


Building the hospital intelligent twins for all-scenario intelligence health care

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Abstract

The COVID-19 pandemic has accelerated a long-term trend of smart hospital development. However, there is no consistent conceptualization of what a smart hospital entails. Few hospitals have genuinely reached being “smart,” primarily failing to bring systems together and consider implications from all perspectives. Hospital Intelligent Twins, a new technology integration powered by IoT, AI, cloud computing, and 5G application to create all-scenario intelligence for health care and hospital management. This communication presented a smart hospital for all-scenario intelligence by creating the hospital Intelligent Twins. Intelligent Twins is widely involved in medical activities. However, solving the medical ethics, protecting patient privacy, and reducing security risks involved are significant challenges for all-scenario intelligence applications. This exploration of creating hospital Intelligent Twins that can be a worthwhile endeavor to assess how to inform evidence-based decision-making better and enhance patient satisfaction and outcomes.

Keywords

Smart hospital, intelligent twins, digital twins, all-scenario intelligence, China

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The fast evolution of big data, network technologies, and artificial intelligence (AI) has set off a new wave of the digital revolution in healthcare. Building a smart hospital is one of the ultimate goals pursued in hospital digital transformation. However, there is no consistent conceptualization of what a smart hospital entails. Few hospitals have genuinely reached being ‘smart’, primarily failing to bring systems together and consider implications from all perspectives.

In China, smart hospitals are graded based on three dimensions; smart medical technology for the doctor, smart services for the patient, and smart management for the administrator evaluated separately.¹ Hindered by the siloed nature of the operating models or interoperability issues surrounding various health information systems, hospitals face challenges achieving a real-time health system with full integration. In 2020, Guangdong Second Provincial General Hospital (GD2H) teamed up with Huawei had explored building a smart hospital for all-scenario intelligence by creating the hospital Intelligent Twins.

Intelligent Twins was first introduced by Huawei at HUAWEI CONNECT 2020,^{2,3} which can be defined as a set of digital twins ensemble together as one integrated

system. The concept of digital twins is a developing concept that can be defined as the interconnection of the digital and physical for data sharing and is characterized by physically geometric visualization, life cycle management, real-time sensing and measurement of system operating conditions, and predictability of system performance/safety/lifespan. Digital twins are a critical enabler for Industry 4.0, particularly in terms of digitalization and visualization. The digitalization process necessitates massive amounts of data generated, gathered, managed, and processed by various sources, including digital twins, posing new issues that must be addressed. The core of Intelligent

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Twins is cloud services, and application AI promotes data utilization. With collaboration from across the cloud, network, edge, and device, Intelligent Twins enables an intelligent, open system that is capable of all-dimensional perception, all-domain collaboration, decision making, and continuous evolution, delivering an intelligent experience for people, cities, and enterprises in all scenarios.²

This all-scenario intelligent smart hospital stands for the perspective of the doctor, nurse, patient, and administrator, focusing on the users' experience. By creating departmental digital twins and intelligent wards that are powered by the 5G application, cloud computing, big data, AI, and internet of things (IoT) technologies, with a combination of building information modeling (BIM), and simulation, it achieved the whole process of intelligent management, covering medical service, teaching, clinical research, and hospital operation.⁴

In the meantime, the Intelligent Twins realizes the all-scenario intelligence, full-element collaboration, life-cycle management, and continuous evolution and growth with the connection of personnel, finance, and property. By achieving these, the hospital can continuously improve the medical services for the patient, increase the diagnosis and treatment efficiency and quality by assisting the doctor, and optimize management levels for the administrator.

The main components of the hospital Intelligent Twins include a hospital smart brain, clinical department digital twins, and intelligent wards.

The hospital's smart brain is the intelligent center of the hospital Intelligent Twins. The interface reflects the hospital's 3D digital twin model, constructed based on BIM technology (Figure 1). The interface integrates five intelligent application modules, including the hospital's overall situation, medical operations, security situations, firefighting situations, and energy consumption conditions. Medical operations include operation situations, core indicators, and performance appraisal. The smart brain demonstrates the visualization and coordination of the overall resources of the hospital. It emphasizes the coordinated operation of section businesses, including security and fire control, emergency commands, and first aid commands. Meanwhile, it can display and analyze the core indicators of each section of business on-demand, and monitor the implementation of the situation.

The clinical department digital twins plays an essential role in the hospital's Intelligent Twins.⁴ A good example is the radiology department, which analyzes operational data to visualize and simulate MRI and CT usage through the workflow. A digital twin was created to illustrate a 3D computer model of the radiology department and its operations. The data sensed through intelligent interaction is connected and gathered into the intelligent hub to form insights and descriptions of the physical world. These perceived data are mapped in the digital twin to realize real-

time and dynamic perceptions of departmental entities. This allows us to dynamically sense the working status of different types of radiology equipment, cameras, smoke detectors, etc., in a real-time manner, and display the equipment's fault maintenance status, work performance, and use of consumables simultaneously. By combining this data with information from AI cameras, wearable devices, and monitoring devices, the queue status of waiting patients can be determined. Moreover, rationally allocating resources, arranging inspection priorities, proactively identifying patient falls, monitoring critical conditions, and sending warning information to relevant medical staff, can be done through the system.

An intelligent ward is a place where the intelligent interaction of devices is essentially embodied. It is presented in three scenarios: ward, corridor, and nurse station. Each scenario is managed interactively through smart screens. In the corridor, there is a door number screen at the entrance of each ward, which displays the name of the bed doctor, the nurse responsible for the ward, and the ward bed number. The medical staff can pitch the screen through a smartwatch to further display the patient's information and status under the bed number. Each bed is equipped with an overhead screen and a bedside screen in the ward. The overhead screen displays the patient's name, nursing level, examination appointment reminder, key precautions (such as a mid-risk fall, drug allergy, etc.), and the names of doctors and nurses in charge. The bedside screen includes examination reminders, vital sign monitoring, report query, medical expenses query, meal ordering, entertainment, education, admission guide, satisfaction survey, etc. The nurse station is equipped with a nursing screen that displays all inpatient information, infusion status information, monitoring, early warning information, etc. Patients wear a smart bracelet when they are admitted to the hospital and download the "Dingbei" application on their smartphones, where all functions of the bedside screen can be displayed. By wearing smartwatches, nurses can receive patient monitoring warnings, automatic infusion warnings, fall warnings, vital sign warnings, cross-electronic fence warnings, and other information to handle the warning information in a timely and proactive manner. The doctor interacts with the patient through the doctor-client setting of the "Dingbei" application in a swift way. AI-powered disinfection robots and logistic robots in the wards can assist nurses in relevant tasks.⁵

The ultimate aim of the smart hospital is to help the implementation of personalized healthcare. Hospital Intelligent Twins can facilitate the fast implementation of personalized healthcare in multiple ways. First, it uses AI to create personalized health recommendations. The "Dingbei" application uses AI algorithms to learn diagnostics from over 300 million electronic health recorders. Patients can then chat with the bot about their symptoms or questions to get personalized, accurate responses. After



Figure 1. Screenshots of the hospital smart brain dashboard.

identifying a patient's potential condition, the bot can connect the user with the best doctors in their area. The personalized, data-driven care ensures all users get the help they need. Second, the wearable device enables persisting monitoring and provides personal tracking and recommendations for chronic disease management in and outside of the hospital. The smartwatch and App make it easy for patients to track their blood pressure, blood sugar, and meals and use up-to-date research to make personalized recommendations for diet, exercise, and chronic disease management. Also, the app uses each patient's data to make accurate recommendations for better treatment. Third, it uses electronic education for personalized care. The bedside screen can be served as an electronic education platform that keeps patient diagnoses, treatments, and notes in one place that patients and their families can easily access. Patients can also use the system to adjust the room temperature, request food, and ensure they have everything. Patients can get personalized care through "Dingbei" after discharge from the hospital that addresses their unique medical history while still having the convenience of staying at home. The free service meets each patient's unique needs with personalized service and care that goes above and beyond.

The GD2H smart hospital for all-scenario intelligence is still in its infancy. Initially, the Intelligent Twins may not be able to make useful recommendations since the AI will take time to acquire sufficient data and train algorithms on different scenarios. Therefore, rule-based algorithms were first applied to make recommendations and some pre-trained AI models, such as face recognition and fall detection, were deployed for specific tasks.

Intelligent twins will bring vigorous development to smart hospitals in the foreseeable future. As a novel

technical means, further exploration is needed regarding application value, standards, and safety. First, the construction of the hospital intelligent twins to achieve all-scenarios intelligence heavily relies on the investment of new information communication technology (ICT) infrastructure. Therefore, in the initial stage of construction, the investment is enormous. A sustainable plan for personnel capacity building and capital investment should be in place, along with the continuous expansion of application scenarios in the hospital. Achieving a balance between the benefit and capital investment requires an urgent need for overall planning and phased implementation.

Moreover, the massive data interaction of disparate systems from different vendors inside the Intelligent Twins urges the establishment of a standard procedure for the healthcare ecosystem. Such a set of standards should be compatible with the actual business of hospitals that can continue to evolve, to develop a principle of construction and technical guideline so as to formulate policy plans and supervision mechanisms that ensure information security to guide to build a standard all-scenario intelligence medical ecology.

Furthermore, the intelligent advancement of hospital operations, services, and management has brought great benefit to patients, medical staff, and management personnel, but the risks caused by such technology are also increasing. Intelligent Twins has widely involved medical activities; however, solving the medical ethics, protecting patient privacy, and reducing security risks involved are significant challenges for all-scenario intelligence applications.

In conclusion, we presented a revolutionary concept of smart hospital-hospital Intelligent Twins, a new technology integration powered by IoT, AI, cloud computing, and 5G applications to produce all-scenario intelligence for health

care and hospital management. Although Intelligent Twins have been widely used in medical activities, resolving medical ethics, protecting patient privacy, and reducing security risk are essential issues for all-scenario intelligence applications. This investigation on the creation of hospital Intelligent Twins could be a helpful attempt in determining how to improve evidence-based decision-making and improve patient happiness and outcomes.

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