, stabbing or cutting, tingling or pins and needles,* and *cramping* in their drawings, while Ohnmeiss (2000) uses *aching, numbness, pins and needles, burning and stabbing*.

Although there are several methods of analysing the current data sets, none of the methods seem to be robust enough to be able to work on their own, or with complete certainty. Moreover, pain drawings are usually stored in a paper format, which allows no further evaluation of the data that is stored upon it and makes searching through the data somewhat an arduous task. To compound the issue, when information from the pain drawings is digitised, it invariably results in loss of information, since current systems that are used for analysis of the pain drawings and the associated questionnaires revolve around statistical packages, such as Excel and SPSS, incapable of handling diagrammatic data. Thus, although diagrammatic data is collected, it is not used as the key component to the data analysis tools. This is somewhat a problem, as people will find it easier to show through a diagram the way that they feel, instead of answering closed questions in questionnaires. Such data cannot therefore be used to its full potential and, in particular, cannot be used in helping with queries within the dataset.

In our work, we have sought to alleviate this problem and have investigated various technological solutions that use the pain drawing as an actual aid to the analysing of the dataset. Furthermore, in our approach, we have enhanced data management by digitally storing the data in ways which allow it to be analysed easier, and have used user-friendly visual techniques for data querying. Lastly, recognising the importance in healthcare of distributed systems such as the World Wide Web providing ubiquitous information, all but one of our approaches use Web-based technologies in order to enable remote data access and management.

BACKPAIN DATA – TECHNOLOGICAL SOLUTIONS

The backpain drawing that a patient completes can be stored in one of two ways: either the image can be scanned, or the image can be subjected to *regionalisation.* In the latter case, the image is firstly broken down into regions, and only information relating to those regions of the human body affected by pain is recorded. The drawback of this approach is that pain location is *generalised*: for instance numbness in the hand might be generalised to numbness in the whole arm, if that is the smallest region encompassing the hand. However, regionalisation leads to simple *image maps*: digitised drawings, broken down into regions, each region being hyperlinked using HTML (the HyperText Markup Language, used for writing Web pages) to a specific document, such as a patient's medical records. Thus, each region becomes an image map hotspot linked to records corresponding to that region. Use of image maps allows for easy data cross-examination, a feature absent if the image is simply scanned. However, scanning an image does allow for the drawing to remain intact, with precise indications of the location and types of pain. Such a solution, although requiring relatively more computer storage space than image maps, can, if it is scanned to appropriate storage formats such as GIF or JPEG, be hyperlinked to the rest of the dataset.

In our approach, web-based image maps were constructed by using a GIF image (broken down into regions using Macromedia's Fireworks package) in conjunction with HTML. Image maps can also be used together with Active Server Pages (ASP) to dynamically update and present data. In our work we have also used Geographical Information Systems (GIS) a specialist analyst tool, which inherently works on image maps. The ASP-based solutions were chosen for their relative ease of implementation, inter-operability with existing legacy systems, as well as their potential to dynamically present in distributed computing environments (such as the Web), whilst the GIS one was chosen for its enhanced visualisation and analysis capabilities. Whilst alternative approaches to client/server programming over the Web, such as Java servlets and the Common Gateway Interface (CGI), exist, they use a greater amount of server resources than ASP, degrading performance of servers and sites. Moreover, since CGI is not inherently multithreaded (whilst ASP is), it also limits the number of concurrent users that can access any CGI-based solution, thus providing an extra reason for our choice of ASP. ASP and GIS technologies are now presented in more detail.

ASP

ASP allows for dynamic content to be used on the Web. The text document that is used to build the Web page contains either Visual Basic or Javascripting and requests the server to carry out some functions, such as database data retrieval or updates, before the HTML page is built dynamically, at run-time. Once the server has carried out its operation, the instructions for laying out the Web page are sent to the client. One of the main uses of this technology is to allow Web pages to interface, and get results from, a database (C-News, 2000; VB123, 1999). In order to make use of this technology, the ASP queries and the database have to be stored on either an IIS (Microsoft Information Interchange Server) or PWS (Personal Web Server) PWS server, thereby allowing the server to carry out the queries on the database and return the information requested.

GIS systems

With the advent of computing and information systems, the analysis of complex geographical datasets and their related databases and flat files has been greatly enhanced by GIS technology (Bernhardsen,1992). GIS tools such as ArcView allow the user to visualize data that may have gone unseen in spreadsheets, charts and other types of reports (ESRI, 1999b). GIS however does not need to be a single system, as it can be made up of a number of different hardware and software components, each performing a role in the storing and integration of digital images and related geographical data, thereby allowing for fast information retrieval (Bretas, 1996).

Using GIS, several methods of analysis can be carried out on the data, such as selection by geographic criteria for the spatial dataset, or using standard database functions such as sum, maximum, minimum, average, frequency distribution, and standard deviation on the nonspatial data held in the database. As most GIS are built using relational databases, SQL (Standard Query Language) statements can also be used in such systems (Bretas, 1996). As the system is visual, it removes the complexity of paper files or large spreadsheets and allows users to point and click in logical ways through the datasets (Theodore, 1998). For instance, if an area of the visual image is selected, the area that has been selected will be highlighted and all corresponding data in the related tables will also be highlighted and vice-versa.

In order to build a GIS, a base map is used, where every point, line and area has been given a unique identification code. These codes can then be linked to the database by inserting a new linking attribute into the database. The GIS software then automatically builds all the links that are needed for the system to work.

Medical GIS

Although visualisation techniques have been used in the medical sphere for decades, with the first recorded use by John Snow in 1854, who used a map to identify the water source responsible for an outbreak of cholera (ESRI, 1999a), it is only in recent years that the medical community, particularly in the United States of America, has become aware of the considerable geographical-related information it stores and of the advantages that its visualisation brings. The medical community have therefore been developing ways to harness the data integration and spatial visualisation abilities of GIS (ESRI, 1999a). Table 1 details a list of functions that GIS have been used for in the medical world (ESRI, 1999b).

Take in Table 1.

To name but two concrete examples, GIS has been used in the medical world for program and site planning (Barndt, 2000), whilst in Singapore, GIS has been used to monitor and control dengue fever (Ho, 2000). It must be understood, though, that GIS is not restricted to maps of the 'real' world, for if something can be broken down into regions and areas, then GIS could be used to store the relating information. The Environmental Systems Research Institute and GeoHealth Inc. have devised Bodyviewer, a new software package that allows the human body to be visualised. It uses the International Classification of Diseases (ICD-9) codes to link the human base image to databases containing information about patients and other relational clinical database management systems (Theodore, 1998).

Web-based GIS

The Web has opened up a number of new possibilities for GIS. These include the distributed sharing of data, the capture and analysis of new datasets, as well as the possibility of GIS data to be accessed by a large number of users using simple, visual interfaces across multi-platform environments (Brown, 1999; Peng and Nebert, 1997; Plewe, 1996; Strand, 1998). The use of HTML in conjunction with GIS also allows the linking of documents, a feature unavailable in older systems. The main advantage of Web GIS is that the user does not need to be able to understand the complexities of specialist software, as all the information and technical ability that they need is to be able to work an Internet browser. This allows people that understand the data to analyse its geographical trends without the need of understanding how the two are tied together within the GIS software (Plewe, 1997).

SYSTEM REQUIREMENTS AND DEVELOPMENT

In our research, we have worked with backpain data provided by NHS Northwick Park Hospital. Here, medical staff currently collect data relating to patients with backpain by the use of three questionnaires described earlier in our paper, as well as pain drawings, where the pain drawing is stored on paper and the questionnaire results are stored in a spreadsheet. Though the latter allows for a small degree of analysis, more complex queries cannot be performed. Moreover, as the diagrammatic data is stored in paper format, it only allows for simple one to one comparisons and makes cross examination and data recovery between patients difficult.

After consultations with medical staff at NHS Northwick Park Hospital it became clear that they needed a system which would allow backpain data to be able to be analysed fully. In order to achieve this goal, both the questionnaire data and the diagrammatic data would have to be converted into more analysable methods of digital data storage using technologies such as HTML, ASP and GIS, which would permit easy cross examination and recovery of the data. The developed system should allow for medical personnel to enter new data and images, as well as to be able to examine the information stored in the system, using a user-friendly visual-based interface. Moreover, as the literature on backpain has stressed (Frank and De Souza, 2000; Matsen, 2001), it would also be beneficial if the developed system could provide the ability to not only allow the use of the backpain diagram to select the appropriate records, but, conversely, to also enable the highlighting on the diagram of the region(s) corresponding to the selected records. Lastly, it would also be of use if the system could be run over an Intranet or the Internet, so as to allow many people to access the dataset. The visual presentation of the patients pain drawing would be done either using scanned images of the pain drawing or a generalised grid system such as the one described by Margolis, Tait and Krause (1986).

Based on these requirements, a total of seven different design solutions were initially suggested. These were then assessed as to what their practicality was and three proposed solutions (a standard spreadsheet linked to an image map, and two static, image map-based, HTML solutions) were deemed to be unsatisfactory for the purposes of the project, as they either would with difficulty work in a distributed environment, or would not allow dynamic presentations. The following systems were then implemented:

- Standard database with scanned images, using queries for all analysis;
- Standard database using a GIF image map via which regional data sets are invoked;
- ASP-related database accessed via a GIF image map, and a
- GIS solution.

Whilst the first suggested system above is a standalone one, it was felt that it should nevertheless be developed, due to its simplicity and inter-operability with legacy technologies. All other implemented solutions are distributed, though, and were chosen precisely because they possess, to differing degrees, visual-based data analysis capabilities. All of the developed systems interact with a database of backpain data. Whilst the design of the database itself is beyond the scope of this paper, it was modelled and normalised using the methods given by Connolly, Begg and Strachan (1999), and the resulting entities are given in table 2. The database was built using Microsoft Access 2000, due to its widespread availability and ease of use, although it must be mentioned that our solutions can still be constructed with alternative database implementations (such as ones using Oracle or Ingres) which, although more resource hungry and complex to integrate in Web-based systems, might scale better.

Take in table 2

As the issue of relating the digitised pain drawings to the corresponding datasets was primordial in our work, we shall now describe our approach in achieving this goal, followed by a more detailed examination of each developed system.

Regional diagram for visual interaction

In order to allow the digitised diagrams to be interactive with the data set, thereby allowing the display of information relating to patients that had a particular type of pain in a specific region, the pain drawing itself had to be broken down into regions. It was decided that the best way to split the human body into regions was to use the dermatome map (figure 2). The reason for choosing the dermatome map was that most medical staff would understand what dermatomes represent and their mapping on the human body. This thus gives a simple system of body regionalisation that everyone would either already understand or simple training would get them to the level of understanding needed. In order to allow for a better resolution of pain regions, the body was split into quarters, thus leaving a rear left and right, and a front left and right for each dermatome. These regions were made into hotspots for the GIF-based solutions as well as GIS, with all regions following a standard code, described in table 3.

Take in table 3.

Take in figure 2.

Standard database using scanned images

Within this design the questionnaire data would be stored on multiple relations within the database. The pain drawings would be scanned (in GIF format) and a relation created that will hyperlink the scanned pain drawings to the corresponding patient's details. Tables can be viewed in forms, which allow the user to see one dataset at a time and therefore look at one particular patient's record of backpain, as depicted in figure 3. It also allows for multiple datasets to be viewed if the data view system was used. This places all the information in a matrix, or tabulated tables where comparisons can be made, as can searching and sorting of the data. If medical personnel wish to see what the patient's pain drawing looks like they can use the associated hyperlink, which then loads the image in a Web browser.

Take in figure 3.

Standard database using a GIF image map to filter pain areas

This design was implemented because with it dermatomes are used as the visual key to querying the database, which represents a natural way for clinicians to access backpain data, as most of their diagnostics start off by considering the position on the human body of the pain itself. Thus, users would be shown a dermatome image map, displayed in a Web browser. By selecting a particular dermatome, a macro would be executed which would query the database, so that only the details of those patients who had pain in the selected area would be shown in the resulting tables. This functionality was accomplished by associating each dermatome region in the HTML image map with a shortcut to the corresponding Access macro, entered instead of a hyperlink in the URL section of the image map. This therefore allows for a visual system to be used to make sure that only information regarding the region that is selected is shown, hence removing unwanted data for that analysis session, as shown in figure 4. Apart from the image map itself, our implementation also stores the initial scanned pain drawing, so that it is possible to look at the original data, thereby allowing for the possibility to check for any generalisation errors.

Take in figure 4.

ASP with a GIF image map

With this design, dermatomes again represent the starting point of the queries. However, in contrast to the previous solution, the current one is distributed and therefore can be run over computer networks, which represents the main motivation behind its implementation. Here, the GIF image map contains links which, when activated, display further options available to the user in two frames on the same Web page. These allow a selection of the type of pain and data required, relating to the selected dermatome, as shown in figure 5. When one of these is selected, ASP queries stored on a Web server would then operate on the resident backpain database using SQL, before then returning the result in an HTML Web page. As the original scanned images are also stored on the Web server, this approach also allows for any generalisation errors to be checked for.

Take in figure 5.

GIS

The GIS solution was created by digitising the outline of each dermatome, stored as spatial co-ordinated polygons. This was then copied four times, one for each type of pain. Each polygon that was thus created in this manner was then given a unique identification number and therefore could be easily linked to the database via its keys. Each polygon was also given its dermatome code name (e.g. 'RRT1'), which related to the corresponding region. A new flat file table was created, which contained as headings the four types of pain, whilst each row contained the study number and the area of pain, as shown in figure 6.

Take in figure 6

This table stored, under different attributes, the areas of pain that each patient suffered from. Each of the different attributes was then linked to the corresponding dermatome image, as well as the rest of the database, as shown schematically in figure 7. Figure 8 depicts a snapshot of the GIS solution, where a query selecting different types of pain ('ache' and 'pain') in the same dermatome region (Rear Left Dermatome C2) has been undertaken.

Take in figure 7

Take in figure 8

SOLUTIONS REVIEW AND COMPARISON

We now review how the developed systems satisfied the original requirements set by Northwick Park Hospital, followed by a detailed comparison between the solutions. Accordingly, all of the implemented solutions were able to store patient questionnaire data as well as the scanned pain drawings, linking the database relations with the corresponding pain drawings. All of the developed systems, with the possible exception of the GIS solution, where supplementary training is required to be able to take advantage of its full functionality, use standard, familiar, visual-based interfaces and point and click functionality to remove the complexity of the database from the user. Using familiar interfaces, the targeted clinical practitioners found that adding new patient records, whilst inevitably laborious for large data sets, is straightforward in all of the solutions. Moreover, the stakeholders found especially useful the fact that, in the developed solutions, all the information relating to a patient can be edited or deleted, including the pain drawing.

Although the standard database using scanned images is not a distributed solution, and is therefore incapable of running over the Internet or an Intranet, it was developed due to its simplicity and usefulness in data collection (data could be gathered on a mobile/standalone computer and then later uploaded to a Web server).

All of the remaining solutions use image maps to link the dermatome regions on the diagram with the corresponding data and allow the user to select a region of interest. This therefore enables the largest part of the query to be performed graphically, as region selection is done by point and click, instead of a complex query written by the user. The similarity between the systems ends here, however. Thus, in the non-ASP, Access database solution, the GIF-image map only acts as the initial search tool and does not allow for any analysis to be carried out using the visual component. Indeed, the user has to be able to use the database and understand the functioning of the system, which demands a certain amount of pre held knowledge or training in Access. Other problems with this system are that the data would need to be stored on all the computers that would use it, and hence there are update anomalies when records are changed. Moreover, this solution is not a distributed one. However, all other solutions work under a client/server framework and place their data on a Web server, and it is to these that we now turn our attention.

The ASP system uses the same Access database, together with ASPs stored on a Web server, which are run when appropriate hyperlinks are activated. Thus, when a region of interest has been selected, the user then chooses the pain type from a list of hyperlinks displayed in an adjacent frame. The main advantage of this system is that users do not need to understand the underlying HTML, ASP or Access technologies - they just have to be able to use a Web browser. The database also does not need to be stored locally. However, the user can only update the database if (s)he has administrator privileges. This solution is useful nonetheless, as it allows comparisons across the dataset to be made without needing to understand the complexity of the database.

Whilst the other methods only allow the selection of one area of interest on the dermatome map at a time, the GIS allows the user to select as many as (s)he wants at the same time. This means that people that had pain in the left leg and left arm can be selected concurrently. If the user made this selection by pointing and clicking it would return all the results i.e. pain in leg only, pain in arm only, and pain in both. If use is made of the GIS query builder, the user can select that the pain has to be in the leg and the arm on the same patient.

Moreover, whilst the GIF-image map solutions only allow users to request certain datasets (e.g. personal datasets, medical), with the GIS solution users can also query the database, using the query builder. This allows users to construct complex queries such as ‘show me the position of pain for everyone that answered *always* for question 6 of the MSPQ’.

Thirdly, whilst the other solutions only allow users to look at each data set as a separate entity, as normally users would look at one table at a time, GIS highlights on each table the information regarding the currently selected record(s). This feature is part and parcel of the GIS functionality, as not only does a GIS show highlighted regions on the diagram, it also highlights corresponding data on all of the tables related to it, which makes this solution particularly suitable for finding patterns. The stakeholders found particularly attractive the fact that the GIS solution both integrated spatial-based clinical information with questionnaire-based data and provided facilities for cross-referencing and querying. The comparatively high level of training needed by the GIS solution, coupled with its complexity and set-up costs represent the main drawbacks of this system, however. These shortcomings were nonetheless felt by the stakeholders to be outweighed by the solution’s enhanced data-analysis potential.

Accordingly, although all solutions provide standard database analysis capabilities (e.g. sorting, use of standard statistical functions), the GIS solution provides the highest amount of functionality. This is due to the fact that, in contrast to the statistical tools provided by traditional database solutions, the GIS solution is based on the way that the graphical interface interacts with the rest of the data, using a dedicated Geo Spatial tool to provide powerful, visual-based, analysis capabilities, not present in conventional statistical packages. Thus queries involving space/time cluster analysis, spatial trends, modelling heterogeneity with covariates, predicting risk and defining corrective interventions, exposure assessment, spatial reasoning and cognition, and correlations are all possible. For instance, using GIS, the user can, in the same query, select multiple regions (e.g. ‘back of the head’) and different pain types (e.g. ‘numbness’ and ‘pins and needles’), and then look for correlations in the dataset, a query impossible to build with the other solutions. Indeed, this enhanced functionality of the GIS solution, not only for visual-based data management, but also for subsequent data analysis and data mining, was the feature most appreciated by the clinicians involved in the project.

CONCLUSIONS

Backpain is one of the most prolific health problems within the population and costs industry lost revenue due to the amount of days people have to take off in order to recover. For several decades now hospitals have been collecting data in order to help analyse backpain patients.

These have included several different psychometric and after treatment questionnaires, as well as pain drawings which are used to record position and type of pain. However, little or no work has been undertaken in which pain drawings and questionnaires are used to check for data patterns between patients. Moreover, even though pain drawings inherently contained positional data, no one seemed to have devised any system that made use of the positional data to link pain areas to the corresponding datasets.

This paper aimed therefore to rectify this problem and proposed a number of solutions, four of which were implemented. After a comparative analysis, the most suitable solution for managing backpain data was found to be one based on GIS technology, which made full use of its Geo Spatial tool in order to view and perform in-depth data analysis.

Furthermore, our work has confirmed the fact that GIS technologies can be used in non-geographical fields, as long as the dataset contains or can contain, spatial data. In this case the GIS was used to map the body. This allows the whole spatial analysis tool set to be used on non-geographical data, and helps the user to find correlations or patterns which may have taken a lot longer using standard visual inspection methods. Queries such as: “does a patient with pain in both limbs feel worse than a patient with pain in only one, and is (s)he more likely to take time off work?” can easily be undertaken using the GIS solution.

Finally, our work has raised some interesting future research questions. Chief among these is the issue of body regionalisation. Although in our work we have split the body region into dermatomes, is this the best grid possible for backpain analysis, especially bearing in mind generalisation effects? Would a finer resolution grid, albeit resulting in a more complex and computationally intense solution, be more beneficial? Finally, work can also be undertaken to explore how standards such as Scaleable Vector Graphics can be used in conjunction with XML-based medical mark-up languages in order to combine visualisation capabilities, on the one hand, with XML’s enhanced search and analysis potential, on the other.

REFERENCES

Balague F., Troussier, B. and Salminen, J.J. (1999), “Non-specific low back pain in children and adolescents: risk factors”, European Spine Journal, Vol. 8, pp. 429-438.

Barndt, M.G. (2000), "A Practical Application of GIS in Program Planning: Selecting Van Sites", *Proceedings of the 2nd International Health Geographics Conference*, Chevy Chase, Maryland, USA.

Bernhardsen, T. (1992), *Geographical Information Systems,* Viak IT, Norway.

Boucher A. (1999) The Prevalence of Backpain in Great Britain in 1998. Department of Health. Available at http://www.doh.gov.uk/public/backpain.htm.

Bretas, G. (1996), "Geographic Information Systems for the Study and Control of Malaria", GIS for Health and the Environment: Study and control of Malaria. Available at http:www.idrc.ca/books/focus/766/bretas.html.

Brown I.M. (1999), "Developing a Virtual Reality User Interface (VRUI) for Geographic Information Retrieval on the Internet", *Transactions in GIS,* Vol. 3, No.3, pp. 207-220.

Chan, C.W., Goldman, S., Ilstrup, D.M., Kunselman, A.R. and O'Neill, P.I. (1993), "The Pain Drawing and Waddell's Nonorganic Physical Signs in Chronic Low-Backpain", Spine, Vol. 18, No. 13, pp.1717-1722.

C-News (2000), "Internet understanding ASP, Computer news". Available at http://www.compternews.com.pk/issue/september2000/news-07.htm.

Connolly. T.C., Begg, D. and Strachan, A. (1999), Database Systems: A Practical Approach to Design, Implementation, and Management, Addison-Wesley, Harlow.

ESRI (1999a), "GIS for health care today and tomorrow". Available at http://www.esri.com/news/arcuser/0499/umbrella.html.

ESRI (1999b) "Health". Available at http://www.esri.com/library/brochures/pdfs/heathbro.pdf.

Frank, A. and De Souza, L.H. (2000). “Conservative Management of Low backpain”, International Journal of Clinical Practice, Vol. 55, No. 1, pp. 21 - 31.

Ginzburg, B.M., Merskey, H. and Lau, C.L. (1988), “The Relationship between Pain Drawings and the Psychological State”, Pain, Vol. 35, pp. 141-145.

Hildebrandt, J., Franz, C.E, Choroba-Mehnen, B. and Temme, M. (1988), “The Use of Pain Drawings in Screening for Psychological Involvement in Complaints of Low-Backpain”, Spine, Vol. 13, No. 6, pp. 681-685.

Ho, J. (2000), “The use of GIS in Dengue Surveillance in a Singapore Context”, *Proceedings of the 2nd International Health Geographics Conference*, Chevy Chase, Maryland, USA.

Jefferson, J.R. and McGrath, P.J. (1996), “Backpain and peripheral joint pain in an industrial setting”, Arch Phys Med Rehabil , Vol. 77, pp. 385-390.

Main, C.J. (1983), “The Modified Somatic Perception Questionnaire”, Journal of Psychosomatic Research, Vol. 27, pp. 503-514.

Matsen, F. (2001), “Backpain”, University of Washington. Available at http://www.orthop.washington.edu/bonejoint/zlvzzzzzl_2.html.

Margolis, R.B., Tait, R.C. and Krause, S.J. (1986), “A Rating System for use with Patients Pain Drawings”, Pain, Vol. 24, pp. 57-65.

Ohlund, C., Eek, C., Palmblad, S., Areskoug, B. and Nachemson, A. (1996), “Quantified Pain Drawing in Subacute Low Backpain”, Spine, Vol. 21, No. 9, pp.1021-1031.

Ohnmeiss, D.D. (2000), “Repeatability of Pain Drawings in a Low Backpain Population”, Spine, Vol. 25, No. 8, pp. 980-988.

Ohnmeiss, D.D., Vanharanta, H. and Guyer, R.D. (1995), "The Association Between Pain Drawings and Computed Tomographic/Discographic Pain Responses", Spine, Vol. 20, No. 6, pp. 729-733.

Palmer, H. (1949), "Pain charts: A Description of a Technique whereby Functional Pain may be Diagnosed from Organic Pain", New Zealand Medical Journal, Vol. 48, No. 264, pp. 187-213.

Papageorgiou, A.C., Croft, P.R., Ferry, S., Jayson, M.I.V. and Silman, A.J. (1995), "Estimating the Prevalence of Low Backpain in the General Population: Evidence from the South Manchester Backpain Survey", Spine, Vol. 20, No. 17, pp. 1889-1894.

Parker, H., Wood, P.L.R. and Main, C.J. (1995), "The Use of the Pain Drawing as a Screening Measure to Predict Psychological Distress in Chronic Low Backpain", Spine, Vol. 20, No. 2, pp. 236-243.

Peng, Z.R. and Nebert, D.D. (1997), "An Internet-Based GIS Data Access System", URISA Journal, Vol.9, No. 1, pp. 20-30.

Plewe, B. (1996), "A Primer on Creating Geographic Services, Mapping on the Web", GIS World Vol. 9, No. 1, pp. 56-58.

Plewe, B. (1997), "So You Want to Build an Online GIS", GIS World, Vol. 10, No.11, pp. 58-60.

Rankine, J.J., Fortune, D.G., Hutchinson, C.E., Hughes, D.G. and Main, C.J. (1998), "Pain Drawings in the Assessment of Nerve Root Compression: A Comparative Study With Lumbar Spine Magnetic Resonance Imaging", Spine, Vol. 23, No.15, pp. 1668-1676.

Ransford, A.O., Cairns, D. and Mooney, V. (1976), "The Pain Drawing as an Aid to Psychologic Evaluation of Patients With Low-Backpain", Spine, Vol. 1, No. 2, pp. 127-134.

Roland, M. and Morris, R. (1983), "A Study of the Natural History of Low Backpain Parts 1 and 2", Spine, Vol. 8, No. 2, pp. 141-50.

Theodore, J. (1998), "ESRI Announces BodyViewer Extension for ArcView GIS", Available at http://www.esri/library/userconf/europroc98/news/avbodyview.html.

Strand, E.J. (1998), "XML Provides Web-Based GIS a Path to Scalable Vector Graphics", Nuts and Bolts, GIS World, August, pp.28-30.

Uden, A., Astrom, M. and Bergenudd, H. (1988), "Pain Drawings in Chronic Backpain", Spine Vol. 13, No. 4, pp. 389-392.

VB123 (1999), "Understanding how ASP can interrogate your database", VB123.com, Available at http://www.VB123.com/toolshed/99_dbWeb/05ASPintro.htm.

Von Baeyer, C.L., Bergstrom, K.J., Brodwin, M.G. and Brodwin, S.K. (1983), "Invalid Use of Pain Drawings in Psychological Screening of Backpain Patients", Pain, Vol. 16, pp. 103-107.

Wiltse, L.L. and Racchio, P.D. (1975), "Preoperative Psychological Tests as Predictors of Success of Chemonucleyolsis in Treatment of the Low Backpain Syndrome", Journal of Bone and Joint Surgery (am), Vol. 57, pp. 478-483.

Zung, W.W.K. (1965), "A Self-rating Depression Scale", Archives of General Psychiatry, Vol. 32, pp. 63-70.

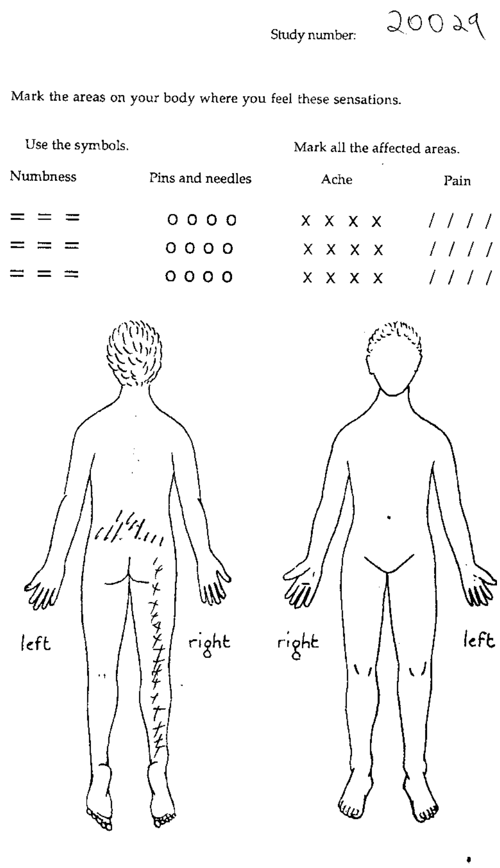

Figure 1: Pain drawing from NHS Northwick Park Hospital.

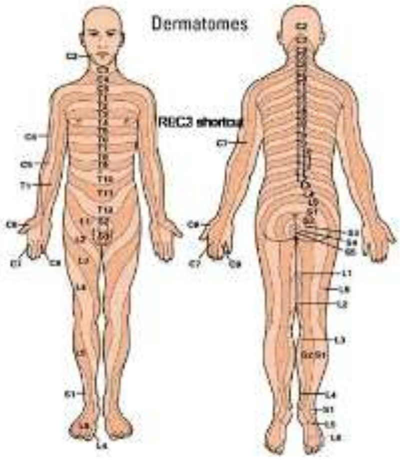

Figure 2 Regionalisation of the body using dermatomes.

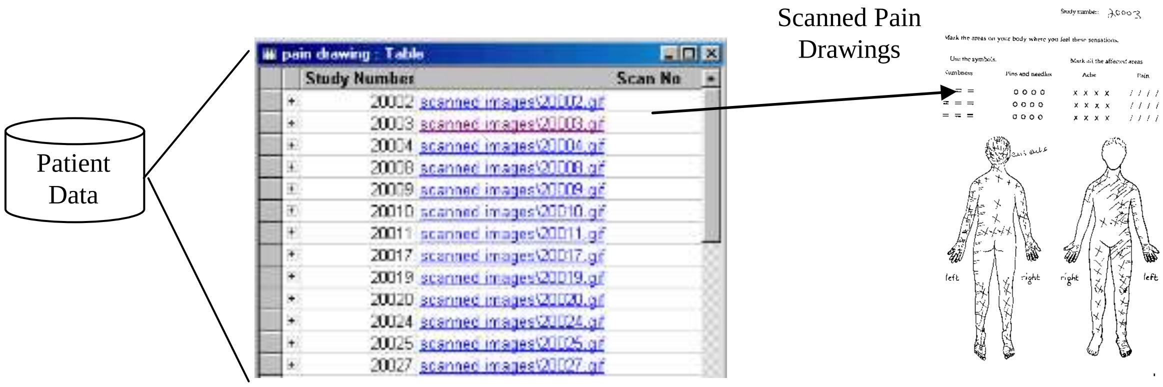

Figure 3 Method of linking the scanned pain drawings to the database.

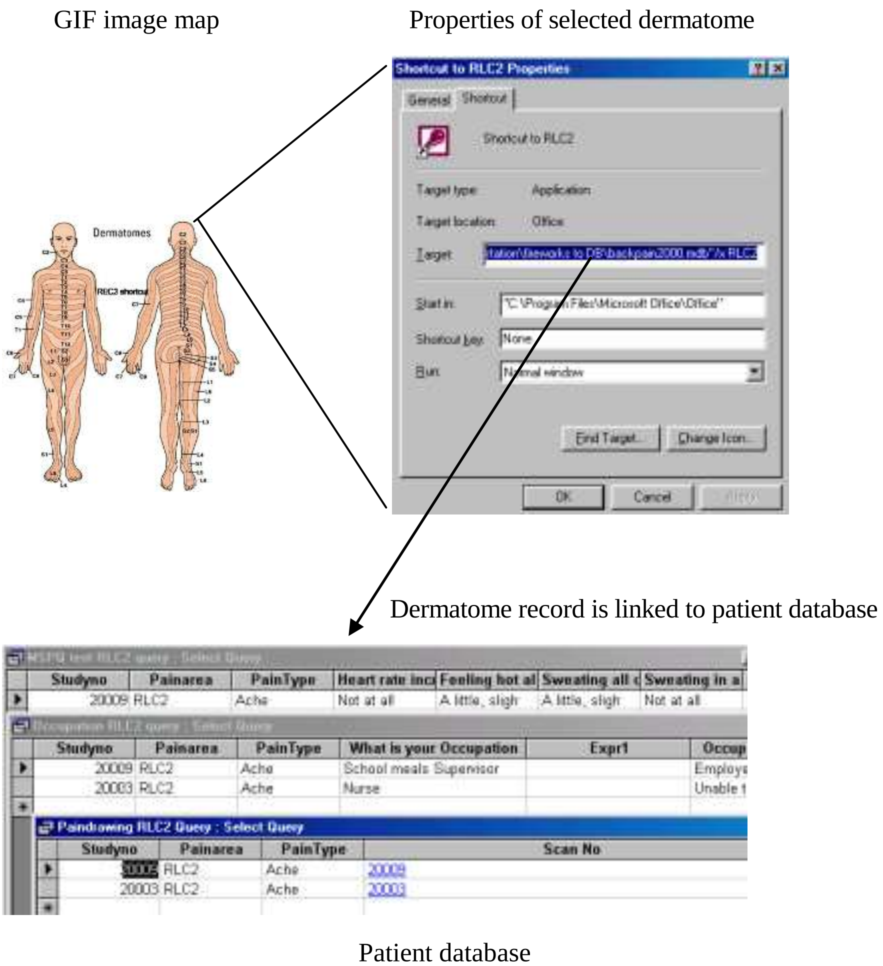

Figure 4 Standard database using a GIF image showing hyperlinking of dermatome to corresponding record in patient database.

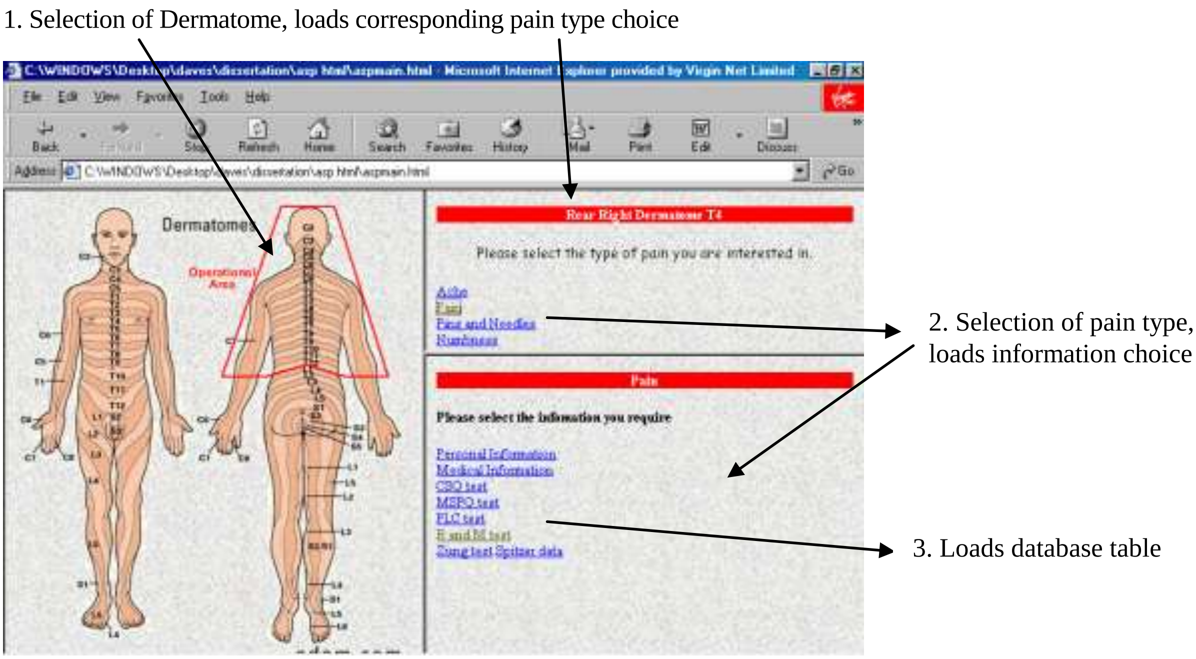

Figure 5 ASP with GIF image map– system snapshot.

4painplaces.dbf

Study_numb	Area	Pain	Ache	Numbness	Pandn
20003				RLL5	
20003				RLS1	
20003			RLS1		
20003			RLS2		
20003					RLL5
20003			RRS1		
20003			RRS2		
20003			RRL5		
20003			FRC4		
20003			FRC5		
20003			FRC6		

Figure 6 Linking table in the GIS solution.

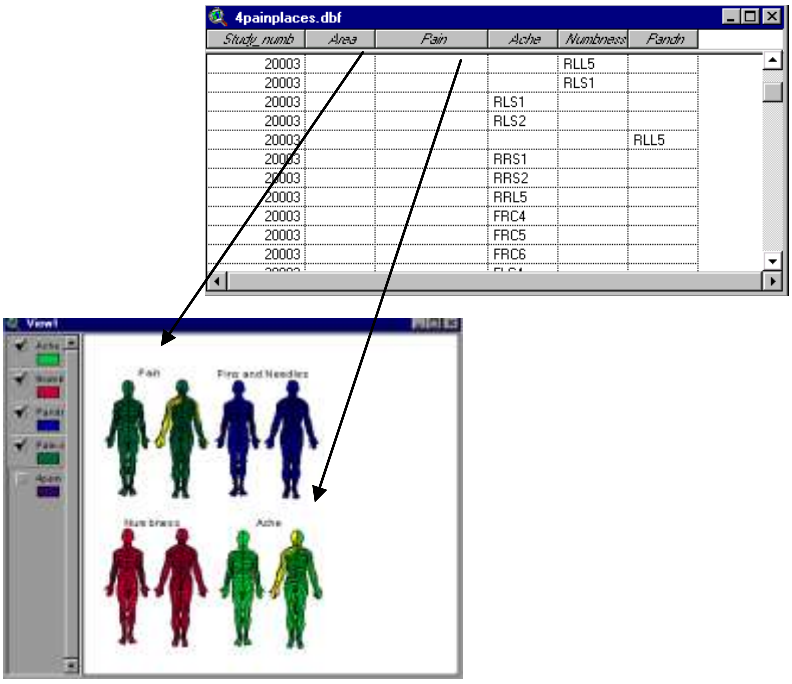

Figure 7. The attributes in the table are linked to the GIS solution using the dermatome codes.

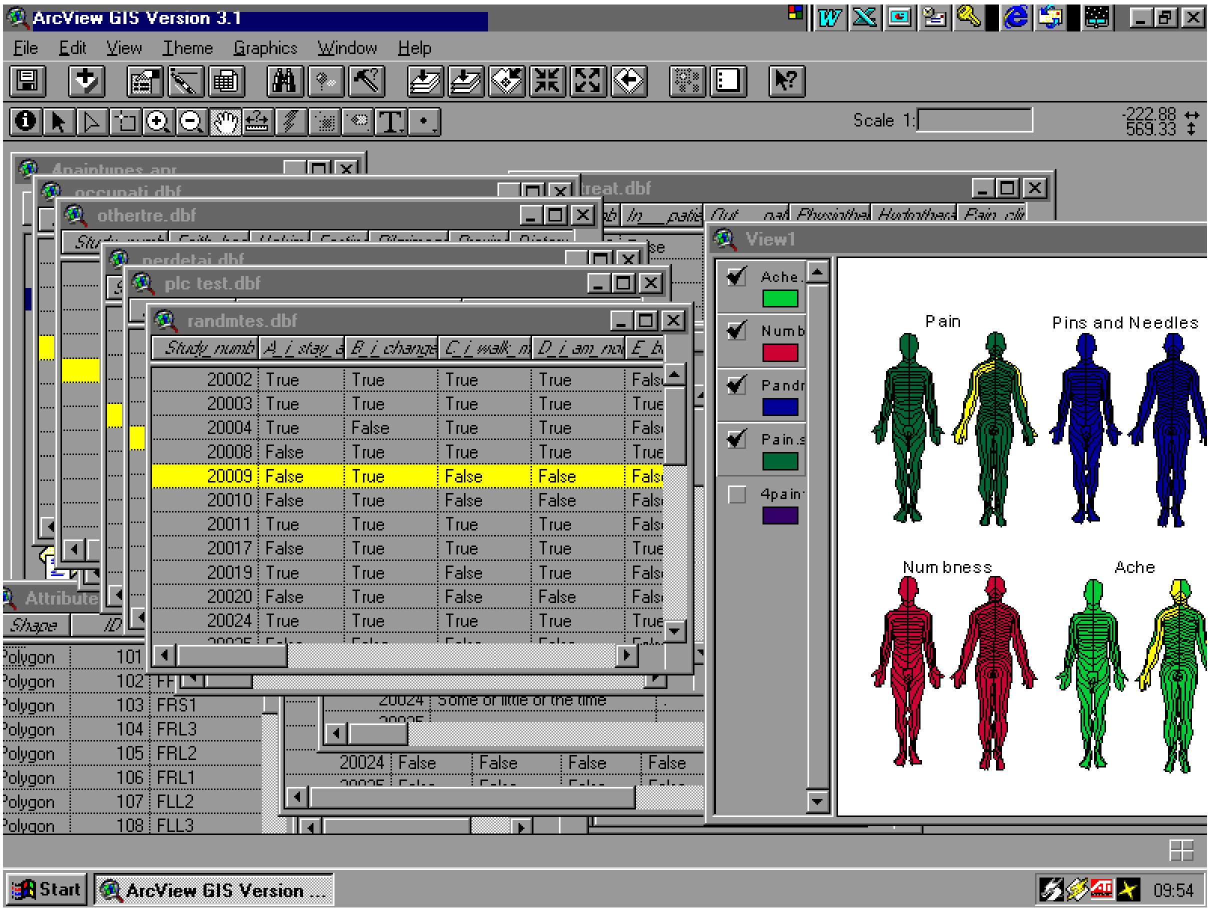

Figure 8 GIS solution –snapshot showing selection of different types of pain in the same region and the corresponding patient records.

Track infectious diseases and identify gaps in child immunizations.
Conduct market studies and document health care needs of a community.
Manage materials, supplies, human resources, and logistics.
Maintain location inventories of health care facilities, providers, and vendors.
Publish health care information using maps on the Internet.
Track infectious diseases and identify gaps in child immunizations.
Route health care workers, equipment, and supplies to service locations.
Manage patient care environments and clinical resources.
Distribute clinical data in a visual and geographic form.
Locate the nearest health care facility of a specific provider.

Table 1 Uses of GIS in a medical setting

Entity name	**Description**
Personal	Personal information of the patient
Address	Home address of the patient
Ethnic	Ethnic back ground of the patient
Occupation	What work the patient does, or if they are retired
Pain drawing	A link to the scanned image of the pain drawing
MSPQ test	The information gathered form the patient in relation to the MSPQ test
Roland and Morris test	The information gathered form the patient in relation to the Roland and Morris test
Zung test	The information gathered form the patient in relation to the Zung test
Medication	Medication the patient is using
NHS treatment	Previous NHS treatment
Meta data	Data relating to past history of back problems recorded while at hospital before
Private medical advice	Other types of medical advice that the patient may have received
Other treatments	Other types of treatments that the patient may have received

Table 2 Main entities of the backpain database

RRT1	Rear Right Dermatome T1
RLC2	Rear Left Dermatome C2
FRL1	Front Right Dermatome L1
FLS2	Front Left Dermatome S2

Table 3 Dermatome regions and their abbreviations.