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Computational Techniques for Solving Complex Real-Life Challenges

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***Abstract*—** The integration of Artificial Intelligence (AI) in healthcare has led to transformative advancements in diagnosis, treatment, and medical imaging and medical service management. This paper explores the multidimensional computational models applied in the healthcare domain, industrial applications; IoT based solutions in agriculture and other verticals for enhancing accuracy, efficiency, and outcomes. In the realm of high performance computing (HPC) and enhanced networking, AI enables medical services to a new height, which includes image analysis, prediction, recommendation, robotic surgery, remote health monitoring and smart health kiosks in green cities. This paper proposes a centralized computing environment that offers several services offered by the system. The detailed communication protocols, on the fly service management and load balancing parameters for the services are yet to discuss.

***Keywords*—**Internet of Things (IoT), Remote health monitoring, Robotic surgery, Image analysis, Edge computing.

I. INTRODUCTION

Scientific problems are categorized into optimization algorithms, numerical simulations, high-performance computing (HPC), internetworking, etc. Researchers and professionals use different computational approaches to model uncertainty, to predict outcomes, and support decision-making with higher accuracy. For instance, weather forecasting, drug discovery, financial modelling, traffic optimization, climate change studies, etc., rely heavily on computational problem-solving methods. As the complexities of global systems are increasing, computational techniques continue to evolve—combining interdisciplinary knowledge, automation and intelligent computation, for designing innovative, scalable, and sustainable solutions for the modern-day systems.

The rapid evolution of Artificial Intelligence (AI) has permeated virtually every sector of modern society including healthcare, industrial evolution, agriculture, entertainment and many more. The convergence of AI and healthcare has ushered in a new era of medical practice that characterized by enhanced accuracy, efficiency, and personalized patient care. As the healthcare industry grapples with challenges related to the increasing complexity of medical data and the growing demand for precise and timely interventions, AI presents itself as a promising solution. With rapid population growth and urbanization, it becomes very difficult for few doctors to treat so many patients. By leveraging AI's computational prowess and pattern recognition capabilities, healthcare providers are empowered to deliver more informed, tailored, and effective medical services. Fundamentally, AI is altering the way of medical professionals approach to diagnosis, treatment, and the interpretation of medical images.

In other sectors thereto, AI based computational models create huge opportunities to find computationally feasible solutions in renewable energy generation, transmission and management; in technology based capital market; insurance sector, and many more.

This paper delves into the transformative role of AI in healthcare, with a specific focus on its applications in healthcare management, and treatment. Section II of this article includes applications of computational intelligence in

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healthcare sector. In section III, computational methods adopted in industrial process development,
section IV deals with IoT based smart home applications, and section V deals with computational methods in IoT based smart agriculture and aquaculture applications. Section VI describes a proposed model that can be tested before implementation in healthcare management followed by a brief discussion and future works in section VII.

II. Computational Intelligence in Healthcare:

Extensive computation on the dataset requires faster computational devices as well as better algorithms to improve their expected results. In healthcare research and application, verticals like disease diagnosis and prediction, medical image analysis, drug discovery and medication, remote health monitoring and telemedicine, optimization of healthcare resources, etc., find extensive use of optimization algorithms and statistical tools. Computational basics around these applications are described in the subsequent sub-sections.

A. Imaging Technologies as a Diagnostic Tool:

With the advancement of hardware manufacturing technologies, GPUs and multi-core CPUs produce the image analysis results in very elegant ways. Their accuracy are also increasing surprisingly with parallel processors and highly parallelized algorithms. Compressive Spectral Imaging (CSI) is an image reconstruction technique that creates multiplexed 2-D image from different angular signals. Several variations of CSI, like Coded Aperture Snapshot Spectral Imaging (CASSI), Coloured CASSI (C-CASSI), snapshot coloured compressive spectral imager (SCCSI), spatial-spectral encoded hyperspectral imager (SSCSI), etc., are used to capture CT scan images. AI assisted CT are now exploiting the benefits of Deep Neural Network (DNN) as a diagnostic tool. Convolutional Neural Network, a variant of DNN, is used to diagnose suspicious tumor or cancer cell through image segmentation and used for image enhancement by looking at the pixel heuristics. Enhanced deep super-resolution network (EDSR) method is used for enhancing the CT image [33].

B. Psychological Disorderness Treatment with AI driven techniques

Identifying the behavioral pattern and psychological feedback from a human being, some mathematical models are used to find the state of mind. Usually, a person's physical movements and his words, are analyzed by Natural Language Processing (NLP) methods and CNNs are used to analyze the image/ video of that person.

Social Network Analysis for finding mental Disorderness: Mental disorderness is a psychological state where patients are unaware about their obsessiveness but try to acquire their personal needs from the environment. The cyber world contains many such patients where they express their views and try to communicate in the web channel through different posts. In the literature, we found many analytical tools that devise the detection mechanisms [1,2,3,5,6,7,8,9,10].

As a solution to this problem, AI based chatbots are introduced that make conversion between the machine and the personnel under treatment with some standard queries and conversations. Based on the replies, popular NLP models like Hidden Markov Model(HMM),Conditional Random Fields(CRF), Naïve Bays' probabilistic classifier, Random Forest(RF), etc. identify and forecast the categories of disorderness of the patient. Recommender systems are also embedded that tells us about the possible solution(s). Based on age, sex and categories of illness, music therapy is a choice to the psychologists for rehabilitation [27].

C. Remote Healthcare Providers:

Telemedicine, Remote Health Monitoring System, Remote diagnostic platforms, Remote Elderly Care Systems, and Remote Therapeutic Models are going to be interesting part of the public healthcare system[12,19,20,30]. Remote Healthcare system is not a competitor to the conventional medical practices. Rather it will assist the healthcare system where the resource scarcity is an issue. Remote healthcare systems are closely associated with the IoT enabled devices and communication channels over the Internet. Foremost requirement of the networks are lowering the latency and increasing the bandwidth for faster communication [29,30]. It is worth mentioning that the system not only saves operating time, also increases reachability and accessibility of the medical services to the villagers. These are essentially deployed during the outbreak of any pandemic and communicable diseases, during flood and earthquake like emergencies when physical presence of medical practitioners are scare.

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One major challenge to the remote healthcare system that it could not perform any invasive diagnostics and result analysis. For the same, a patient has to be shifted quickly to the hospital or diagnostic centre for tests and that requires a necessary transportation service. Remote Healthcare providers also operate GPS enabled ambulances that quickly respond to manage the patients. eSanjeevani, India's national telemedicine service, and the National Tele Mental Health Programme, etc. are established and monitored by the Ministry of Health and Family Affairs. These services will be popularized in upcoming days.

D. IoT and Edge Implementation for Smart City:

In the smart city implementation, the healthcare providers often rely on the IoT and Edge based computing model that captures patient data from the dedicated kiosks or wearable devices and transmit data to the proximity Edge devices for taking decisions[14]. The Edge computing paradigm typically follows distributed computing where workload are shared amongst the participating Edge computers. Fig. 1, depicts the layers of an IoT and Edge based healthcare services where arrow heads shows the direction of data flow.

In this working model, computation is modelled on the captured data. Deep Learning based image analysis and diagnostic tools are deployed to find the diseases, if any, in non-invasive manner. Based on the diagnosis, Knowledge Based Intelligent Decision Support Systems will recommend medicines for the users. During the smart city development, Health Kiosks are recommended to install at familiar places where people will avail such services for their general check-up [18]. In these health kiosks, actuators and/ or pill dispensers are embedded that are used to deliver common drugs for generic diseases.

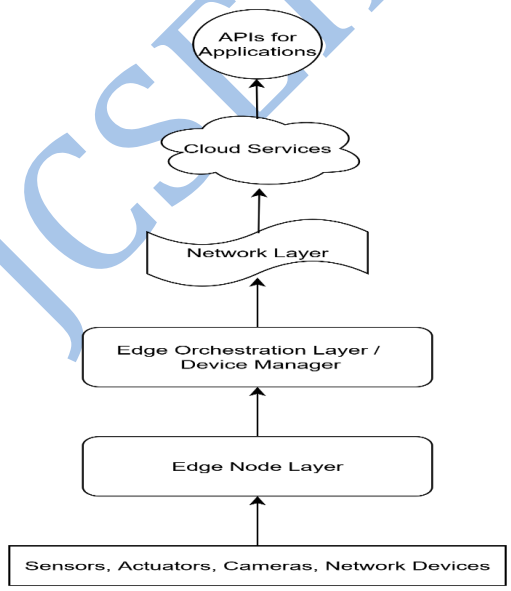

Figure 1. Layers of an IoT and Edge based Services

Another GIS based services also be deployed with this IoT & Edge based network that manages ambulance service for the emergency situations where patients are to be transported to a reliable hospital for his best treatment. Mobile Apps can be developed for the same to manage the healthcare ecosystem [23]. To manage privacy and security for the patients as well as healthcare providers, Elliptic Curve based lightweight security mechanisms can be deployed [14].

E. Medical Service Management as a Computational Model:

Medical resource management are the prima-facie activities to the healthcare providers. Many computational model has been developed and incorporated during portal development. The aim of such management is to provide satisfactory medical services to the stakeholders. Resource optimization, increase in staff efficiency, maintenance of medical equipment and other resources, are very crucial from government and business point of view. Quality parameters can be fuzzified and can be processed for optimization. Fuzzy Decision Support System(FDSS) can be used to improve quality of services in the hospitals [31]. It is often observed that to earn more profit from a hospital establishment, the physical and mental health of the doctors,

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nurses and associated medical & non-medical personnel are overlooked, which in turn, degrades the quality of service. This process highly effects on liable and dutiful staffs and hence their retention to the service. Resource utilization with man- power efficiency is a major challenge to us. Bio-inspired optimization algorithms and fuzzy based optimization techniques can be applied to create a sustainable environment [11][13][15].

Healthcare planning and resource management is the present area of research where the satisfaction of all associated people is a major concern. Affordable cost management, resource planning, expanding the life expectancy from the healthcare institutions are the major input parameters for optimization [17, 18, 19,21,22,32]. Multi-objective fuzzy optimization is a machine learning based process where huge computation is performed with Genetic Algorithms. Several variants of GAs are employed today to solve such complex problems.

III. AI Driven Industrial Process Development:

Real time Industrial process control and optimized product development is the key feature of Industry 4.0 standard. Process automation, control, quality management, inventory management, supply chain management, processing customer feedback, optimized employee and resource management, reducing product cost, etc. are the major thrust area of research.

IoT Enabled Industrial Process Toolkit: In the industrial process control and automation, prior data from the same environmental setup have to be collected. These set of data either be collected manually, from the previous operational history or data may be collected by installing appropriate sensors as depicted in figure 2. These sensed data are collected at local disks or transferred over the Internet to another machine.

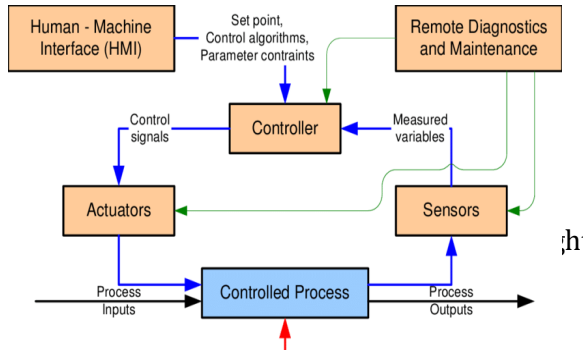

Figure 2. Typical Industrial Process Control System [35].

The controller or an EDGE device analyse the sensed data to take the decision. Accordingly, control signals are generated that govern the actuator(s) to control the process. Typically, the actuators include smart valves, triggering motors for set on or off, controlling conveyor belts, starting boilers, and many more [26].

During analysis of stored data, either Linear Programming based algorithms or approximation algorithms can be applied. The decision is taken based on requirements of the process where precision and computational latency are the factors. During microchip production with the nanoparticles, precision is a factor whereas manufacturing of manures requires less computational latency for safety of the plant.

In recent times, IoT and EDGE based device controllers perform better in comparison to centralized computing architecture. Sensed data are processed near the IoT device and able to generate appropriate control signal to operate actuator(s). This reduces processing cost and network latency and offers better distributed environment.

In the EDGE environment, another feature can be embodied, known as predictive maintenance of the devices of the production unit. Gathering information from the moving parts and valves, an EDGE network can simulate the behaviour of the components. From such simulation, a predictive maintenance schedule can be generated which reduces the downtime of the plant and increase the life span of the equipment of the plant. This EDGE based simulating models are termed as Digital Twin (DT) in the literature. In such DT environment, the computation is a data driven approach that use fuzzy optimization and prediction tools.

IV. IoT Enabled Smart Home:

In smart home design, essential components include sensors of several kinds, connecting network devices, actuators and other appliances for our daily use. Connectivity from sensors to the processing device, usually microcontrollers, and from processing device to the actuators are established by popular technologies like ZigBee, Wi-Fi, Bluetooth or LoRA, are used with full-duplex mode of communication . Accessibility to any cloud service enables the environment operable over the Internet. Now, these services are popularized in many countries. In smart home environment, a feedback path is established to push the operator/ actuators react on certain

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set value of a defined parameter. Manipulation of different signals, handling actuators in a defined way, and maintaining the state of the sensors, are challenging tasks for the designers.

V. IoT Enabled Agriculture and Aqua Culture Model:

To increase profitability, and to increase productivity, technology driven solutions are adopted in agricultural and aqua-cultural fields. To know the soil health, IoT enabled sensors like NPK, soil moisture, temperature sensors are used. After processing the sensed data, actuators like smart sprinkler, fertilizer dispenser, agricultural drones, etc. are used for watering, distributing useful nutrients and pesticides to protect the cultivated plants. In this computing model, precision is not taken seriously, but prior data to be analysed for maintaining the surrounded condition.

In aqua-culture, to monitor dissolved Oxygen (DO), water temperature, pH, turbidity, etc. sensors are used to monitor water parameters [36]. In IoT enabled automatic aerator system developed to trigger pump when DO level decreased beyond a set value of 6.0 ppm and when temperature of the aquatic field rises beyond 30 degree Celsius. Such computation requires the knowledge on communication protocol and generic programming skills.
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VI. Proposed Model for Medical Service Management:

Cloud platforms enabled distributed medical services offers paperless access of the patient data to the health service providers. It may preserve patient data securely through Electronic Health Record (EHR) service.

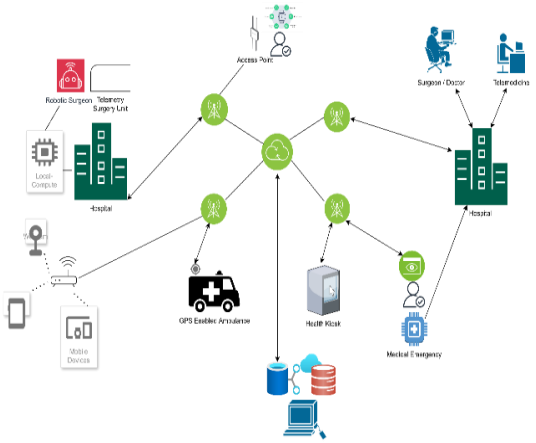

Figure 3. Users around the Healthcare System

In the proposed system, healthcare service providers, especially institutional service providers, are the key players of the system and they are networked by the public service telephone network or through satellite communication. A central data centre will be established for storing patient data, which will share patient information on demand basis. This will minimize the cost of pathological tests and essentially will share earlier diagnostic and treatment history amongst the doctors. The challenges associated with this public service environment are:

a. Availability of resources
b. Latency requirement of the network
c. Anonymity of user data with respect to their personal integrity
d. Console management in telemetry/ robotic surgery
e. Precision in imaging

Amongst these challenges, user anonymity alongside user authenticity and privacy policy framework must be worked out. Real-time image capturing, analysing, and data delivery to the end user is another computational challenge. This challenge also include network latency and algorithmic efficiency in a computing environment.

VII. Discussion and Future Scope:

Mathematics and computation are very close associates to each other. The approaches of computing are also revolving around the time. Prior to popularization of AI & ML, procedural algorithms were an obvious choice amongst system developers. Now, situation changes when approximation algorithms are replacing classical problems that are helpful to solve real problems. Even though, the classically known NP-hard problems are approximated by Genetic Algorithms(GA) and other deep learning(DL) algorithms. In the present development, recommender system, image analysis as a diagnostic tool and distributed computing mechanism should be adopted to receive utmost service from the ICT environment. Minimizing network latency, robotic surgery and telematics surgery may be adopted. This will increase the availability of expert doctors in a specialized vertical where distance is not a fact of burden. Detailed communication protocols, on-the-fly service management and load balancing

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parameters for the services are to be examined thoroughly. Edge based distributed computing model for this environment is an alternative solution since, Edge based near the IoT computing model requires less network delay and higher throughput for it

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