Construction of Aged Patient Spine Database with Degenerative Diseases

Seungwoo Lee¹, Dongmin Seo¹, Soon-Chan Hong¹, Sang-Ho Lee¹, Hanmin Jung¹

¹ Information and S/W Research Center, Korea Institute of Science and Technology Information, 245 Daehak-ro, Yuseong-gu, Daejeon, 305-806, Korea {swlee, dmseo, schong, shlee, jhm}@kisti.re.kr

Abstract. As our society gets aging, degenerative spinal diseases and related surgical procedures will increase exponentially. To prevent unnecessary spinal surgery and support scientific diagnosis of spinal diseases and systematic prediction of treatment effects, we introduce e-spine, which is a computerized simulation model of human spines. As background data for realizing e-spine, we present aged patient spine database with degenerative diseases. We collected medical data from 178 patients for nine diseases and designed and constructed a database for efficiently searching and managing the data. This data will be used for developing mathematical spine model and spine implants.

Keywords: e-spine; aged human spine; spine database; degenerative spinal disease; spine image

1 Introduction

Spinal diseases make everyday activities of people difficult and impede economic activities, resulting in a compromised quality of life. As our society gets aging, degenerative spinal diseases and related surgical procedures will increase exponentially. According to Korea Health Insurance Review & Assessment Service, spinal surgery in 2004 increased at a particularly high rate – by 68.2% among ages 60-69 and by 94.6% among ages 70 and older, comparing to 2002 [1]. The resulting medical burden and economic loss are also increasing at a rapid rate.

There have been several research projects in which digital human data was constructed in Korea, China and EU as well as U.S. The first project was VHP (Visible Human Project) [2] which was planned by U.S. NLM (National Library of Medicine) in 1989 [3]. Inspired by the VHP, KISTI (Korea Institute of Science and Technology Information) started VKH (Visible Korean Human) [4] and DK (Digital Korean) [5] projects in 2000 and 2003, respectively. China started its own digital human project, CVH (Chinese Visible Human) [6], in 2002. They constructed digital human data sets consisting of continuously-sectioned color images, CT and MRI of whole bodies of Chinese male and female [7]. EU developed VPH (Virtual Physiological Human), a framework which aims to enable collaborative investigation of the human body and was inspired by Physiome project [8]. EU also developed a
biomedical data management and sharing service through LHDL (Living Human Digital Library) project [9].

Unlike these previous works, we focus on aged human spines with degenerative diseases to construct database for e-spine [10], which is a computerized simulation of mathematical model of human spine and, once fully established, will allow virtual testing before surgery on real aged human spine and also help to design implants for patients having spinal diseases. We have produced and collected many images, geometries and property data of spines from various cadavers [11][12]. However, the data from cadavers has some limitations because the data came from frozen dead body, not living body. For example, MRI images from a cadaver are meaningless. To complement this issue, we need to collect medical data on vertebras from living humans. In particular, we should collect medical data from patients having degenerative vertebra diseases to analyze characteristics of vertebras with diseases. We collected various images such as CT, MRI, and X-ray from many aged patients having degenerative diseases on cervical and lumbar vertebras or inter-vertebral discs and also made 3D shapes from series of CT images. These images and 3D shapes were built up into a database for efficient search and management.

The rest of this paper is organized as follows. Section 2 defines degenerative diseases we should target. Section 3 explains medical data obtained from patients and its database, which is followed by conclusion in Section 4.

2 Degenerative Diseases on Human Spine

Human spine is usually divided into three parts: cervical, thoracic and lumbar vertebras, starting from head. As humans get aged, they often suffer various degenerative diseases on cervical and lumbar vertebras or inter-vertebral discs, while they rarely suffer such diseases on thoracic vertebras. We, therefore, decided to target following degenerative diseases frequently occurring at cervical or lumbar vertebras of aged humans and further decided to classify these diseases into four or five grades (i.e., grade 0 to grade 3 or grade 4) through consulting with several specialists in human spine. The larger the grade number, the severer the disease is. The grade 0 commonly indicates normal and the grade 1, 2, 3, and 4 generally corresponds to mild, moderate, severe, and very severe grade of diseases, respectively.

- osteophyte, ligament calcification (including ossification of the anterior longitudinal ligament (OALL), ossification of the posterior longitudinal ligament (OPLL), and ossification of ligamentum nuchae (OLN)), endplate sclerosis, disc height reduction, disc herniation (it has five grades: normal, bulging, protrusion, extrusion, and sequestration), disc degeneration (it has five grades), facet joint degeneration, spondylolisthesis, osteoporosis.

3 Construction of Patient Spine Database

As part of database for e-spine, we collected various image data of aged patients having degenerative diseases on vertebras described at Section 2 from three hospitals
in Korea. Before collecting, the data were all reviewed and proved by specialists in human spine and IRB (Institutional Review Board) of each hospital. We considered the coverage of the data by collecting at least two patient data for each grade of diseases, except the grade 0 (normal). Most of the data were obtained from aged patients over 50 but some were gathered from somewhat young patients because even young people occasionally suffer from degenerative diseases on their vertebra.

3.1 Spine Image and Shape Data

The data collected from patients consists of various images such as X-ray, CT, MRI, and BMD because different types of images are useful for diagnosing different types of diseases. These images are stored in one file format, DICOM (Digital Imaging and Communication in Medicine), which is a standard format for storing medical data.

To build up these image data into a database, we first defined meta-data of the images by referring to DICOM header information because DICOM format defines all information related to the image in its header. Following is the meta-data list selected from DICOM header to manage the images in our database:

- image type, modality, study description, series description, equipment model, body part, slice thickness, magnetic field strength, protocol name, patient position, view position, sensitivity, patient orientation, photometric interpretation, rows, columns, bits allowed, and bits stored.

In addition to these meta-data, we defined ‘radio reading’ to store interpretation of a specialist in medical imaging because some of images were accompanied with their interpretation.

Some images like CT often compose a series of images produced with small intervals and these images need to be stored and managed as a group in our database for efficient search and management. So, we add series numbers to the end of each image file name while sharing the prefix of each file name, and manage the file name prefix with the start and the end of series number as additional meta-data.

From the series of CT images, we can make 3D shape model of spine body by piling up image series in order and filling up small triangles to correct intervals between the images. This process was done with Maya\(^1\), a 3D animation software.

3.2 Spine Disease Data

Disease information of patient is composed of disease name, body part where the disease occurred, and disease grade. Among nine degenerative diseases described in Section 2, the collected data covers six diseases on cervical vertebra and discs and eight diseases on lumbar vertebra and discs. In detail, we collected image and disease data of 178 patients among whom 49 patients had cervical vertebra-related diseases and 129 patients had lumbar vertebra-related diseases. The data were obtained from at least two patients for each grade of cervical vertebra-related diseases and at least five

\(^1\) http://usa.autodesk.com/maya/
patients for each grade of lumbar vertebra-related diseases, except spondylolisthesis. The detailed statistics about the collected data is shown in Table 1.

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3.3 Deletion of Personal Data

Medical data such as X-ray and CT images may often contain private information of patients. Especially, medical images in DICOM format include much personal information, such as patient’s ID, name and birthday, in their DICOM header. This private information should be removed before collecting if the information may uniquely identify a specific patient. However, some of personal information, such as age, statue and weight, needs to be collected because it is very important for classification or characteristics of medical data while it cannot uniquely identify specific patients. So, we defined following personal information as meta-data to be maintained and automatically removed other personal information from DICOM header of medical images:

- sex, date of birth, study date, age, statue, weight

Here, age can be calculated from date of birth and study (i.e., examination) date.

Some of medical images such as BMD often have personal information written in themselves. In other words, patient’s ID and name are commonly written in the image of BMD sheet. So, we manually removed these written characters from BMD images using image editing tools.
3.4 ER Model for Patient Spine Database

Medical image, shape, disease and patient data are conceptually combined into the ER diagram as depicted in Fig. 1 and built up into patient spine database. The ER diagram shows four entities such as Patient, Image Series, Shape Model, and Disease and four relationships between those entities such as Has, Study, BelongTo and pileUp. Each patient has more than one disease and each disease occurs at more than one patient. ‘Has’ relationship has body part (disPart) and grade of disease as its attributes. Each image series data is obtained from a patient and the relationship ‘Study’ represents patient attributes at that time of image production. ‘pileUp’ relationship represents that each image series data can be modeled into several vertebra shapes and ‘BelongTo’ relationship represents that each shape belongs to a patient.

5 Conclusion

This paper presented patient spine database constructed as background data of e-spine. Focusing on aged human spines with degenerative diseases, we collected various images produced by CT, MRI, or X-ray on cervical and lumbar vertebrae or intervertebral discs and also made 3D shapes from series of CT images. The data were obtained from 178 patients among whom 49 patients had cervical vertebra-related diseases and 129 patients had lumbar vertebra-related diseases. The image, shape, disease, and patient data were built up into a database for efficient search and management.

Patient spine data as well as cadaver spine data will be used to make various mathematical human spine models having different characteristics caused by degenerative diseases. The data can also be distributed for various research purposes.
Hospitals are generally keeping various data obtained from patients before and after treatment or surgery. We need to extend the coverage of data to be collected because such data will be very useful for education as well as research and development in medical industry.

Acknowledgements

This work was supported by 2012 National Agenda Project (NAP) funded by Korea Research Council of Fundamental Science & Technology (P-12-JC-LU02-C01).

References