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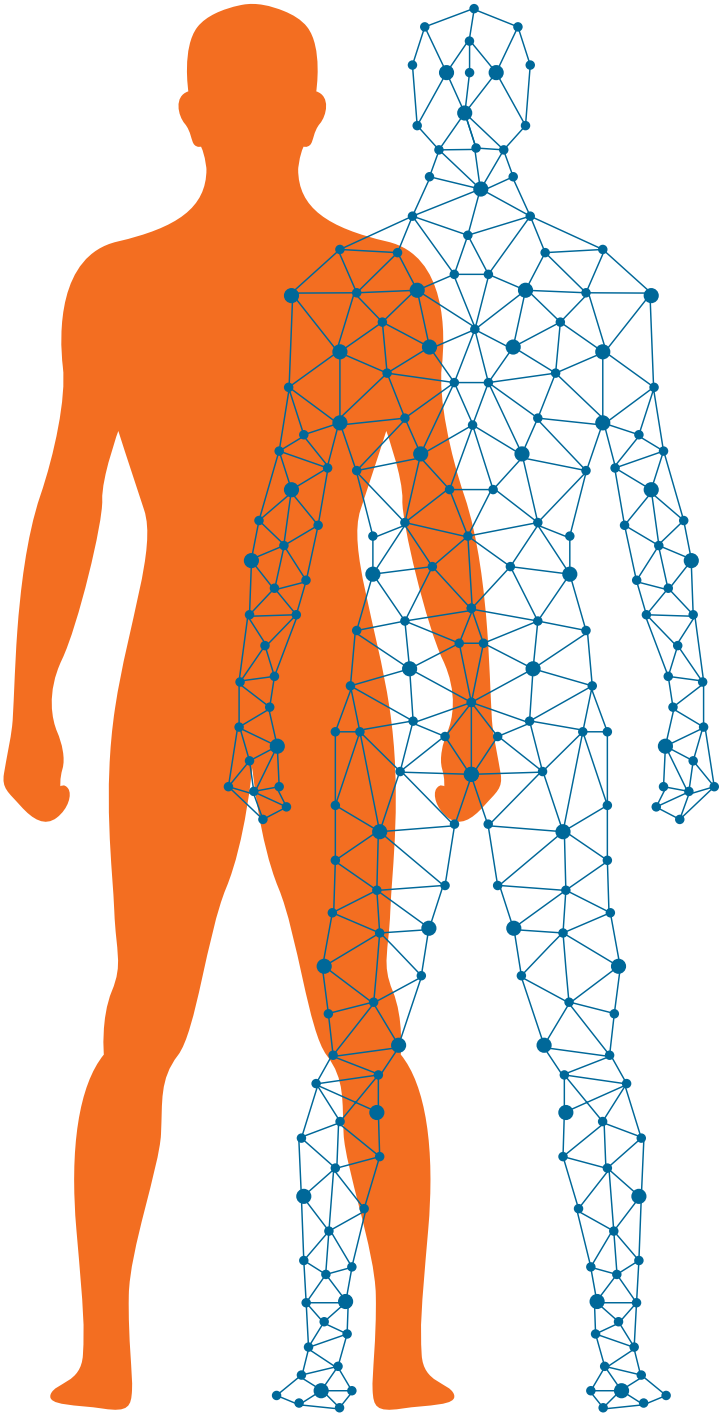

Digital Twins in Healthcare:

Enabling mass personalization of care delivery

How *Digital Twins* can enhance quality while reducing costs

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Topics Include:

- The data deluge in healthcare
- A clear definition of a digital twin, and how it is different from the old ways of collating patient data
- The challenges of creating a digital twin, and how new algorithms seek to unify the chaos of patient digital exhausts
- The inherent promise digital twins hold for both clinicians and patients

Executive Summary

In this paper, you will learn how far we have come in generating massive amounts of patient data, but how unprepared we are to make use of it. A digital twin promises an outcome driven approach to handling the data deluge arising from the patient's interconnected biology, provider interactions, and the environment.

The data speaks volumes, but is anyone listening?

An Abundance of Data

What kinds of patient information are available right now that most organizations fail to fully capitalize on?

EMR notes

Test results

Medical procedures

Hospital telemetry

Social media activity

Home medical device data

Wearable data

Smart phone data on personal activity

Social and environmental exposures, such as job stress or a big move

Just to name a few…

Human beings and their activities are generating a wave of information that can be harnessed to drive new models of care delivery. Data is expressed in everything from biochemical changes in cells to physiological shocks, such as a stroke or heart failure and the emotionally intense moments in our lives. The one common characteristic of many of the processes associated with these events or changes is their measurability. As our scientific knowledge increases, and with the concomitant evolution in techniques for measurement, more and more of the inputs and outputs of these processes can and sometimes are being collected as machine-readable data.

Today much of this data is escaping capture by healthcare systems and is not being put to the best use possible because we do not organize our technologies to do so. This paper describes a model for healthcare systems in which computing becomes the foundation of care delivery services. This model— driven by an industrial concept called the Digital Twin —is both a guiding principle for digital investments as well as an architectural blueprint for organizing computing capabilities to capture the digital exhausts of all individuals they serve. The primary purpose of such computational power is to characterize every individual or patient that is under the care of the health system. This form of “patient typing” encompasses not just digital phenotyping but all the other evolving typing methodologies, to support processes to prevent disease as well as effectively and efficiently deliver patient-centric care.

What is a digital twin?

A digital twin can be defined as a dynamic digital replica of the patient, created with data that is historically available. It is also designed to capture data continuously from the life of that individual. A digital twin is intended for more effective care interventions by helping clinicians and other intersecting care technologies to really "know" the patient. A digital twin data architecture dives deep to help characterize the patient's uniqueness, such as:

What is this patient's medical condition?

What is the ecosystem surrounding this patient?

What are the patient's goals and values?

How is this patient responding to a drug?

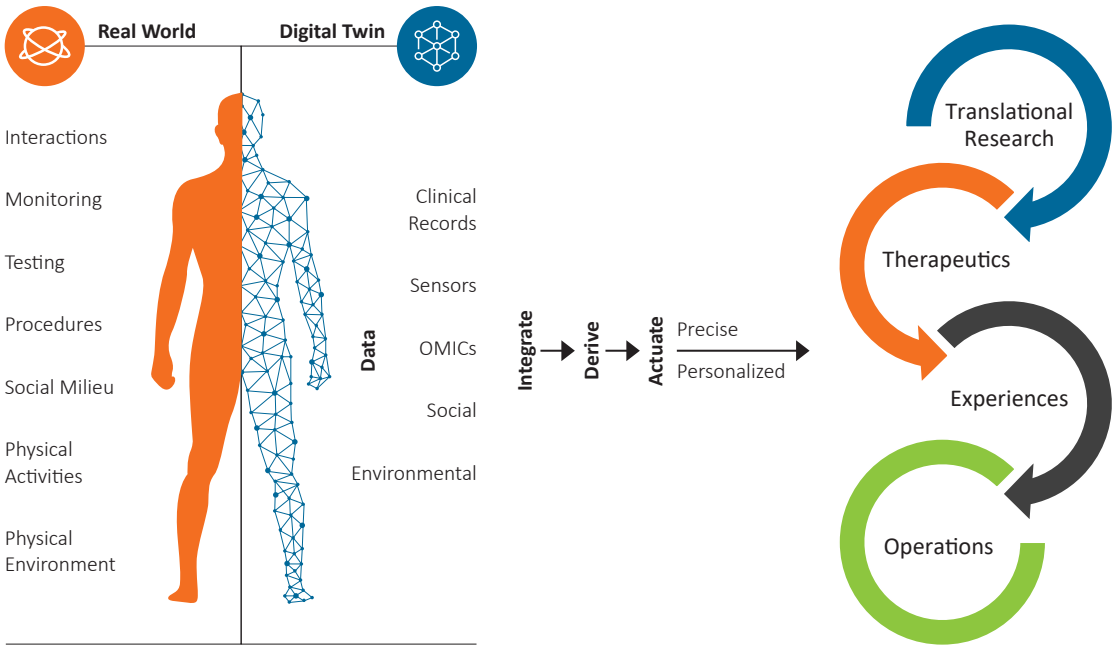
How will the patient respond to a method of therapy?

The data feeding into a digital twin is multidimensional and continues to accumulate from inputs, such as:

- Reading changes in the patient's physical environment or new lifestyle choices (a newfound taste for Asian food, or a new interest in extreme sports, and others);
- Correlating clinical events
- Detecting new social exposures, such as resulting from a change in residence; or
- Sensing biological responses to changes in medication

Human life is not static, and in a digital twin paradigm, it is seen as millions of individual "parts" operating as a machine. The core component of a digital twin - the algorithms - are the mathematical operators that give sense and purpose to the data generated by this machine and stored in the architecture. The algorithms, which are acting on the data, are designed to achieve specific clinical and economic goals of the health system.

Digital Twin Powering The New Healthcare



Digital twin and the computation problem

The Digital Twin is not just another way to collate data. It is a computing platform that curates and organizes data and its derivatives with a deliberate goal of relating the different "parts" of an individual to guide or automate actions for both providers and patients.

Here is an example: Tracking blood sugar levels and medication compliance is the conventional method of monitoring a diabetic patient. Several new technologies have come into the market to measure these levels continuously. However, new computing capabilities that are building blocks in the Digital Twin platform will utilize this data in the context of high levels of refined sugar in the patient's typical diet, his genetic makeup, lifestyle choices, and previous responses to different drugs to determine an appropriate response to the current blood sugar level of the patient. The processes actuated by this "operational scenario" will drive not only medication management but also lifestyle guidance. The result is a much more targeted clinical outcome for the patient.

The example above illustrates how the essence of a digital twin can be distilled down to a computation problem—the intelligent mapping of a patient's needs to the available resources. The entire care delivery system will be acting on mathematical outputs in different scenarios. The following is not an exhaustive list of different output types, but illustrates the complexity in organizing data and algorithms to address the complex health system dealing with varying patient types:

- If a patient has a surgical procedure, how many days of hospital stay will be required?
- How frequently should a patient be called to ensure he/she is sticking with a treatment regimen?
- How often should a patient visit with his/her clinician?
- Would this patient stick to the treatment program better if he/she was given a taxi voucher to attend the therapy?
- What drug dose is just right?
- What is the best caloric, nutrient, or fat intake? Is a patient's weight gain indicating risk?

Always Evolving

When creating a digital twin, it is important to start with a genuine economic and clinical need but to also ensure that the design principles of the platform are geared toward expanding the digital twin into other areas of care delivery.

Healthcare is traditionally an environment of silos, so the twin must develop a collaborative interoperability across these silos.

As you can see, each of these is a result of a different computation harnessing different dimensions of a patient's digital twin and actuating entirely different processes. One can imagine that such complexity will require an organizational unit dedicated to the development, deployment, monitoring and continuous improvement of the processes.

The challenges of creating a digital twin

By now it should be clear that the actual instantiation of a digital twin is a serious challenge. The difficulty lies not only in organizing the movement and storage of data but also in designing, deploying, and managing algorithms for the various patient types and processes in a health system.

The data exhausts are vast, multidimensional, and unstructured, and can come in at a very high velocity. Algorithms, on the other hand, are data hungry, during development as well as in execution. They sit between the patient data streams and clinical decision makers to provide a set of rules-based recommendations or machine-created predictions that actuate processes generating even more data. So, there is a very tight but potentially fragile relationship between the organization of data, the performance of algorithms, and the continuous generation of new data to train these algorithms. Consider the example of the diabetic patient: If the patient's digital twin is incomplete, the result will be the incorrect targeting of resources- people, therapies and other health system resources- to his or her condition. A faulty twin, in this case, could be one in which the patient's diet is not under consideration and the algorithms- for medication decision support – are oblivious to this critical factor. The fault could be either because there is no way to collect this data or because the algorithm designer did not consider this parameter. The result of a faulty twin is a continuation of the status quo in healthcare- high incidence of medical errors, avoidable costs of care, and unhappy patients.

Digital twins can transform population health

Conventional population health programs require a simple definition of what is a chronic disease patient (such as one with Chronic Heart Failure or Chronic Kidney Disease). Yet, therapeutic decision making, at the level of a physician, requires complex phenotyping mechanisms that can be automatically mapped to a drug and the dosage for a patient. This adds to the complexity not encountered normally in conventional chronic disease programs.

Persistent Systems is currently working on projects where AI augmented therapeutic decision making is being established under these core requirements. One population health project goes to the level of processing patients' data to characterize a disease deeply enough to automate the choice of drugs. It is being successfully used with non-clinicians who are using AI to guide them through the choice, timing, and dosage of medicine. It is helping them manage patient populations effectively and remotely, achieving clinical goals quickly while reducing total expenditure.

A promising road ahead

Creating a digital twin is not just a matter of managing and analyzing data but about taking a completely different approach to patient data and delivering care. It is about creating a complex but internally consistent computing architecture to address and connect different parts of an individual so that providers and patients can derive actionable insights to make informed decisions. It is about ensuring the precise allocation of available resources to achieve the Triple Aim - reduce healthcare costs and medical errors while improving patient satisfaction.

New computing technologies and techniques are finding its way into healthcare research or innovation projects at health systems. The Digital Twin offers these health systems a strategy to synchronize these disparate efforts while establishing a new information architecture. This strategy toward data and analytics promises a new kind of health care system where scale, speed, and accuracy become the norm.

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