Validating Scanned Foot Images and Designing Customized Insoles on the Cloud

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Abstract

People with foot problems need special healthcare: foot care. Customized insoles can provide this care. They are inserts that are placed in the shoes. They correct biomechanical and postural inaccuracies in foot. Insole production contains four phases: foot image scanning, image validation, insole design and insole manufacturing. Currently, image scanning and validation is separated in location and time, i.e. podiatrists take images and insole designers validate them at different location and at different time. A cloud-based solution, the CloudSME one-stop shop simulation platform, enables remote access to image validation and insole design service deployed and running on the Cloud. The remote access allows podiatrists validating scanned image while the patient is in their offices. The simulation platform also supports remote design of customized insoles.

1. Introduction

Feet are the body parts that people use to move on the ground. They affect the osteo-articular and muscular system depending on how they move and support themselves on the ground. Throughout everyday life feet bear people's weight. At each step taken feet support between two and four times the weight of the body. There is an estimate that a normal person can take the same amount of steps that would circle the world four times in the course of his/her life. Discomfort or injuries that appear in areas of the foot may be caused by the shape of the feet or by the way how people step. According to a recent survey, done by the American Podiatrist Medical Association (APMA) [1], 77% of the adults in US experienced foot problems of which 27% is pain in heel and pain in the ball of feet. Further, the survey concluded that 10% of the surveyed people regularly use prescribed orthotics insoles for shoes.

To address these foot problems orthotics insoles [2] are placed inside the shoes for restoring natural foot function and position. They address problems not only in the feet but also in other parts of the body, such as the knees, hips, and lower back. Between regular and orthotics insoles there is an important difference. Regular insoles are designed to provide a cushioning effect and shock absorption but they do not solve any biomechanical problem. Orthotics insoles are functional devices aimed to correct and optimize the functionality of foot and are customized considering patient's feet. They match the contours of the feet precisely to provide a better distribution of the weight against the top surface of the insoles reducing peaks of concentrated pressure. Orthotics insoles can accommodate a unique foot structure and pathology. These insoles help to manage biomechanical and postural inaccuracies in foot by correcting biomechanical inefficiencies and deformities. Orthotics insoles also improve foot function by accommodating and controlling excessive motion. These insoles reduce pathological stresses of the foot or other portions of the kinetic chain including stresses caused by muscular-skeletal deformities and an inability to absorb shock.

To address issues related to foot healthcare services may be needed at all ages. This care can be supported by customized (or tailored) insoles adapted to foot after a podiatrist has conducted a complete evaluation of patient's feet, ankles, and legs. People with foot problems, professionals with physically demanding jobs and sportsmen may need these insoles.

There are three basic types of insoles [3] considering their manufacturing methods:

- **Prefabricated insoles**: These are mass produced and can be bought off the shelf. They provide general arch support or cushioning to areas of the foot without any specific personalized features.
- **Customized prefabricated insoles**: These are modified prefabricated components. These can be produced by adding of a metatarsal pad to relieve pressure in a specific area, or by introducing a heel lift for the treatment of leg length discrepancies.
- **Customized insoles**: These are manufactured from a castor mould of the patient's foot. These often provide the best-fitting orthotics and give the best results.

Traditionally, the customized insoles are preferred to pre-fabricated insoles for patients with foot problems

The production of customized insoles has been established for many years. The molds can be plaster casts taken directly from the patient's foot. Traditional plaster cast mold manufacturing methods have a long production lifecycle and are expensive. It is also often difficult to tailor these insoles to meet patients' requirements. Latest developments in design and manufacturing of customized insoles, such as advanced scanning technology and sophisticated CAD/CAM systems have changed the landscape. Using scanning devices to digitize the surface of the foot and enabling direct manufacturing of customized insoles based on the scanned images has enabled decreasing the production time and even manufacturing costs. Considering these advantages this paper will focus on validating scanned foot images and designing customized insoles.

In section 2 overview of design and manufacturing process of insoles is given. Section 3 outlines the 3D Scan Insole Designer that enables validation of the scanned images and design of customized insoles. In section 4 a remote scanned image validation and insole design is described through two use scenarios. Section 5 explains how 3D Scan Insole Designer is ported to the Cloud to support remote execution of user scenarios described in section 4. Section 6 presents how two SMEs validate scanned images and design customized insoles on the Cloud. In section 7 several insole design software are described and investigated. Finally, section 8 contains the conclusions and further works.

2. Designing and manufacturing customized insoles

According to [3] there are three major phases in production of customized insoles (See Fig. 1):

phase 1: – examining the patient, scanning his/her feet and generating scanned images

phase 2: - validating the scanned images, designing customized insoles

phase 3: - manufacturing the insole based on the customized insole design

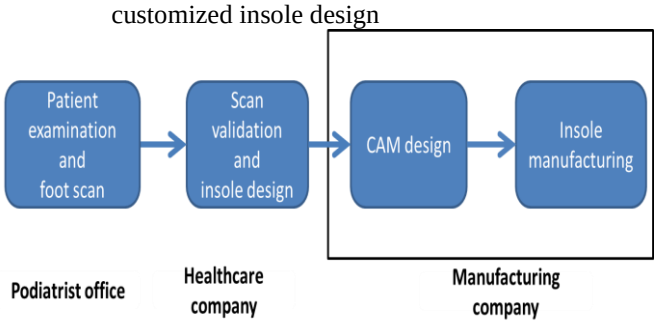

Figure 1. Customized insole production cycle

The movements and stresses experienced in the feet during different activities depend upon age and body of people. Patients are exposed to different forces through the feet depending on their body and particularly their feet. As a result, the insole must be prescribed based not only on the geometry and biomechanical requirements of the foot but it must also take into consideration the lifestyle of patients. These factors must be all considered to provide an accurate prescription for patients. In phase 1 a biomechanical assessment of the patient's foot is undertaken as the first step to produce a customized insole. Podiatrists use a scanning device to take and digitize the profile of the foot. They also compile a patient examination report. In phase 2 healthcare companies validate the scanned images and insole manufacturers design the customized insoles. The design of customized insoles in phase 2 requires a comprehensive knowledge of several areas affecting feet. This information is added to a database consisting of knowledge gained from previous patients including biomechanical data, material type and other properties of customized insoles designed and produced previously. Having the customized insole design rapid manufacturing can deliver a mass production of personalized insoles in phase 3. Scanning accurately the foot and validation the scanned image produces a three-dimensional image that enables customized CAD design of insoles. Having this design the relevant CAM model is created, which considers the geometry of the foot and the shoe in which it is to be placed, the materials to be used and the manufacturing process itself.

There are three types of companies involved in production of customized insoles:

- **Healthcare companies**: They validate the scanned feet images of patient's foot before sending them to an insole manufacturer. The validation identifies low quality or wrong images and recommends podiatrists to retake these scans.
- **Insoles manufacturers**: They design customized insoles with CAD programs using the validated scanned images and produce the customized insoles on CNC milling machines.
- **Footwear manufacturers**: They offer shoes with customized insoles produced by insoles manufacturers. They also adapt shoes according to patient groups' specific needs for example safety shoes for builders, etc.

There are three types of actors involved in customized insole production:

- **Podiatrists**: They are healthcare experts who work with the patients. They scan patient's foot and forward the scanned images to the insole designers.
- **Insole designers**: They are engineers who validate the scanned images created by podiatrists. If there is any problem with the images they ask podiatrists to retake the scans. Next, they design the customized insole and forward it to insole manufacturers.
- **Insole manufacturers.** They are engineers who run the insole manufacturing process using the customized insole designs.

3. Automisation of image validation and customized insole design

Ingeniería y Control Electrónico S.A (INGECON), a Spanish SME delivering products and services for the IT and electric utilities sector, and Podoactiva, a Spanish

biotechnology SME specializing in chiropody and biomechanics, jointly defined a foot scanning and insole design process. Podoactiva developed and patented a 3D scanning method [4] to take foot images. (See in Fig. 2.)

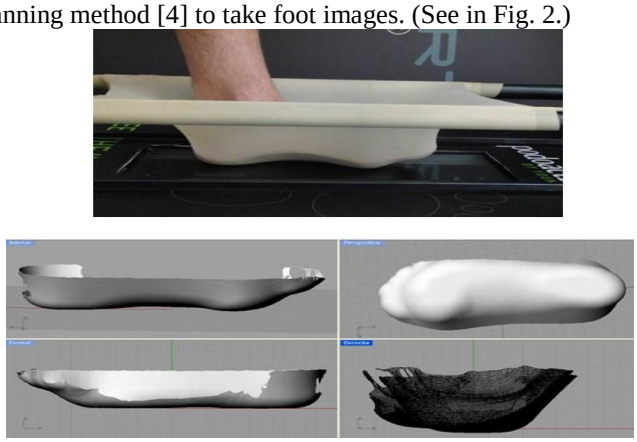

Figure 2. Scanning foot image produced by the Podoactiva 3D scanning method

Podiatrists scan the patient's feet and generate an stl file (STereoLithography) in their office using this scanning method. This file contains the scanned image of the patient's foot. The stl format is widely used in manufacturing for rapid prototyping and computer-aided manufacturing (CAM). The podiatrists send the file with the scanned images to insole designers to validate them and design the customized insoles.

Based on Podoactiva insole production experience Podoactiva and INGECON identified four major tasks for validation of scanned images and design of customized insoles (Fig. 3). First, scanned images must be validated. The validation checks the smoothness of the image surface, i.e. whether there is any butterfly wings, any holes, non-continuous edges, etc. If there is any problem in the image the podiatrists has to retake the scan. Having a validated scan first, the insole must be designed considering the selected shoe form. Next, they must be manually adjusted considering the patient's examination report sent by the podiatrist. Finally, the insole design must be optimized and final design (or sketch) (See in Fig. 4) must be generated and sent to insole producers.

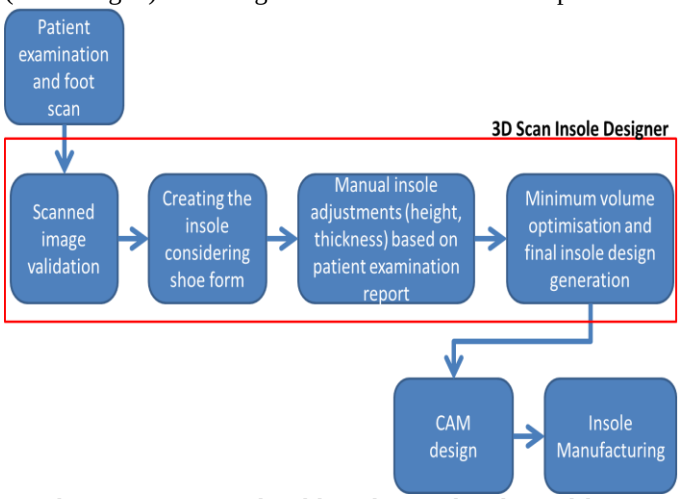

Figure 3. Customized insole production with 3D Scan Insole Designer

INGECON elaborated the 3D Scan Insole Designer [5]. It is a PC-based simulation software running under the Windows operating system. It is implemented on a third-party commercial CAD program, such as Rhinoceros [6], as a set of CAD plug-ins. It allows both scanned image validation and insole design. To execute this software the user must start a CAD program specifying the required operation and submitting its parameters. The 3D Scan Insole Designer appears as a plug-in on the CAD GUI. (See in Fig. 4.)

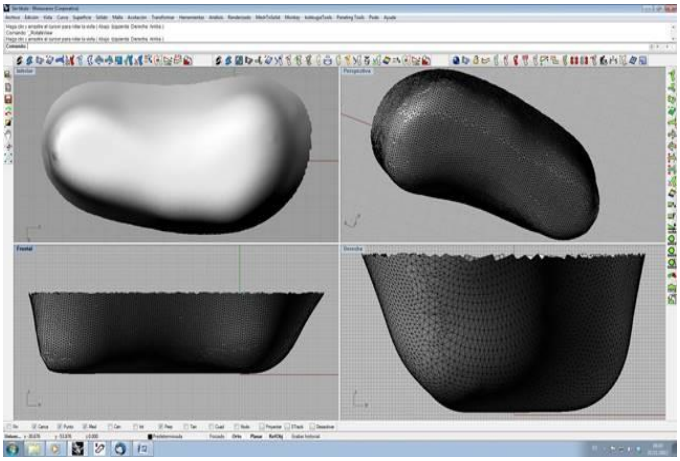

Figure 4. Graphical User Interface of the 3D Scan Insole Designer

The major drawback of this process is that foot scanning and its validation is separated in both location and time. Podiatrists scan the patient's foot in their office. They send these scanned images to insole designers who validate them and design the customized insole. If the scanned images are wrong podiatrists have to make another appointment with the patient to scan his/her feet again. As a result, non-valid images may lead to extra costs and time delays.

To improve this process scanning foot and validation of scanned images must be completed at the same location and at the same time. Providing remote access to 3D Scan Insole Designer podiatrists can scan and validate foot images while the patient is still in their office. If there are any issues with the images they can rescan the patient's foot and validate the images again.

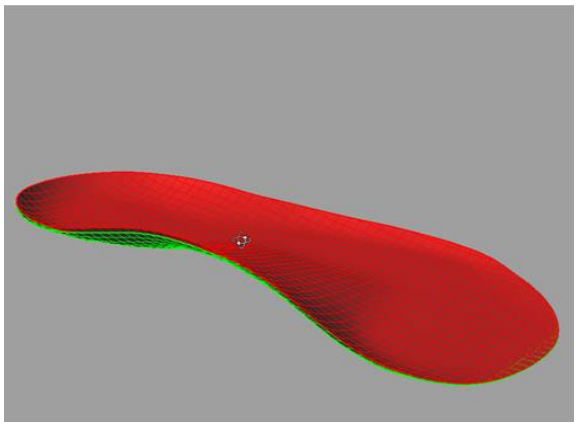

Figure 5. Customized insole design

4. Cloud-Based foot image validation and customized insole design

Having a remote access to the 3D Scan Insole Designer allows not only the integration of scanning foot and validation of the scanned images in location and time but also enables running the insole design process remotely. Considering these options two user scenarios have been identified:

- User scenario 1: remote validation of scanned images,
- User scenario 2: remote design of customized insoles.

4.1 Requirements of remote scanned image validation and insole design

INGECON and Podoactiva compiled a list of functional requirements, such as validating scanned images and designing customized insoles and non-functional requirements, such as data, performance, security, system, user requirements needed for using 3D Scan Insole Designer. Having this list they have collected and analyzed requirements of several Spanish podiatrists and insole designers they have been working with. These requirements are as follows:

- **User requirements.** Podiatrists do not have the same skills as insole designers. They are not regular CAD users. As a result, they need a seamless and user friendly access to 3D Scan Insole Designer tailored to their experience and skills. They want to use this software via internet and a web browser without direct access to any CAD program. In contrary, insole designers are advanced users who want to use all existing functions of the insole designer software remotely.
- **System Requirements.** Rhinoceros CAD software and the 3D Scan Insole Designer runs only on the Windows operating system. This version must be accessible. The minimal hardware requirements of these software packages are 8GB RAM, 250GB disk and Open GL graphics card.
- **Data requirements.** Podiatrists want to upload each scanned image to a backup storage. Even if the image size is small (15-20 MB per image) storage capacity up to 30 GB a month is needed considering that an insole designer company may handle up to 2000 insoles a month. As a further requirement an incremental backup of all images must be stored on a daily basis.
- **Performance requirements.** At one side a single validation may not last longer than 30 seconds. The challenge is that 10s or even 100s podiatrists may try to run simultaneously the insole design software to validate scanned images. At the other side the insole design takes a few minutes but there are much less insole designers than podiatrists.
- **Licensing requirements**. A CAD program license is required to execute 3D Scan Insole Designer. Thus, parallel executions need as many licenses as many validation or design processes are being executed at the same time. It is critical to control and manage simultaneous access to the designer software in order to avoid using more CAD instances than licenses purchased.

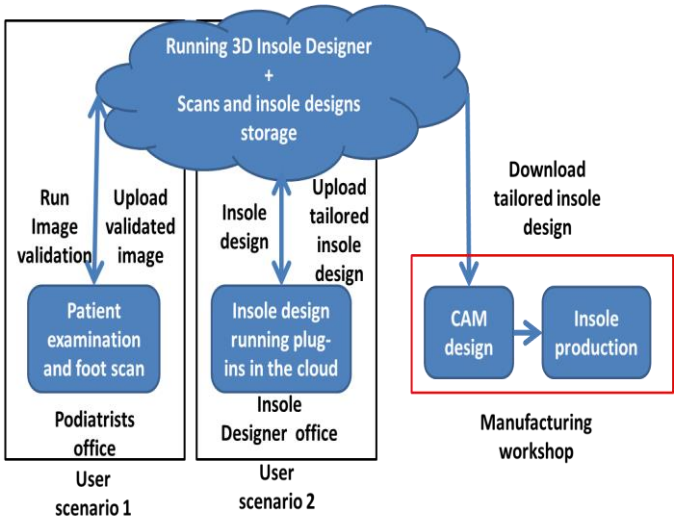

Figure 6. Customized insole design and manufacturing

- **Financial requirements.** The current licensing model of 3D Scan Insole Designer is a PC based model. According to this model users pay per installation. They also need a third party CAD license to run the insole designer software. There must be a new licensing model based on an annual fee per company to maintain the cloud infrastructure including CAD licenses and usage fee for each validation and design activity.
- **Security Requirements.** Validation of scanned images and designing insoles deals with personal and medical information is subject to critical legal requirements. As the patient information is going to be stored remotely, all transferred and stored data must be encrypted. If information is transferred to third party, written patients consent is also required.

Considering the requirements of the user scenarios and the remote access the insole manufacturing process has been modified as shown in Fig. 6.

4.2 User scenario of remote scanned image validation and insole design

User scenario 1: Remote validation of the scanned images. Podiatrists as new users validate the scanned images using the 3D Scan Insole Designer. They have to perform the following steps:

- Step 1: logging into the insole designer. Users must login and a page that enables uploading an stl file with the scanned image of the patient's foot is displayed.
- Step 2: uploading the scanned foot images. Users upload the stl file and select the validation operation

- Step 3: validating scanned images. Users run the validation invoking the 3D Scan Insole Designer remotely.
- Step 4: checking the status of the scanned images. The validation returns the status of the scanned images: scan is valid for design or scan is not valid and must be retaken.

With these simple steps podiatrists are able to check the quality of the scanned image of the patient's foot. If the scan is not valid podiatrists have to rescan the patient's foot and restart the process from step 2. Integrating scanning and validation of images decreases the insole production time avoiding recalling the patient to retake the scan.

User scenario 2: Remote design of customized insoles. The users **and** the inputs of this user scenario are insole designers and the validated scanned foot images forwarded by the podiatrists. The challenge of this user scenario is to deliver all services of the 3D Scan Insole Designer remotely hiding the remote access and achieving better performance. This user scenario contains the following steps:

- Step 1: logging into the insole designer. Users must login to get remote access to the insole designer software.
- Step 2: creating the insole design. The software creates the design the insole using the validated image as an input.
- Step 3: adjusting the insole design manually. Users can modify the design considering the patient's examination report.
- Step 4: finalizing the insole design. The software optimizes the design and generates the final design version to be used in manufacturing.

5. Porting and running image validation and insole design to the cloud

5.1 Cloud-based remote access to services

The major challenge is to provide 24/7 remote access to the 3D Scan Insole Designer to run image validation and insole design. The Cloud can address this challenge providing the required computing and data resources on-demand. The CloudSME project [7] has elaborated the CloudSME Platform [8] (See in Fig. 7). It enables software vendors and service providers to deploy and publish their programs and services on the Cloud. They can configure these entities considering requirements of their users, install the user interface the users want to use and specify how to access these entities, how account and bill resource and service usage. The platform incorporates one-stop shop that allows users to find and run the registered and published programs and services.

The key components of the CloudSME platform are the CloudSME AppCentre and the CloudBroker Platform. The CloudBroker Platform is a web-based cloud service that supports deployment and execution of programs and services in the Cloud. It enables cloud resource providers to register those resources they want to offer users. This platform allows on-demand, pay-per-use and scalable execution via the internet. It enables access to IaaS resources of academic and commercial clouds, for example Amazon and CloudSigma cloud, to run the pre-deployed programs and services. The CloudBroker AppCentre is one-stop shop that provides a web based single entry point users to search, select and run programs and services deployed on the CloudBroker Platform to run business and industry processes. The AppCentre offers user interface for different types of front-ends, i.e. web interfaces, desktop clients and CloudSME access technologies: CloudBroker Platform [9] and WS-PGRADE/gUSE [10]. The AppCentre makes available not only programs and services but their documentation and usage scenarios. It also manages billing and pricing including price management, payment integration, keeping track of users' spending, etc.

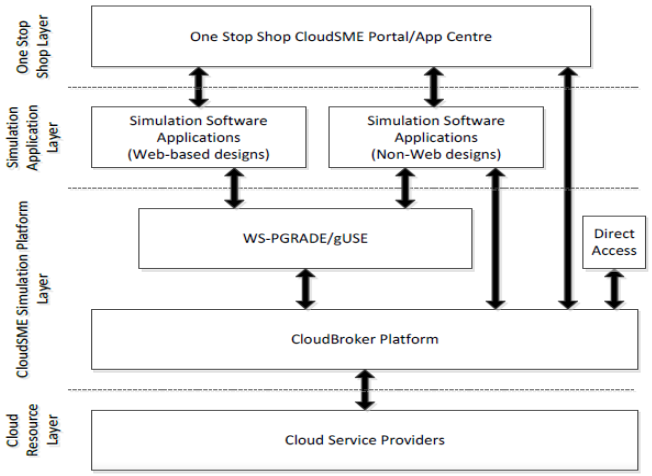

Figure 7. One-shop stop CloudSME Platform

In order to make the 3D Scan Insole Designer as a remote cloud-based Software as a Service (SaaS) INGECON deployed it on the CloudBroker Platform and made it publicly available on the CloudSME AppCentre. The CloudSME Platform provides two types of user interfaces to support remote execution of image validation and insole design:

- **3D Scan Insole Designer Web Portal**, developed by INGECON, connects directly to the CloudBroker Platform through the CloudBroker API (See Fig. 8).
- **Podoactiva Validator**, developed by SZTAKI, uses the gUSE/WS-PGRADE science gateway framework to access the CloudBroker Platform.

Users can access the CloudBroker Platform from their desktop computer through a web server. They invoke a CAD program through a web portal. It forwards the input data (for example scanned images) and the type of the operation (for example scanned image validation) through the web server to the CloudBroker Platform. It creates and submits a CloudBroker job, for example a job that uploads the scanned image to the Cloud, and launches the CAD program that runs the plug-in that validate the scanned images. After completing the operation CloudBroker downloads the output files with the modified image and the operation status (successful or failed)

and sends it through the web server back to the user's desktop computer.

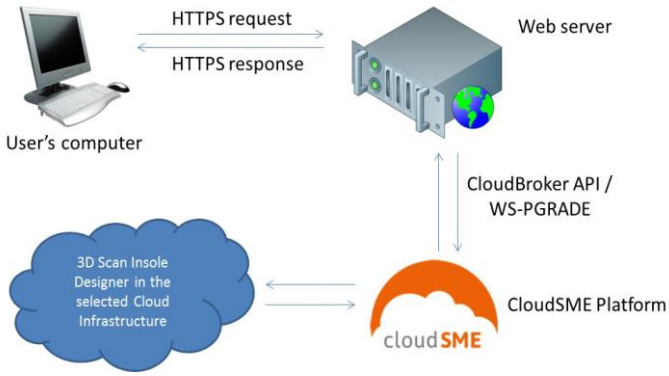

Figure 8. Running the 3D Scan Insole Designer on the CloudSME Platform

The CloudSME Platform provides two types of security measures. First, the communication layer security using SSL to provide transport layer encryption between client and platform, and between platform and cloud infrastructures, as well as for file transfers between platform and storage, client and storage, storage and instance, and platform and instance. Second, the authentication and authorization security uses login and password for each user and different levels of user roles.

5.2 Implementation of the scanned image validation user scenario

After the login operation users can access the upload page (See in Fig 9) where they can upload the scanned images of patient's feet and start the validation.

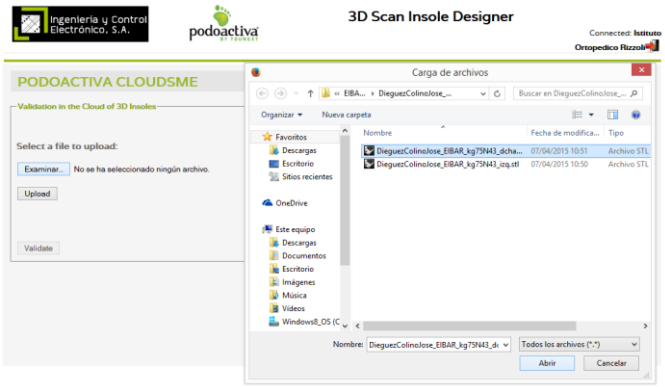

Figure 9. Page uploading the scanned image and starting validation

The validation generates six jpg images (See in Fig. 10) for each scanned image: top, with section cut or not, frontal and back, right and left laterals image. It also creates a new stl file with the validated images and stores it in the Podoactiva directory to make it available for insole designers.

Currently two SMEs: Base Protection and Podoactiva provide support podiatrists to run the remote scanned image validation service.

Figure 10. Page displaying validation results

Podoactive integrated this service with the Podoactiva Enterprise Resource Planning (ERP) platform. First, podiatrists scan patient's feet (step 1 in Fig. 11). Next, they validate the scanned images using the image validation service on the CloudSME Platform (step 2 – step 4 in Fig. 11). If the scanned images are valid they ask Podoactiva engineers to design the customized insole on the CloudSME Platform using the insole design service (step 5 – step 7 in Fig. 11). Finally, Podoactiva insole designers forward this design to the Podoactiva insole manufacturing engineers who produce the customized insole (step 8 – step 9 in Fig. 11). Both the image validation and insole design service are executed remotely using the pre-deployed 3D Scan Insole Design software.

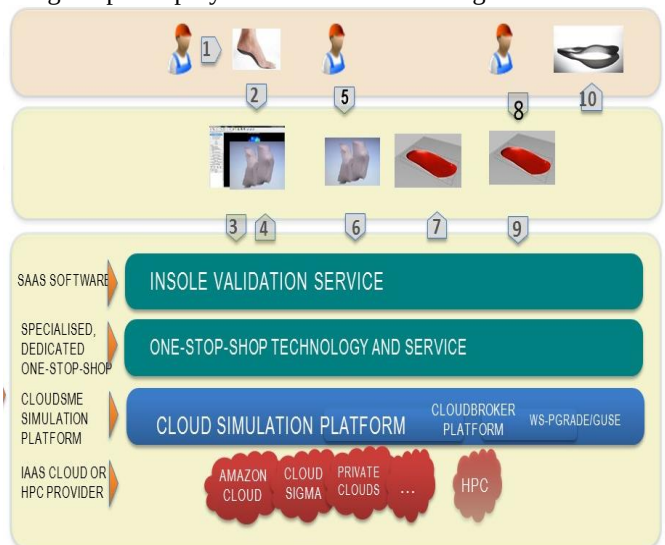

Figure 11. User scenario 1- Podoactiva as user

Base Protection, an Italian SME, [11] produces both customized insoles and safety shoes. They create a new range

of safety shoes using the 3D Scan Insole Designer combining it with their expertise in safety shoe manufacturing. Base Protection uses only the scanned image validation service on the CloudSME Platform (step 2 – step 4 in Fig. 12) through the 3D Scan Insole Designer Web Portal.

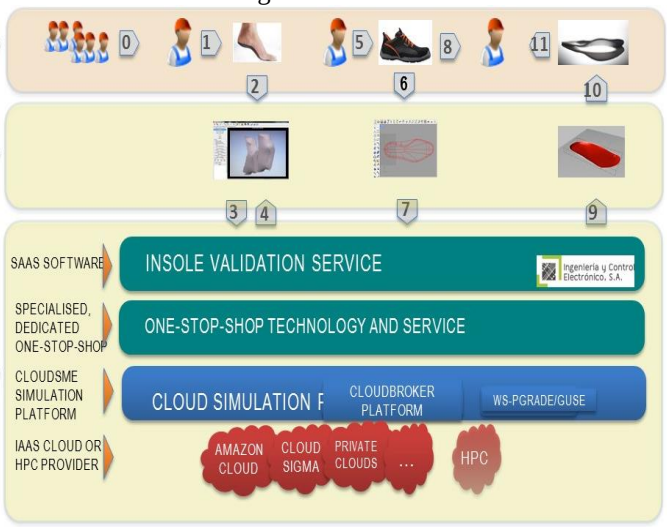

Figure 12. User scenario 1 – Base Protection as user

INGECON and Podoactiva elaborated two business models to run the scanned image validation service. In the first model Podoactiva provides this service through the Podoactiva ERP. Users, such as podiatrists, healthcare companies and hospitals, have to register to access this service. They can upload the scanned images of a patient's feet and launch validation service seamlessly through the Podoactiva ERP using their Podoactiva account. Podoactiva pay for the service use on a pay-per-use basis and charge users through the invoice of the manufactured insoles. The costs include payment for using the cloud resources, the CloudSME Platform and the 3D Scan Insole Designer. The second business model allows users to run these services through the CloudSME one-stop shop. They have to create their own user account at the one-stop shop. To launch the validation service they must buy credits at the one-stop shop. The credits are used to cover the costs of the validation service on a pay-per-use basis.

5.3 Implementation of the customized insole design user scenario

To support remote customized insole design INGECON has developed a new proxy plug-in that enables the execution of this service in the Cloud instead running the 3D Scan Insole Designer on a desktop computer. This plug-in is added as an extra plug-in to the host proxy CAD program deployed on the desktop computer. The proxy plug-in forwards a request to execute a service with the required parameters to the CAD program deployed in the Cloud. This CAD program identifies the service request and runs it. Users can monitor the execution of the operation in the Cloud via the Remote Desktop of the insole designer software (See the right screen in Fig. 13). After completion the CAD plug-in returns the outputs to the proxy plug-in that forwards it to the user's desktop computer.

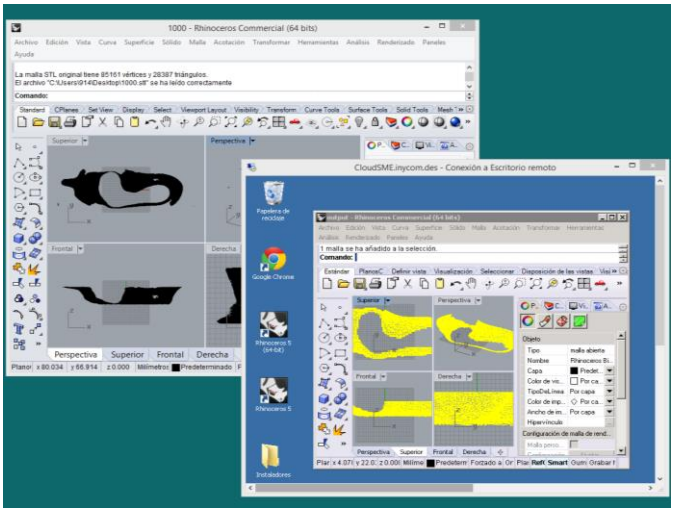

Figure 13. Remote Desktop User Interface of the 3D Scan Insole Design

6. Evaluation of the cloud-based image validation and customized insole design

CloudSME developed a service for validating scanned foot image, deployed on the CloudBroker Platform and published it on the CloudSME AppCentre. Podiatrists started using this service as a production service on a regular basis. The average execution time of the validation service is in the range of a minute. See details in Fig. 14. Podiatrists gave a positive feedback about this service because of the following reasons. First, podiatrists can learn quickly how to use this service not even knowing anything about the 3D Scan Insole Designer software to validate scanned images because it does not require advanced computing knowledge and skills such as CAD user skills. Second, the cloud based validation service allows checking scanned images in the podiatrist office while the patient is there. i.e. it enables running the scanning and validation operation at the same location and at the same time. As a results, it prevents recalling patients when the scanned images are of faulty or of low quality. Thus, it significantly decreases the production time of customized insoles. Third, the accuracy of the customized insoles' is higher and its quality better than previously because of higher quality foot images. Fourth, the one-stop shop provides functionalities, such as billing, queuing and serving simultaneous requests that otherwise should have been implemented by SME software vendors. Fifth, porting the validation service to the Cloud also decreases license fees of the 3D Scan Insole Designer and the CAD program.

The achievements of the remote scanned image validation can be summarized as follows: 80% reduction in rejections,

- 5% shorter the design phase,
- 25% increase in the customer's satisfaction and
- 100 K € savings in software licenses (1000 € per podiatrist)

CloudSME elaborated and ported a prototype customized insole design service to the CloudBroker Platform. It enables insole designers at both healthcare companies and insole manufactures to create customized insole designs accessing this service remotely. This service has a few advantages. First, nowadays, engineers design the insole in one run from getting the validated images to the final sketch. Sharing design software, repository image and sketch in the Cloud makes possible setting up an interactive team-oriented design process where engineers can specialize in different design phases. This could further reduce the design time by another 25%.

Figure 14. Execution statistics of the cloud based service for validating scanned foot images

Second, porting the insole designer software to the Cloud allows insole manufacturers to reorganize the design process to meet requirements of rapid prototyping. Third, the 3D Scan Insole Designer has been developed on a third party commercial CAD program. It is very difficult to ensure its proper IPR protection. Running this software on the Cloud helps the IPR protection both for the software vendor and for the manufacturers. It also makes easier application support, compatibility management, version control and release updates as the software is available at a single location instead of having many executables in many different PCs. The current implementation has some performance issues. Since it is an on-demand service it must be deployed each time when there is a request to run a design operation. It takes about a few minutes to start this service. This start up time must be significantly decreased.

7. Related works

There are several software packages that support validation of scanned images and design of customized insoles.

STT Systems [12] scans the patient's foot using Solescan Rubra. It generates a 3D representation of the sole of the foot. This scanned image is transferred to Insole Studio that helps designing the orthotic insole. This software package allows designers to design and adjust customized insoles for patients. The adjusted insole designs are forwarded to the manufacturers via the internet using the Insole Studio export module. Having the insole design the code for a milling machine is generated to enable automatic production of a positive version of the corrected surface. This surface is used to manufacture the insole through a thermoforming process.

Precision Made Orthoses Laboratory [13] use adaptable and innovative orthoses design software with an open source CAD software to have flexibility within the design process. This approach allows adequate orthoses dressing and adjustments required for some patients. They are able to produce devices that are adaptable and reproducible when required. The Laboratory has CNC machining facilities to enable highly accurate insoles with a superior finish to be produced.

Delcam Healthcare Solutions [14] use the high precision iQube foot scanner that can produce high quality 3D images in seconds. It can scan patient's foot in non-weight, partial-weight and full-weight bearing positions. The scanner excludes the casting process and saves money on shipping costs. Having the scanned images the OrthoMODEL software can design any type and complexity of customized insoles. This software has a customized user interface that hides the CAD engine allowing Podiatrists design and adjust insoles. The software supports any type of correction or add-on such as posts, skives, arch fillers, met-domes, cobra cut outs etc. OrthoMODEL allows designing soft anatomical insoles for diabetic patients, rigid polypropylene devices for correcting gait or foot positives for vacuum forming. OrthoMill, built on the PowerMILL CAM engine, controls manufacturing of insoles using the OrthoMODEL designs as inputs. It creates the toolpaths needed to produce high quality custom insoles in minutes.

All these software provide similar validation and design functionality but they do not offer remote access to these services. As a result, these software packages have the same limitations as 3D Scan Insole Designer had before it was ported to the Cloud.

8. Conclusions

The CloudSME project ported and deployed the 3D Scan Insole Designer to the CloudSME Platform. It provides the scanned image validation as a remote service and allows running the insole design service on the Cloud through a CAD program deployed on a desktop computer.

Previously podiatrists were not able to do validation of scanned foot images. They are medical experts who cannot be considered as advanced computer users. Porting 3D Scan Insole Designer to the Cloud allows them remotely and seamlessly access the validation service using a web portal to upload the stl files with the scanned images and execute validations on the Cloud. This service does not require advanced computing skills for example how to use a CAD program and purchasing extra hardware and CAD software. Having the cloud-based validation service podiatrists can check the scanned images while the patients are still in their office. It must be emphasized that cloud based validation does not significantly increase the patient examination time. Previously, if a scanned image was not suitable for design only insole designers were able be detect it and the patients had to go back to the podiatrist office to repeat the scanning

process. Running validation while the patient in the podiatrist office significantly decreases the insole production time.

Insole designers are advanced users who are able to use CAD programs on their PCs. Having remote access to the 3D Scan Insole Designer they can invoke plug-ins remotely in the Cloud during the insole design instead of executing them in their PC. They also have access to extra computing and data resources on the Cloud. They use a proxy plug-in running in their CAD program. This plug-in calls the insole designer software deployed in the Cloud. The prototype insole design service has a performance issue. Currently the response time of the design functions is around 90 seconds. It is too long because the design actions must be dynamic and quick actions. Designers need a Rhinoceros license to use this CAD program locally on their PC and another license in the Cloud to execute the "real" design functions remotely.

As further works three issues have been identified: response time of the insole design service must be decreased and proper CAD program license policy must be defined. One option to have a proper license management could be purchasing several CAD licenses to run the insole design service on the Cloud and use a licence queueing to avoid executing more CAD instances in parallel than licenses available. Third, 3D printing must be investigated in producing the customized insoles.

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