Web based Microservice Framework for Survival Analysis of Lung Cancer Patient using Digital Twin

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Abstract

One of the most promising technologies that is raised from the fourth industrial revolution is Digital Twin (DT). A DT captures attributes and behaviors of the entity suitable for communication, storage, interpretation or processing within certain context. A digital twin based on microservice framework architecture is proposed in this paper which identifies elements required for the complete orchestration of microservice based Survival Analysis of Lung Cancer Patients. Integration of microservices and Digital Twin Technology is studied.

1. Introduction

The concept of Digital Twin (DT) originally appeared in manufacturing literature at the beginning of 2010s, referring to a digital representation of an asset (e.g., physical objects, processes, devices) containing the model of its data, its functionalities and communication interfaces [1]. In recent years, DT has been applied to multiple different areas of industry such as smart cities and manufacturing settings (automobile industry etc.). The healthcare sector is another area for the application of Digital Twin technology.

The impact of the growth and developments enabling technology on healthcare is unprecedented as the once impossible is becoming possible [2]. One of the current applications in healthcare DT is simulating effects of certain drugs. Similarly other applications within a healthcare setting is the use of a Digital Twin gives researchers, healthcare providers the ability to simulate environments specific to their needs whether it be real-time or looking to future developments and uses. Many applications within healthcare setting do not directly include the patient but are beneficial for the ongoing care and treatment, hence the key role such systems have on patient care [2].

The digital twin, in this case, is meant to be useful for realizing more effective care interventions, helping Physicians and other intersecting care technologies in understanding the survival rate of the patient. In this context, the main research question that we consider in this paper is about constructive simulation of DT with Microservice based Survival analysis of Lung Cancer Patients, in particular what sort of integration can be conceived and what are the benefits that Web based Microservice Framework for Survival Analysis of Lung Cancer Patient using Digital Twin can bring. Along with the microservices we observe how this framework can be employed as recommendation system for the Physicians and healthcare organization.

2. Related Work

2.1 Digital Twin in Healthcare

An agent-based digital twin service is proposed in [1]. The concept of mirror worlds is developed in context of Multi-Agent Systems. The case of Trauma management has been used in the context of digital twin. Pre-hospital procedure of Trauma and in Hospital Trauma Management are treated as individual digital twins and are then interoperated with microservices.

2.2 Microservices to support Predictive Analytics

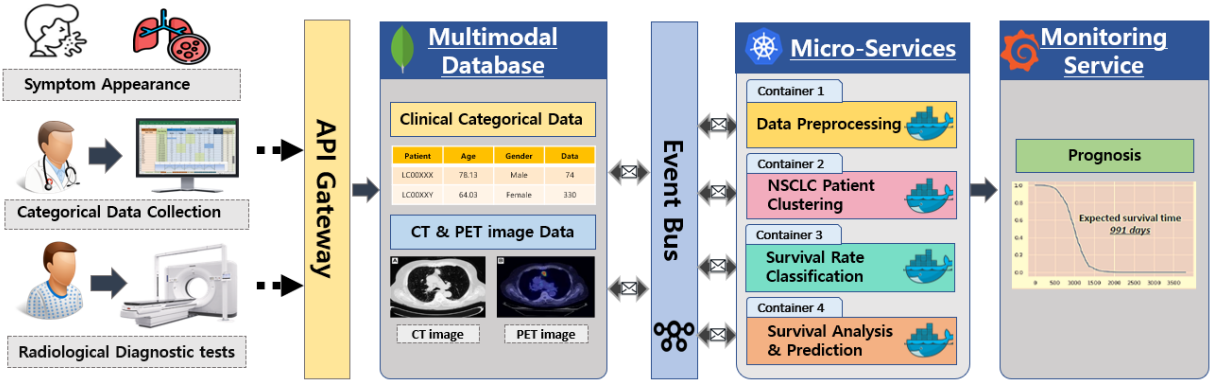

Figure 1. Overview of Microservice Framework for Survival Analysis

Web objects concepts to support scalable and efficient services for IoT applications are dealt in [4]. The article has proposed a way to analyze data from heterogeneous sources and provided a multilayered model based on microservices and web objects concepts.

3. Microservice Framework for Survival Analysis of Lung Cancer Patient using Digital Twin

Real world objects are related to physical people requirements. The requirements include disease symptoms, clinical tests, pathological tests, medical treatment plan pathways and management, which requires a quick optimal solution in real time according to the patient's physiological state, the environment and external factors information to achieve early warning or disease prevention and treatment. With this, demands from virtual people require disease screening tests, data mining, survival analysis etc., to support the survival rate analysis identification. These tasks can be decomposed into sub-tasks which only focus on a specific problem such as data preprocessing, survival classification, and survival analysis in the cloud microservice platform.

The motivation to build the DT framework comes from the concept of digital counterpart of healthcare services for lung cancer survival analysis. Digital counterpart is mirroring of not only physical objects or people such as patient but also the processes involved [1]. In this paper the aspect of microservices is emphasized as an important part of DT.

3.1 Clinical Diagnostic Tests

After considering patient's clinical history, medical signs and patient's reported symptoms Physician suggests some diagnostic tests such as radiological imaging along with other diagnostic testing criterion to confirm with the diagnosis. The diagnosis data including clinical data, CT/PET image scans are uploaded by Physician using API Gateway of the proposed microservice framework for survival analysis. API Gateway acts as a reverse proxy to accept all application programming interface (API) calls, aggregate the various services required to fulfill them, and return the appropriate result to the Physician.

3.2 Data Storage

Data is available across wide range of modalities, from visual data in the form of images and videos to language data in the form of text and speech. In this case multimodal data in the form of image data and clinical categorical data(text) have been used.

The Physician can upload the clinical categorical data and radiological scans (CT/PET images) on the database registry where it gets stored. The Event Bus provides a pipeline through the microservices for the database to be accessed by all microservices according to the requirement.

3.3 Microservices

The proposed microservices application architecture involves breaking a monolithic application into its component services. After identifying the individual services, we refactor the monolith so that each service runs autonomously as a separate "microservice". Then they loosely connect these microservices via APIs to form the larger microservices-based application. The microservices are processed in a container individually on a cloud-based server. Kubernetes, a Container Orchestration tool is used to efficiently allocate processing resources to the container as required. The proposed microservice architecture provides better fault isolation, scalability, flexibility to use the programming languages and technologies that best fit for the proposed framework. The stream processing in the framework implies stateful operations, but microservices should be stateless. Thus, stateful stream processing can be supported in the proposed architecture with the help of Event Bus. Event Bus

makes it possible for the microservices to work independently.

3.3.1 Data preprocessing

One of the microservices from survival analysis of lung cancer patient is Data Preprocessing. As the uploaded data by Physicians is raw data (real world data) it becomes crucial to transform the data into machine understandable format. During this process, one hot encoding is performed. For image data PET/CT image shape is transformed.

3.3.2 NSCLC Patient Clustering

In NSCLC Patient Clustering, Feature Extraction is performed using multimodal data (Clinical data, CT/PET images) of lung cancer patients to find new lung cancer patient's survival cluster instead of using the final stage (referred with the help of American Cancer Association's TNM staging classification system.) DEC (Deep Embedding for Clustering) technique based on deep learning is implanted for the NSCLC Patient Clustering.

3.3.3 Survival Rate Classification

Survival Rate of Lung Cancer Patient over 5 years period is predicted with Binary Classification using multimodal data (Clinical data, CT/PET images). RESNET 3D 18-layer model is used to extract features for CT/PET image data.

3.3.4 Survival Analysis and Prediction

DeepSurv, a Cox proportional Hazards model survival method is used for modeling survival analysis of the lung cancer patients. Patient's survival date is predicted. Feature Extraction from multimodal data (Clinical data, CT/PET images) is performed and have been used for survival analysis.

3.4 Monitoring Service Interface

In order to provide effective visualization and analysis information of the survival analysis, Grafana platform is used. Grafana Platform increases operational efficiency for the proposed framework. Monitoring service interface provides the Physician with survival rate prognosis of the patient which acts as a decision support in further treatment plans.

4. Recommendation System

The proposed architecture uses an ontology-based knowledge graph to get clear view of interoperability between virtual objects (VO), composite virtual objects (CVO) and services.

Real World Objects (RWO) are not necessarily directly connected to the applications. To control and maintain the RWOs, as they are in physical world, RWOs are virtualized using semantic ontology. For proposed framework, patients, Physicians, clinical data, CT/PET scanner machine, CT/PET scans etc., act as RWOs. Information collected from these objects is transformed and stored on Database Registry from VO level. CVOs are created by combining multiple functionalities of VOs, constraints and service policies. System Knowledge Creation particularly collection and transformation of the RWO data, data modality management that is multiple modalities of data (Clinical data, CT/PET images), Patient monitoring is where functions of CT/PET scanner, information related to patient such as medical history of, diagnostic tests data are processed and stored in the Database Registry. Service level contains services provided in the proposed microservice framework that are Survival Analysis, Survival Classification and NSCLC Patient Clustering. Applications such as Decisions of Lung Cancer Treatment Prognosis and Initial treatment

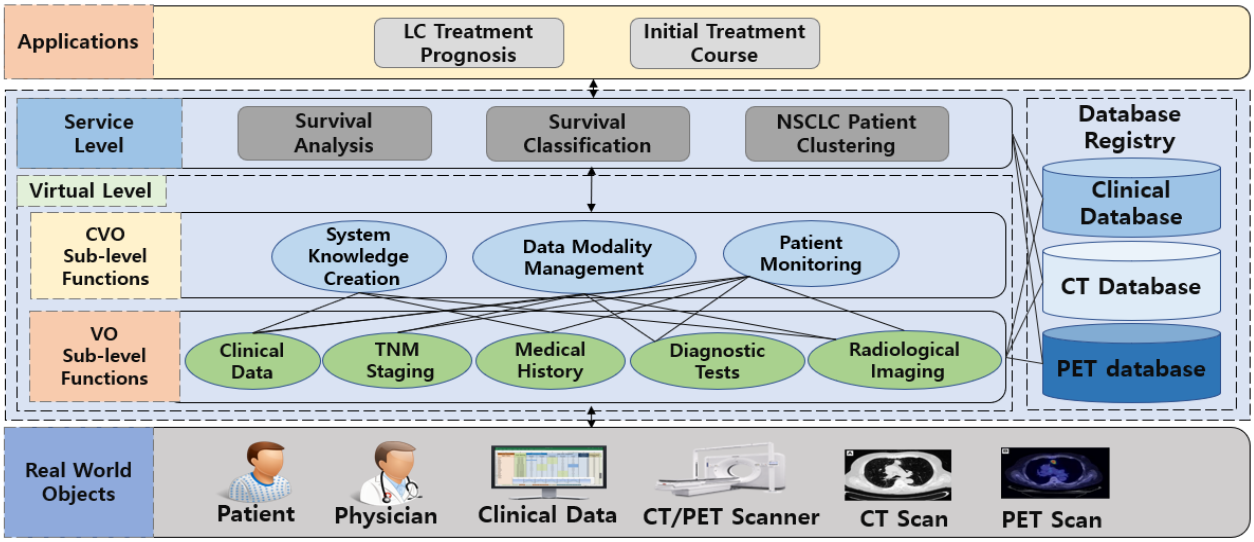

Figure 2. Level Wise Survival Analysis Recommendation System Architecture

Course are supported by the Service Level. Main advantages of level wise Survival Analysis Recommendation System Architecture are user centric service provisioning, situation awareness and knowledge based intelligent decision making. This enables control and broad spectrum of both choreography and orchestration between available services. In Figure 2 required Real world objects i.e., physical objects are represented in the form of virtual objects in VO level. Relevant VOs and their information, for specified composite VOs, is accumulated at CVO level and the web services are offered by collaboration of CVOs. Applications are supported by the service level.

5. Conclusion

The Web based Microservice Framework for Survival Analysis of Lung Cancer Patient using Digital Twin is proposed in this paper. Each task is treated as microservice and deployed on the cloud infrastructure. Third party users such as data analysts and Physicians will be able to quickly determine initial treatment prognosis based on the survival rate of the patient determined using the proposed framework. The digital twin based microservices will be in execution on the hospital private cloud infrastructure and can be accessed only from applications running within such context. Future exploration will be complete development of the designed conceptual architecture.

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