A Framework about Using Internet of Things for Smart Cancer Treatment Process

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Abstract

This paper introduces a new framework of using Internet of Things (IoT) in the context of cancer treatment. The framework depends on the integration of different stages of cancer treatment including radiotherapy and chemotherapy. At the radiotherapy stage, a mobile application is connected to a cloud to serve online consultation and successive appointments. Likewise, at the chemotherapy stage appointments are given to the patient and online consultation is also accessible. Besides, during the drug infusion process the patient is tracking to recognize the response of his/her body against the chemotherapy dose. All the appointment features are connected to scheduling algorithms that can be adopted from the recent literature. Moreover, all the lab-test results of patients are uploaded instantaneously to the cloud so that decisions towards the dose amount and its timings are made. Regarding the customized chemotherapy doses, optimization models can be adopted from the recent literature to give the optimum doses. On the other hand, decision support platform can be adopted to check the treatment efficacy for standard protocols.

Keywords
IoT, cancer treatment, decision-support, radiotherapy, chemotherapy

1. Introduction

Industry 4.0 (The fourth industrial revolution) is a name for the current trend of automation and data exchange in manufacturing and service technologies. It includes cyber-physical systems, the Internet of things (IoT), cloud computing and cognitive computing. IoT is a system of interrelated computing devices, machines, objects, animals or people and the ability to transfer data over a network without needing human-to-human or human-to-computer interaction. IoT has evolved from the union of wireless technologies, micro-electromechanical systems, micro services and the internet. This convergence has helped remove the walls between operational technologies and information technology, allowing unstructured machine-generated data to be analyzed for insights that will give improvements.
In the context of healthcare, IoT will solve the problem that people have limited time, attention and accuracy, and are not very good at pick up data about things in the real world. If we had computers or smart devices such as wearable devices that knew everything there was to know about things. With data they gathered, one would be able to track and count everything and greatly reduce waste and cost.
(IoT) is the information network of physical objects such as machines, vehicles, home appliances, buildings, and other items embedded with electronics, sensors, software, that allows connectivity, exchange data, interaction and cooperation of these objects to reach common goals [1]. IoT has many applications areas such as transportation, healthcare, smart homes and industrial environments [2].
Healthcare is expected to receive more attention of IoT applications such as remote patient monitoring, smart sensors and medical device integration. It has the potential to keep patients safe and healthy, improve how physicians deliver care. Healthcare IoT can correspondingly boost patient engagement and satisfaction by allowing patients interact more with their doctors.
In this paper, we introduce a framework about using IoT in the context of cancer treatment. The framework depends on the integration of different stages of cancer treatment including radiotherapy and chemotherapy. At the radiotherapy stage, a mobile application connected to a cloud of the patients is proposed to serve the online consultation and successive appointments. Likewise, at the chemotherapy stage appointments are given to the patient and online consultation is also accessible. Besides, during the drug infusion process the patient is tracking to recognize the response of his/her body against the chemotherapy dose. All the appointment features are connected to scheduling

algorithms that can be adopted from the recent literature. Moreover, all the lab-test results of patients are uploaded instantaneously to the cloud so that oncologists can make decisions towards the dose amount and its timings. In terms of the customized chemotherapy doses, optimization models can be adopted from the recent literature to give the optimum doses. On the other hand, decision support platform can be adopted to check the treatment efficacy for standard protocols.
The remainder of this paper is organized as follows: section 2 gives an overview about cancer treatment; section 3 presents some problems with cancer treatment; section 4 introduces the proposed framework.

2. Overview about Cancer

Cancer is caused by cells that divide at an uncontrollable rate resulting in the unregulated production of new cells. Cell division of normal cells is tightly controlled in the body, but in the case of cancer cells, the body fails to regulate this function. The gradual increase in the number of dividing cells creates a tumor. If this tumor is invasive, it is called a malignant tumor. Cancer cells can spread throughout the body by two mechanisms: metastasis and invasion. Metastasis refers to the penetration of cancer cells into the blood stream and migration to normal cells of the body. Invasion refers to the penetration of cancerous cells into the neighboring tissue. Cancer has four stages: stage 1, 2, 3, and 4. Stages 3 and 4 have a larger number of dividing cells and are less responsive to treatment compared to the first two stages.
There are more than 100 different types of cancer. These types are usually named after the organs or tissues where the cancers form. For instance, lung cancer starts in cells of the lung. Also, it may be described by the type of cell that formed them.
Cancer is treated using various kinds of treatments such as surgery, radiotherapy, chemotherapy, hormonal therapy, immunotherapy, targeted therapy, transplants, and much more. Chemotherapy is used to treat many types of cancers either alone or in combination with other treatments. In chemotherapy, a single chemical drug or a combination of multiple drugs is administered through the patient's blood stream and/or orally. Due to the different types of cancer and the fact that it goes in different stages, one course of therapy is not a good fit for all patients, and thus the oncologist decides the treatment plan according to several chemotherapy protocols. It is important to note that the protocol should be strictly followed and given in specific times. Moreover, every protocol has a different infusion time. In addition, chemotherapy is cyclic in nature, and before every dose, several lab tests should be done. Therefore, chemotherapy is a complicated process, and each patient is unique with his/her specific needs.
Until the 1990s most cancer care was delivered in an inpatient setting; inpatient means that patients stay in hospitals. Today, almost all cancer care is delivered in an outpatient setting. A description of patient flow in a typical Outpatient Chemotherapy Clinic (OCC) is presented in figure 1. As early as a patient goes to the OCC according to a previous appointment given by the scheduler, a receptionist arranges the necessary support to fulfill registration. Second, before the patient is examined, he/she should prepare his/her most recent lab tests and of course the planning chart. Based on these lab-test results, a nurse (or physician) assesses whether the patient will see the oncologist or go to the infusion clinic to take the chemotherapy dose directly. In the consultation stage, the oncologist examines the patient, see the lab-test results and the patient's chart, then he/she approves, adjusts, or cancels the dose. In the case of cancellation, the oncologist schedules another appointment for the patient according to the modified treatment plan, and therefore the nurse updates the scheduler to assign that next-day appointment. These activities are regularly performed to patients who are not new. In the case of new patients, the oncologist plan a chemotherapy regimen for that patient after examination and the lab-test results, and possibly starts the dose infusion process on the same day according to the available time slots and resources on that day which are planned by the facility scheduler. Third, the oncologist states and sends a prescription of the decided dose to the pharmacist to prepare it. The pharmacist collects the prescription by hand, telephone or email, in relation to every facility infrastructure, then the pharmacist prepares the dose. The patient keeps waiting until the dose becomes ready. After the pharmacist prepares the dose, a porter takes it to the infusion clinic, meanwhile, a nurse takes the patient to start the dose infusion. Once the infusion process becomes steady, the nurse redoes the infusion start-up with another patient. It is worth noting that the infusion nurse is a shared resource in the infusion clinic. Hence she can monitor more than one patient concurrently. If complications occur during the infusion process, the nurse administers that situation until the patent's vitals become normal. Finally, the nurse finishes up the infusion process for the patient and provides him/her instructions and the patient is discharged.

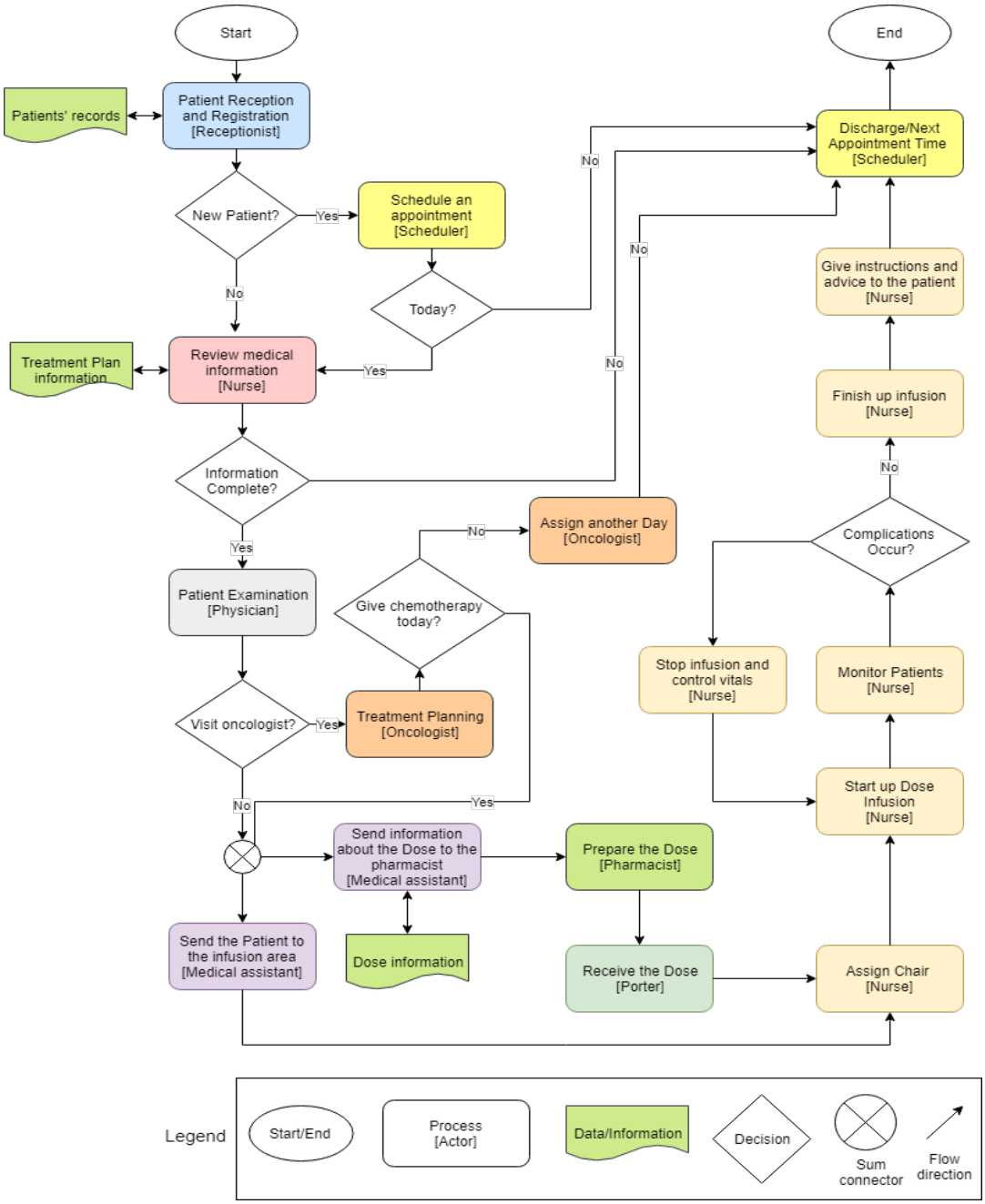

Figure 1. Patient flow in the OCC

3. Problems with Cancer Treatment

A survey was conducted in 2011 about the performance of OCCs [3], and the main operational problems are found in five stages, scheduling, registration, lab test, drug preparation, and treatment.

3.1 Operations Planning

Operations planning in OCCs aims at the assignment of patients to the treatment day and the exploitation of all resources efficiently. Nevertheless, the treatment plan of chemotherapy has to be strictly followed without delay. It was stated in [4] that "*a delay in chemotherapy delivery reduces the Dose-Intensity (DI) received. It has been calculated that each 7-day delay results in an approximate 5% decrease in the DI.*" However, due to fluctuation in

demand and variability in the treatment durations under time and resources constraints, the decision maker is forced to delay some treatments away from their planned day.

3.2 Patient Wait Time

One of the ways to improve efficiency and service is by reducing the delays in the chemotherapy delivery process. Patient wait times is one of the critical outcomes of process delays and is an important quality indicator which affects the level of satisfaction of the patients [5]. Patient wait becomes more critical when the patient is a child that is hard to control and manage.

3.3 Nurse Workload

The oncologist is in charge of deciding the suitable treatment protocol for a patient and the nurse is responsible for administering the dose infusion. Most of the oncologist tasks are delegated to the oncology nurses such as patient education, counseling and assessing the patient response to the treatment and providing counseling to the patient's family members. A survey by the National Academic Press found that much of the nursing time is spent in doing indirect care delivery tasks. The survey concluded that about 23% of the nursing time is spent in filling out patient care-related notes and documentation [6]. They found that there is a considerable increase in overtime and double shifts [7]. With the added responsibility of nurses and the shortage in this resource, it is vital to implement new models of care that will facilitate optimal care delivery by improving the efficiency and utilization of different resources in the OCCs. According to the survey conducted by the Oncology Nursing Society [8], the number of chemotherapy treatments administered per day by a nurse considerably varies.

4. The Proposed Framework

The proposed framework as shown in figure 2 consists of four main stages, the treatment planning stage, operations planning stage, patient appointment scheduling stage, and patient database. All the four stages are connected to each other and via a cloud that updated and integrated on a mobile application that can be accessed by the patient, the nurse, and the doctor.

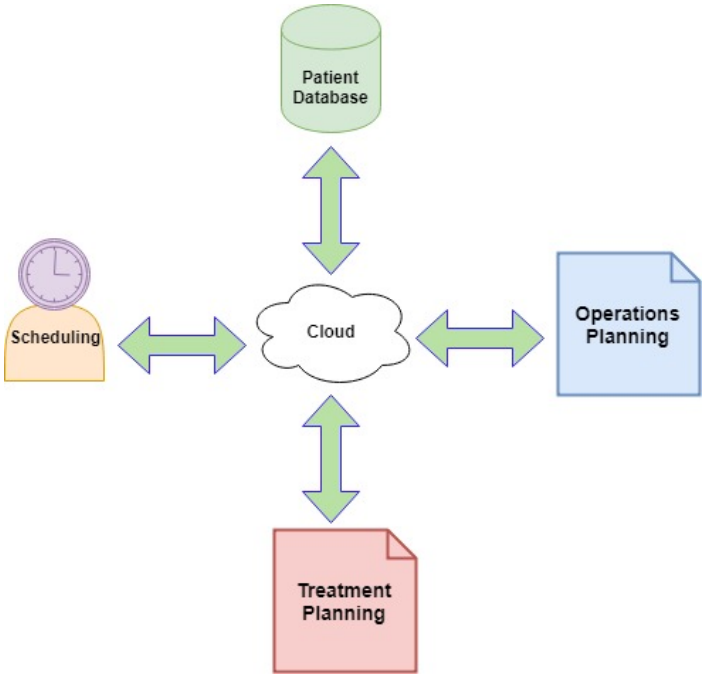

Figure 2. The Proposed Framework

4.1 Treatment Planning Stage

The treatment planning stage is the stage in which the treatment method such as radiotherapy or chemotherapy is decided. If chemotherapy is decided, the best chemotherapy protocol is decided and sent to the operations planning stage.

4.2 Operations Planning Stage

At the operations planning stage, all the resources are considered to converge to the best treatment days for each current patient and new ones. The recent literature is already has algorithms such as in [9, 10] that can be applied to decide the patient treatment plan and the facility operations plan.

4.3 Patient Appointment Scheduling

At this stage, the patient is given a specific time to come to the clinic to take the treatment considering the minimum patient waiting time and treatment completion time. The work of [11–16] can serve well in this stage which contain patient appointment scheduling algorithms and mobile applications to facilitate the booking services and online consultation.

4.4 Patient Database

During and after the treatment process, tracking sensors and wearable devices are installed to monitor patients. Furthermore, all the lab-test results are uploaded to the cloud to be invited when needed.

5. Conclusions

This paper introduced a framework in the context of cancer treatment facilities especially radiotherapy and chemotherapy. The framework integrates four main stages of treatment, namely, treatment planning, operations planning, patient appointment scheduling, and patient database. Sensors are proposed to track patient during the treatment process and wearable devices are proposed as well. A mobile application is proposed to give the access of updating and notification for the patient, doctors and nurses. The proposed framework would make the treatment process as a whole and therefore facilitate the treatment burden on patients.

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Biography

Mahmoud Heshmat is an assistant professor at the Mechanical Engineering Department, Assiut University, Egypt. He earned his PhD from the Industrial Engineering and Systems Management Department in the Egypt-Japan University of Science and Technology (E-JUST), Alexandria, Egypt. During his PhD study, he was an exchange student at Tokyo Institute of Technology, Tokyo, Japan for one year. He earned B.Sc. and MSc in Mechanical Engineering, Design and Production Section from Assiut University, Egypt, and worked as a teaching assistant and then assistant lecturer at Assiut University. His research interests include, operations research, simulation, optimization, healthcare management, scheduling, and manufacturing.

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