A supportive environment for the long term management of knee osteoarthritis condition

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ABSTRACT
This paper describes the efforts for building a supportive and integrated environment for the long term management of knee osteoarthritis (OA) and is intended to be used by both patients and medical professionals. More specifically, medical professionals will be provided by a useful input regarding the health status of the patients as the related medical data will be properly visualized and presented. This will give a better insight of the condition and its progress, in order clinicians to carry out personalized medicine and better follow-up. On the other hand, patients will be provided by an environment that will monitor their lifestyle data (daily dietary and physical activity, pain level etc) and will warn them, if they do not manage to be compliant with the special medical guidelines. The monitoring will rely on techniques of self-life logging, enhancing patient engagement. Moreover, the platform will function as a supportive system to the patients by offering advice and assistance, allowing users to play a key role in monitoring and managing their own health. In this way, the oaCARE app was build and is described in detail in this work.

Categories and Subject Descriptors
J.3 [**Computer Applications**]: Life and Medical Sciences – *Health.*

General Terms
Algorithms, Management, Performance, Design, Human Factors

Keywords
Digital patient, osteoarthritis, application, self-management, patient/citizen engagement, personalized healthcare, oaCARE

1. INTRODUCTION
Osteoarthritis is the most common form of arthritis, affecting millions of people worldwide [1]. It is a degenerative condition of joints and is characterized by loss of the articular cartilage that acts as a protective cushion between bones within a joint and by growth of a new bone in affected joints, causing stiffness and pain. Osteoarthritis affects mainly the knee, hip, hand, spine and less often, the feet. Its symptoms often develop slowly and worsen over time. Joint pain and stiffness may become severe enough to make daily tasks difficult. Some people are no longer able to work. When joint pain is severe, doctors may suggest joint replacement surgery.

Osteoarthritis usually affects more women than men, and tends to turn up as people get older but is also common amongst people of working age. Nearly one in five women over 60 in UK has osteoarthritis [2]. The number of people with osteoarthritis is increasing as the population ages, and as the prevalence of obesity, a risk factor for osteoarthritis, also continues to rise [3].

Other common factors that may increase the risk of developing osteoarthritis are –apart from sex, age and obesity- previous joint injuries, certain occupations (if a job includes tasks that place repetitive stress on a particular joint), genetics (some people inherit a tendency to develop osteoarthritis), bone deformities and other diseases (e.g. diabetes or other rheumatic diseases) [4].

A patient visits Primary Care or GP complaining for knee problems and knee pain symptoms. The clinician proceeds with the diagnosis of the osteoarthritis condition by physical exam in conjunction with imaging test (radiographs and MRIs) and lab tests (blood tests and joint fluid analysis). As there is no known cure for osteoarthritis, clinician advices the patient for lifestyle interventions i.e., mild daily exercise, reduce body weight and proper medication for reducing the pain and improve the patient's overall condition. If these conservative treatments don't help, other procedures may be applied (e.g. surgical, lubrication injections etc) [5].

This paper presents the oaCARE app, a web application for the long-term management of the knee osteoarthritis condition that will benefit both patients and medical professionals. More specifically, clinicians will be provided by a useful input regarding the current patients' health status and the progress of the condition, as the related data (imaging, lifestyle, drug, clinical history and symptoms) will be properly visualized and presented. This will allow clinicians to perform personalized treatment and better follow-up for patients. On the other side, oaCARE app will give the opportunity to patients to play a more active role in monitoring and managing their own health. They will be provided by an environment that will monitor their lifestyle (daily dietary and physical activity data) and will warn them if they do not manage to reach the clinician's guidelines. Furthermore, they will be able to record the pain level and their symptoms. The oaCARE app will also allow patients' education on the knowledge of the condition as it is expected that a good knowledge of a condition will lead to enhanced patient behaviors.

2. DEVELOPMENT

The oaCARE app is developed using PrimeFaces Mobile framework [6-7]. PrimeFaces Mobile (PFM) is a UI Kit to create JSF applications optimized for mobile devices. PFM is built on top of jQuery Mobile, a touch-optimized HTML5 UI framework providing support for various platforms. In addition to the seamless integration with jQuery Mobile, PFM features a Mobile Renderkit for popular PrimeFaces components, ajax framework extensions, mobile ajax behavior events, integrated navigation model, lazy loading of pages, responsive widgets and more. It should be mentioned that the design of the oaCARE app is responsive i.e. it can be seamlessly displayed in different screen resolutions from smartphones to tablets and personal computers.

3. DATA INVOLVED

Different types of data are involved for the diagnosis, prognostication, monitoring and treatment of the osteoarthritis condition. This data ranges from imaging and scoring systems to patients' lifestyle and drug data.

3.1 Imaging data

The importance of imaging in assessing all joint structures for diagnosis, prognostication and follow-up has been well recognized. In daily clinical practice, conventional radiography is still the most commonly used imaging technique for the evaluation of a patient with known or suspected osteoarthritis. It is the simplest, least-expensive and most widely deployed imaging modality. On the other side, the ability of magnetic resonance imaging (MRI) to visualize all joint structures in a three-dimensional way has significantly improved our understanding of the natural history of the condition. Because of high cost per examination, MRI is not routinely used in clinical initial assessment or during disease follow-up of patients. However, MRI has become a key imaging tool for osteoarthritis research due to its ability to visualize pathologies that are not detected on radiographs [8].

3.1.1 DICOM server

Both radiographs and MRIs are stored as DICOM files (.dcm). DICOM stands for Digital Imaging and COmmunications in Medicine and represents years of effort to create the most universal and fundamental standard in digital medical imaging [9]. As such, it provides all the necessary tools for accurate representation and processing of medical imaging data. Moreover, contrary to popular belief, DICOM is not just an image or file format. It is a data transfer, storage and display protocol built and designed to cover all functional aspects of contemporary medicine.

DICOM files are stored in PACS (Picture Archiving and Communication System) systems. PACS is a medical imaging technology which provides storage and access to images from multiple modalities (CT, ultrasound, MRI, PET) and is strongly related to DICOM, the reference standard in medical imaging. Its functionality is DICOM-driven, which guarantees its interoperability.

The PACS that was chosen for managing the imaging data in oaCARE app is the so-called DCM4CHEE server [10]. DCM4CHEE a cross-platform system developed in Java. It is a free and open - source DICOM archive and image manager, forming the server side of a PACS system. It is actively developed and updated, with modules including HL7 and WADO, and is based on JEE, JMX and the JBOSS Application Server. Administration is through a web-based interface and is compatible with a wide range of databases (PostgreSQL, MySQL, SQL Server and Oracle).

Patients are totally responsible for managing their own imaging data. They can upload their imaging data through an easy-to-use UI, as shown in Figure 1. DICOM imaging data is uploaded by choosing the desired data in ZIP format. Upon uploading to PACS, DCM4CHEE indexes and stores the DICOM elements automatically based on their annotations. Patients can also filter the data (e.g. based on modality etc) and download it in zip format. Besides the uploading and downloading service, the user may also delete DICOM files.

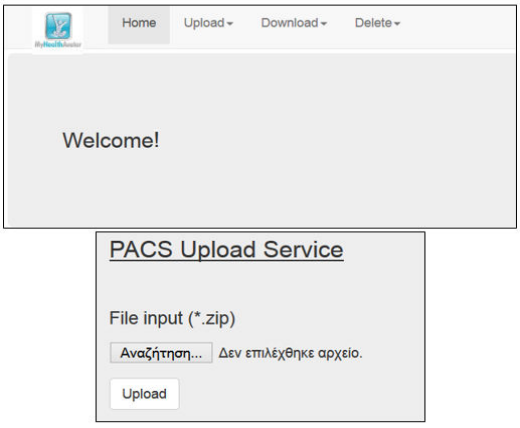

Figure 1. PACS UI

3.2 Scoring data

The severity of radiographic osteoarthritis can be assessed using semi-quantitative scoring systems. The Kellgren and Lawrence (KL) grading system [11] is a widely accepted scheme used for defining radiographic osteoarthritis based on the presence of a definite osteophyte (=grade 2). The grades for classifying the severity of osteoarthritis are:

- grade 0: no radiographic features of OA are present
- grade 1: doubtful joint space narrowing (JSN) and possible osteophytic lipping

- grade 2: definite osteophytes and possible JSN on anteroposterior weight-bearing radiograph
- grade 3: multiple osteophytes, definite JSN, sclerosis, possible bony deformity
- grade 4: large osteophytes, marked JSN, severe sclerosis and definitely bony deformity

Another metric is the Joint-Space Width (JSW) which measures the cartilage thickness in knee osteoarthritis. This quantitative measurement can be accomplished either manually or by a software application.

3.3 Lifestyle data

Some factors that may increase the risk of developing osteoarthritis are strongly related to patients' lifestyle. By adopting a healthier lifestyle a reduction of the osteoarthritis symptoms can be achieved. By monitoring such data through the oaCARE app, clinicians have a better insight of patients' current health status while patients know exactly the level of compliance with the doctor's instructions.

More specifically the lifestyle data is:

- Weight: Being overweight or obese increases the stress on weight-bearing joints, such as your knees and hips. Even a small amount of weight loss can relieve some pressure and reduce your pain.
- Activity: Mild exercise (swimming, walking or biking) can increase the endurance and strengthen the muscles around the joints, making them more stable.
- Diet: A well-balanced diet is essential. Although experts do not recommend a specific diet for osteoarthritis, choosing healthy foods offers many benefits (keep weight down, build strong cartilage, reduce inflammation).

3.4 Drug data

For the integrated management of the knee osteoarthritis drug data information is also required. This is not only limited to all the prescriptions, medications and dietary supplements that the patient take and the dosages, but also medications that are prescribed by the medical professionals as treatments for reducing pain and maintaining joint movement (no known cure for osteoarthritis exist).

4. FEATURES OF THE oaCARE APP

The oaCARE app comes in two versions; a version dedicated for patients and a version dedicated for clinicians.

4.1 oaCare app – Patients' version

The patients' version incorporates functionalities for assisting users in long-term self-management of the knee osteoarthritis. It offers a supportive environment for empowering patients in looking after their own health, raising their self-awareness of the osteoarthritis risk factors while encouraging for a healthier lifestyle in terms of daily exercising, losing weight and controlling diet.

Firstly, the user logs into the platform and then he redirected to the home page of the app, which presents the patient's lifestyle in a more comprehensive way, in diagram format (Figure 2). Specifically, the metrics that are presented are a) activity that the patient executes per day (in minutes); the activity trackers that are used are FitBit, Withings and Moves b) patient's weight (weekly self-tracking) c) pain score for the problematic knee(s) that is extracted by the pain questionnaire; patient fills out the questionnaire on a regular basis or if he feels that the pain gets better or worse d) radiographic score (KL and JSW) that was prior inserted by the clinician, after the examination of the radiographic data. In case that the clinician has previously set up deterioration thresholds for the aforementioned metrics, the app is able to warn the patient properly (e.g. "You did not exercised enough the latest month.", "Be careful with your diet. You gained weight.").

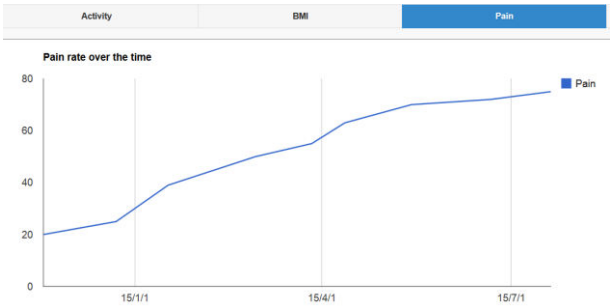

Figure 2. Lifestyle / Pain / Score data representation

The user can also view his imaging data (radiographs and MRIs) in conjunction with the radiographic score data that has previously been inserted by the clinician. Furthermore, the user can be informed about the deterioration thresholds that was previously set up by the clinician, in case that he wants to adopt and plan his lifestyle properly.

The patient can also (and has to) fill out the pain questionnaire periodically; on a regular basis that has been previously defined by the clinician or if the patient feels that the knee pain gets better or worse. The questionnaire contains questions which help in identifying the patient's pain level (e.g. "What does your pain feel like" or "How strong is your pain" or "How your pain changes with time").

Moreover, the user can search over the educational material for the osteoarthritis condition and may be informed about the nature of the condition, the symptoms, the causes, the risk factors, the treatments and drugs, the lifestyle remedies etc. It is expected that a good knowledge of the condition will lead to enhanced patient's behaviour, allowing him to play a key role in monitoring and managing his own health. Finally, the patient can directly communicate with his clinician using the messaging module.

4.2 oaCare app – Clinicians' version

The clinicians' version has been developed in order to provide a useful input to clinicians regarding the current health status of patients, as the related data (imaging, scoring, lifestyle and drug) will be properly visualized and presented. This will give a better insight of the patient's condition and his progress for carrying out personalized medicine and for better follow-up.

Firstly, the clinician logs into the platform and then he redirected to the home page, from where he can select a patient from the patient list that is presented. From the menu, the user can view the patient's imaging data (radiographs and MRIs) and update or edit the two radiographic scoring metrics (KL and JSW), as shown in Figure 3.

Moreover, clinician can examine the lifestyle (activity, weight and diet) and pain score data, which are presented in a diagram and tabular format, and based on that input he can a) review patient's

current health status b) update properly the deterioration thresholds c) update or send warning messages to patients.

Furthermore, the clinician can upload educational material (links or files) that may be helpful for patients for better understanding of the nature of the condition, or for further learning about the recent advances in the osteoarthritis research. Finally, the clinician can send a message to the patient or respond to his questions.

Figure 3. Radiograph presentation and its scoring metrics

5. ADDED VALUE

The oaCARE app provides a unique platform that empowers both patients and medical professionals for the long-term management of the osteoarthritis condition. It will function as a supportive environment to empower citizens in looking after their own health, raising their self-awareness of any potential risk of developing diseases while encouraging their healthy lifestyles in terms of doing routine daily exercise and controlling their diet. It offers a one-stop service for citizens in terms of data collection and self-management services such as record, monitor and education. Citizens will be able to upload periodically their own health data, e.g. pain score data, using their mobiles. The app will also monitor patients' daily dietary and ambulatory activity and warn patients if they are not compliant with the guidelines issued by the medical professionals. The app will also promote citizens' education on the knowledge of the condition as it is expected that a good knowledge of the condition parameters will lead to consistent patient's behavior. In addition, medical professionals will be provided by a useful input regarding the health status of patients as the related data will be properly visualized and presented using interactive visualization techniques. This will give a better insight of the condition and its progress for carrying out personalized medicine and for better follow-up.

6. CONCLUSIONS

This paper presents the oaCARE app, an application that assist both patients and medical professionals for the long-term management of the knee osteoarthritis. The scope of the app is to provide patients an easy-to-use way of managing and monitoring their medical data related to knee osteoarthritis, from the emerging of the condition until today, enhancing patients' engagement. On the other side, the oaCARE app will benefit clinicians as they will be able to view the patient's medical data over the time, assisting them to better understand the patients' current health status and the progression of the condition. Furthermore, a genetic predisposition evaluation service would be implemented for examining if an increased risk of developing osteoarthritis exists. This could be used by the patients in order to understand their personal risk of developing osteoarthritis, and the impact of their behaviour and lifestyles towards the risk. The app could also be extended in order to cooperate with other health management applications and services, e.g. for diabetes management [12], allowing the exchange of useful information by both apps and the provision of a better input to the patient.

7. ACKNOWLEDGMENTS

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