Platform independent telepathology system for pathologists

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***Abstract*—The present article introduces a telepathology software system, which can be applied for making remote diagnosis. In the field of professional development, researches and medicine, telepathological systems have great importance. Telepathology can bridge effectively geographical distance, between pathologists and digital samples. The realized system supports to view digital slides in a distant and vendor independent manner, include audio and text based comments, opinions, and in order to make a diagnosis, strict data- and privacy protection rules have been followed.**

I. Introduction

The purpose of the remote diagnostic system is to create a service which helps the remote diagnostic assignments of medical experts. The aspect was not to move the pathological samples, but those can be viewed there, from a distant PC, where the sample was originally emerged, so there is no need for copying big slides, and duplicating them in a system, cloud, or storage unit. The second aspect was that not to bound the system to each scanner manufacturer's file format, so by whichever hardware the sample was made, it could be examined. If we disregard these aspects, there are numerous solutions for this problem. For example, Pathonet [1] is a system like, which is a portal for digital slide storing. In Pathonet, some so-called slide servers are defined, which can be considered as a cloud technology based slide storage. The slides are available from any place via Internet connection, they can also be viewed and can be annotated parallel in the same time. It provides a managed process, and it is supporting only vendor specific (3DHistech) digital slides. The iPath [2] is an internet pathology suite, which is similar to the Pathonet slide's storage system. There are further existing alternatives, for instance, such an online web conferencing system [3], which uses skype as a data-transfer channel. Although it does not provide the safe maintenance of data, as well as it results dependence from another service provider. The process itself also cannot be fully manageable. Another solution [4] is a web based system, by which the pathological consultation can be carried out. According to realization, the image transport is realized via e-mails, and only after receiving it can be viewed. Though this solution does not provide the realization of pathological protocol either, furthermore, the e-mail solution could raise data protection question, and image size limitation issues. The system [5] which is used between Iran, Germany and two European telepathology servers, is quite similar to the previously mentioned one. Furthermore, numerous articles were published about different experiences in connection with online pathology, which are made for fulfilling specification tasks [6], [7], [8], [9]. Neither of them are platform-independent, and do not follow the pathological protocol.

In Section II. we describe the overall system design concept. In Section III., the whole operational process is described, from the emergence of the task until its solution. Section IV. explains the testing with its results and Section V. will provide conclusions of our work and Section VI. gives some information about planned future work.

II. Presentation of the remote diagnostic system

One of or main purpose during the development of the system was to eliminate the weaknesses of the diagnosis process, and to develop an easily-to-use software system. The system can be divided into main services. One of the main services in the system is the task management service. The making of diagnoses can be considered as a kind of task, which can be done by one or more medical experts. These tasks are registered in the system as tickets, and the tickets can be assigned to medical experts. The viewing of slides, the making of diagnose and findings can be summarized in a service workflow.

Slide scanner vendors have their non-interoperable software solutions to visualize the digital slides. Within our developed telepathology system we are using remote desktop sharing, and the slides can be viewed with any of the existing vendor dependent viewers, thus eliminate a need of a common multi-vendor slide viewer software. The same services are able to handle digital tissue, smear or any kind of telepathology images, the viewer of the slide is just loosely coupled to the system.

A. System architecture

The system architecture is modular, and contains numerous sub-system. A schematic view of the system architecture is shown in Figure 1.

1) Ticket-tracking sub-system: It is a web based sub-system, in which each ticket represents each tasks. These tasks are to make diagnose. This sub-system records all the

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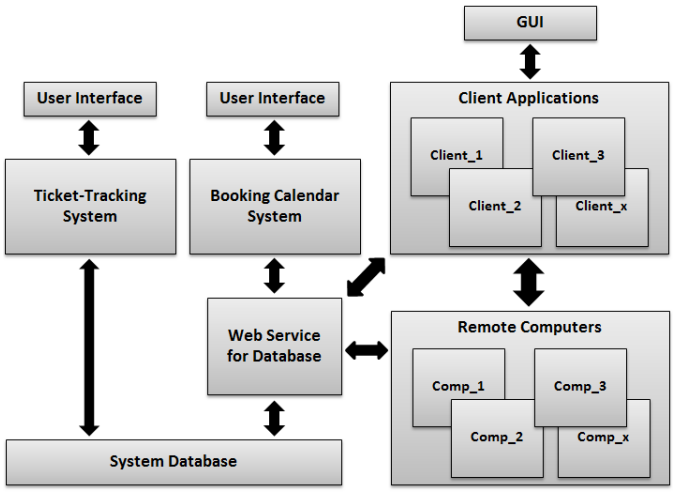

Fig. 1. System architecture.

information in connection with the task, such as the deadlines, the exact description of the task, as well as different documents can also be attached. Those medical expert(s) who accomplish the tasks are stated as the keepers of the task. Depending on entitlement, tasks can be made and accomplished. The task's status changes according to the different stages of its completion. The priority of the tasks can be set, and also observers can be added to them. In accordance with the pathological protocol, medical experts of different status can make diagnose. The status of the tasks belongs to the medical expert's role. These can be the following: candidate, specialist, revisor, and final revisor. Depending on the difficulty and definition of the tasks, the examination processes can be the following:

Candidate → Revisor → Final revisor → Resolved
Candidate → Revisor → Resolved
Candidate → Resolved
Specialist → Revisor → Final revisor → Resolved
Specialist → Revisor → Resolved
Specialist → Resolved

The final revisor can see the previously made diagnoses, whereas the others can only see their own work.

The sub-system automatically sends e-mail messages to users about the actual status of each tasks, or information. When a ticket emerges, at the time of handout, closure of tasks, and about every important changes, an email will be sent. At the handout of task, the data for the continuation of further finding process will be sent, such as the accessibility of appointment-booking system, and the data necessary for the actuation of the client application.

2) Booking calendar sub-system: In the Booking calendar, system appointments can be booked based on the previously got information, for the appropriate distant computer. Here we should give the appropriate data, and the distant computer has been booked for the period, when we would like to fulfil the finding tasks; when we would like to view the sample.

3) Client application: An installed software on the medical expert's own workplace, by which he can reach distant PCs, and he could write diagnosis and record audio recordings on this computer. The computer should have Windows operation system and should run a client application which is developed especially for this purpose. Via this application, the medical expert could connect distant PCs, record audio files or store text comments, and take screenshots of the problematic areas. After finishing the working process, the audio and text stocks belonging to the given ticket will be simply uploaded to the central storage.

After the successful diagnosis, the status of the task changes into Resolved, after a failed process it will remain at its current status. The administrator, who has created the task decides what comes next.

The client application's user interface can be seen on Figure 2.

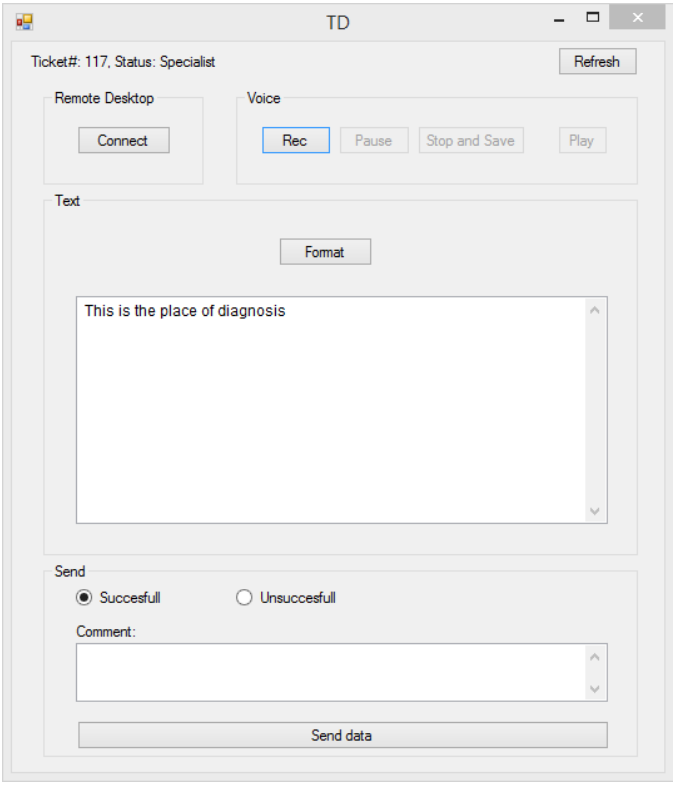

Fig. 2. Client application user interface.

4) Remote computers (location of the sample): Those computers, which can be used for remote diagnostic purposes by doctors with access in the ticket tracking system. These computers can be situated at any point of the world, but these should run Windows operating system. On these clients, the doctor can carry out some diagnostic process with the help of some kind of software (software for opening samples made by digital tissue scanner). On those computers a service runs, via the computers are able to connect to the system database, with the purpose of getting the login information necessary for the next period. The list of usernames and passwords is for the

identification of doctors. The service at a pre-set time queries the certification data for the forthcoming period from ticket tracking system, and according to that it changes the distant PC's user account. Afterwards, with the client application, the connection to the PC will be possible, and the samples can be viewed. There are more computers defined in the system, there is no restriction for that. These PCs are those, which are in connection with the samples, or the samples are placed on them.

III. Introduction of business logic

The internal workflow of the system can be described as following (shown in Figure 3). As a first step, a task should be created in the ticket tracking system. Depending on entitlement, an institution/ hospital can make one. Afterwards, one possible way is to assign the medical expert to accomplish the task. The other way is that the medical expert undertake the task himself. As it has happened, then he can see the data of the task, as well as he can get email notification about further actions. He will get information about the following steps via email, for instance, about the accessibility of appointment booking system, or the data connected to client application. If he booked the distant PC in advance for the needed appointment, and he opens the client application on that particular time, he has the opportunity to connect to the distant PC, on which the slide can be find. After all these, with the previously introduced client application he makes diagnose. Hereinafter further review can be ordered, or if the diagnosis was successful, the task can be terminated.

In the ticket tracking system, the tickets' actual status can be queried, listed according to numerous aspects; it can be seen that in each status which tickets can be found, and who their keepers are, and all other data can also be seen.

IV. Testing

Through the system's testing, the testing of functions was brought to the forefront. During the development, of course, there were numerous testing phases; that is how the unit tests, component tests, black-and-white box tests, interface-tests, integration tests and the complex system tests were made. Afterwards, at first, tests were made during normal use and extreme use as well. One of the biggest bugs arose at such complex, international testing. At the point of this particular bug, the problem was the alternation of winter-summer time zone. Regarding the resources, there is no specific condition. In a device, in which the side viewers of different manufacturers work and these have internet connection, our system works. It means that the device should have at least 1GHz processor, 2GB RAM, and a 20GB hard disk size. Concerning the internet connection, there is a minimum of recommended speed, which is 1 Mbps in case of up- and downloading as well. According to tests, if it has this speed, then the slide viewing and data saving also work appropriately. The system meets the expectations and the system specification properly.

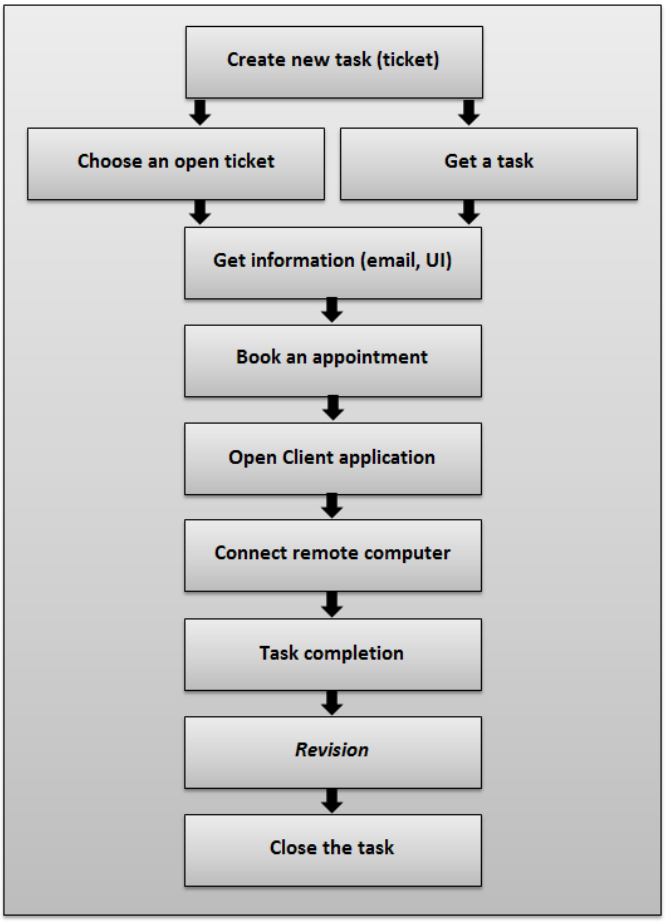

Fig. 3. Flowchart of diagnosis.

V. Conclusion

The present software system is able to fulfil remote diagnostic tasks. The system maintains the whole working process, from the incoming requests till the end of finding or diagnostic process. It actively supports the description of a task to be done, the attachment of existing documents, the attachments of audio blogs, the management of status, the person of the executor of the task, revisions, the emerged data of the tasks' walk of life, notes, and the emerged data during the finding process. The system supports multi-user access. Multiple remote client and virtual computers can be connected in parallel, therefore more finding samples will be available at the same time, and thus, multiple tasks can be performed per unit of time.

The system is platform-independent from the scanner's manufacturer, which means that the access and the viewing of remote samples made by any kind of scanner is possible. There is no need for collecting the samples, neither other data movement, since these have been viewed in the place of its creating.

In the system, there is possibility for querying statistics, therefore the tasks can be managed simply; the people, who carry out the tasks can be checked easily; the expenses and

resources can be calculated, and the regional gaps can also be ascertained.

But the system is universal in the sense that not only medical diagnostic tasks can be performed by it, but other tasks, in which a digital storage should be reached, or take a look at it, and which cannot be sent to the examiner due to legal or other reasons.

The whole process can be planned and supervised in advance, simply and easily. There are distributed, predefined roles, by which the eligibility issues can be eliminated. Using the system, the finding or examining task can be accomplished from every point of the world, independent from the expansion of the sample and the manufacturing process.

VI. Future Work

Besides the management of tasks, there is an increased need for further commercialization of the system (e.g.: including online payment services). Another future plan is to incorporate quality control services into the system.

To enable more users, the system is planned to be ported also to other client platforms besides Windows, such as the support of MAC OS platform, (developed by Apple), on a personal computer. In addition, there is also a great demand for mobile devices; for instance, tablets, mobile phones, so that the Android platform (developed by Google) support is also concerned as further development target.

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