University of Colorado Denver

HEALTH ADMINISTRATION RESEARCH CONSORTIUM

PERSPECTIVE

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# INTELLIGENT HEALTH FIGHTING PANDEMIC

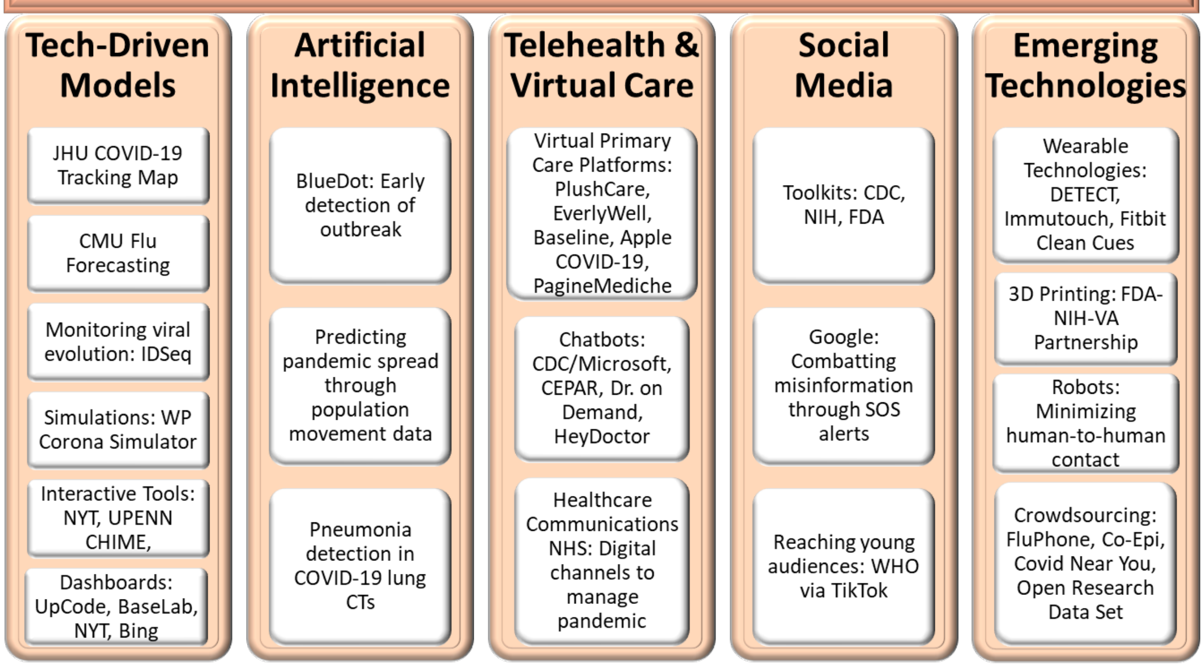
**HARC -** The fight against the pandemic is an exemplary case of intelligence being used in health, with supports from science and technology. We need trained people with relevant skill sets to contribute more.

To inform on this concurrent issue, **Drs. Stefan Poikonen, Yu Du, Marlene Smith, Jiban Khuntia discussed with Grace Goschen at HARC.** The insights in this perspective revolve around how analytical tools and applications and digital systems are emerging to play an essential role in fighting the COVID pandemic.

The use of intelligence in health care is not new, but it was confined to the peripheries of clinical diagnostics, treatment, and decision making. The COVID-19 pandemic has propelled intelligence to the forefront of healthcare facing customers, managing supply chains, and informing public health. This phenomenon is unprecedented and is conceptualized as an "intelligent health fighting pandemic" by the faculty team for this perspective.

To start with, Grace and Jiban prepared a landscape survey of examples of intelligent health fighting the pandemic, available as a HARC research brief (Figure 1). The brief summarizes the areas under the themes: (1) technology-driven models, (2) artificial intelligence, (3) telehealth and virtual care, (4) the role of social media, (5) other emerging technology such as wearables, robots, and more. During the pandemic, the critical development that came to the forefront is "Modeling and Mapping the Curve." Epidemiological models such as the John Hopkins University's COVID-19 Tracking Map, the Washington Post's Corona Simulator, the NYT death toll algorithm, and others including tools that explore the impact of COVID-19 on hospitals, have allowed for public outreach and provided real-time data to researchers while offering accurate forecasting of spread patterns, hospital capacity, and PPE supply requirements.[1] These tools inform several vital aspects of the 'curve' associated with COVID-19 and have impacted our policymakers' efforts to flatten the curve. For other similar applications, please refer to the research brief.

FIGURE1: SCOPE OF INTELLIGENT HEALTH FIGHTING THE COVID-19 PANDEMIC




**The Spheres of Intelligence Fighting Against the Pandemic?**

Reflecting on the areas where intelligence has helped, the faculty team agrees that the fight is almost in all spheres: Governments worldwide are taking drastic measures to curb the spread. Scientists are trying their best to find a vaccine. People are trying to be safe by tracing contacts. Restaurants and businesses are trying to survive.

One research area, amongst others, explored in intelligent health is that of "Extended Intelligence." This refers to digital solutions such as artificial intelligence algorithms used to predict outbreaks via news reports, zoological and botanical disease networks, official proclamations, global airline data, historical population movement data, and more.[2] These algorithms were used to track the spread of COVID-19 throughout and outside of China at the beginning of the outbreak.

Beyond this, exploratory and predictive algorithms were developed to show how shutdowns and other policy measures delayed epidemic growth, and diagnostic AI tools assisted physicians in diagnosing COVID-related pneumonia through CT scans.

**Dr. Stefen Poikanan**, whose research involves network analytics, epidemiological modeling of viral transmission based on network structure, and sampling measurement, has done similar work in developing algorithms and AI. He notes that when it comes to COVID-19, broad explorative algorithms will be useful in predicting the big picture, while exploitative algorithms will help identify populations with the most pressing COVID-19 needs.

**Dr. Yu Du**, who specializes in data-driven mathematical optimization, modeling binary quadratic problems, combinatorial optimization, and mission learning, has done similar optimization work on gene mapping, particularly cancer cell differentiation. For instance, she applied efficient nonlinear optimization algorithms to solve doubly regularized support vector machine models on real data sets in cancer research. The data sets are the gene expression profiles of 102 tissues (sample size): 50 of which are normal and healthy, and the rest 52 tissues are known to be prostate cancer tumors. The data sets have been studied extensively to identify the genes that differentiate cancerous tissues from healthy tissues. Since identifying these biomarkers is critical to the early detection of prostate cancer, Yu's team fit classification models

**Illustration 1: Yu Du's Proposed Model for Optional Allocation of COVID-19 Testing Kits[5]**

How to determine an optimal allocation of testing kits, as in the context of virus detection, to a population of n people whose members may or may not be infected?

Suppose $q_i$ = the estimated value of having person i tested, and $q_{ij}$ = the additional value of having both i and j tested (beyond the value of $q_i + q_j$) – as where these individuals interact with different groups of people and it is desirable not to limit testing to those who interact within the same group. The $q_{ij}$ coefficients can be made larger if the groups that person i and person j interact with are high risk groups.

The objective is to maximize the total value of the people tested. This can be modeled as a quadratic binary problem where the number of people tested equals KitsAvailable, the number of test kits available on a given day.

Define $x_i = 1$ if person i is given the test; 0 otherwise. Then the cardinality constrained QUBO-Plus model is obtained by:

$$\text{Maximize Total Testing Value} = \sum_{i=1}^{n} q_i x_i + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} q_{ij} x_i x_j$$

subject to

$$\sum_{i=1}^{n} x_i = \text{KitsAvailable} \qquad \text{(C1)}$$

This basic model incorporating constraint (C1) can readily be enriched in a variety of ways. For instance, suppose each person i belongs to a Group k indexed by k = 1, …, K, where members of Group k are identified because they interact or because they are a geographical community or have other features in common considered likely to influence their risk. (These groups may also be identified by a QUBO clustering algorithm.) This results in constraints of the form:

$$\sum_{i \in I_k} x_i = V_k \quad \text{for k = 1…K} \qquad \text{(C2)}$$

where $I_k$ denotes the individuals in group k and $V_k$ denotes the number of kits to be allocated to group k.

Here the sum of the $V_k$ values equals KitsAvailable. The $V_k$ values may be proportional to the sizes of the Groups k or may be skewed by the estimated riskiness of each group as a whole.

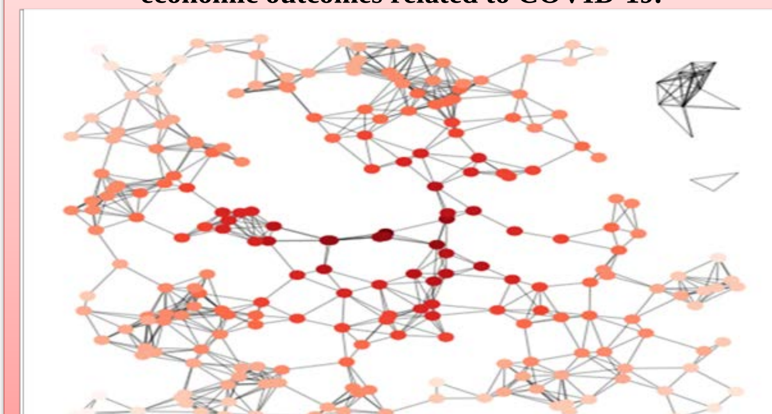
The foregoing problem with constraints (C1) and (C2) can be solved very effectively by a special designed heuristic algorithm called AlphaQUBO and the new quantum computer technologies such as D-wave Advantage solvers.

on the data sets to classify the cells using their expression profiles and identify the genes that distinguish cancer cells from normal cells. The data sets are in high dimensional with up to 12,533 feature size.

Beyond the specific optimization work, Yu illustrated a more general type of combinatorial optimization application that corresponds to modeling binary quadratic problems. In this case, with her collaborators, Yu has worked on an application relevant to responding to an epidemic outbreak (see Illustration 1).

**Dr. Poikanan** also sees the value in network optimization research. He envisions studying which policy tools, such as reducing restaurant density and closing schools, have had the most significant reduction in adverse health outcomes relative to the cost of applying these policies. He explains that each category, such as restaurants, hospitals, or schools, can be represented as a node with approximate spread rates. This would allow for algorithmic means of modeling which policy tools produce specific health and economic outcomes. It would be possible to structure this research as an optimization problem, where one seeks to minimize the linear combination of health and economic costs.  Network methods could also be applied to optimize the allocation of early vaccine doses to maximize positive health impacts.

**Illustration 2: Network algorithms and analysis provide a means of studying and optimization not only health, but also economic outcomes related to COVID-19.**



**Dr. Tony Cox,** an associate professor of Business Analytics, is very optimistic about applying AI/ML algorithms to identify and quantify health risks, characterize uncertainties, and clarify causality in epidemiology.  Dr. Cox draws from more than three decades of expertise in risk analysis and modeling areas to motivate research in simulating short-run and longer-term impacts of the COVID-19 pandemic on digital care management, telehealth adoption, and financial risks to payers and providers. He notes, "I and others have developed and validated models with direct implications for helping healthcare providers, and payers understand the effects of COVID-19 on patient behaviors to help optimize the business and medical responses."

**Illustration 2: Tony's Proposed "Intelligent Leadership in Healthcare" Training Pathways and Outcomes**

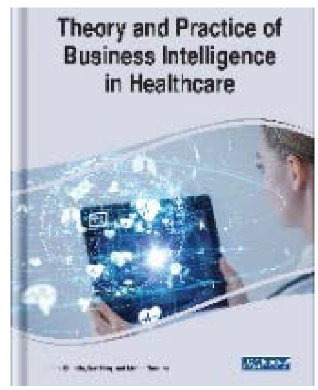
- Increased computational intelligence in the machine and artificial intelligence areas is emerging as a core competence for modern healthcare.
- Care delivery, quality goals, and strategy in the health care environment all benefit from decisions derived from intelligent applications.
- Managers need to study intelligence-enabled healthcare, preparing for the future, do hands-on exercises (from scratch), and develop expertise.
- Game-changing courses and training should include:
  (1) Identifying the right tools and applications for different challenges and opportunities,
  (2) Apply recent breakthroughs in intelligent tools and modeling approaches to empower providers and patients,
  (3) Navigate the upcoming paradigm changes and complexities, while successfully implementing and managing intelligent tools and applications in healthcare.

Tony proposes using artificial intelligence to delineate causally explainable patterns and interventions for individuals and groups confronting pandemic risks. His current interests in COVID-19 risk mitigation and risk management include developing more trustworthy causal forecasting models using spatiotemporal data and predictive validation techniques; decision optimization systems for patients, providers, and payers; and design for more resilient organizations that can survive and adapt to unpredictable new conditions. The last mile is applying these models and methods in organizations fighting the pandemic or exploring the 'new normal' of post-pandemic business solutions. Dr. Cox proposes that managers need to learn these tools and applications and apply the skill sets immediately— a practical goal with short-spanned training and certificate courses, focused on urgent needs, designed for mid-level managers (see Illustration 3).

**Dr. Marlene Smith,** who has applied analytical techniques to forecast scheduling needs for emergency departments, says that interest in analytical research into the novel coronavirus might be gauged by participation in public machine-learning competitions. An early competition on Kaggle (www.kaggle.com), for example, involved the application of visualization methods to track numbers of infections in the early phases of the pandemic; the pooled daily and regional data set allowed researchers to understand patterns of infections over time and differences by regions; e.g., South Korea, Brazil, and Switzerland. Among other challenges in Kaggle are those involving machine-learning models to predict accession and mutations of the coronavirus RNA and artificial intelligence assessments of chest x-rays to differentiate between patients with healthy lungs, coronavirus pneumonia, SARS, and acute respiratory distress syndrome. Meanwhile, at InnoCentive (www.innocentive.com), researchers have been challenged to develop gamification approaches to address the social issues impacting the coronavirus's spread and propose new personal protection equipment designs.

## What is the Future?

The Wall Street Journal reported that the "COVID-19 pandemic has underscored the importance of IT in medical research[3]." No more, the terms 'intelligent applications or solutions' are the fad of fancy. They are a necessity. The data collected through sensors, images, scripts, texts, monitoring devices, and cell phones can be used for many health care purposes—starting from diagnosing and monitoring to treatments. Dr. Khuntia, in his recently edited book "Theory and Practice of Business Intelligence in Healthcare, has emphasized how analytics and applications can help in informed decisions in various levels and domains in healthcare[4].




"It points to a very emerging need for students from a career management perspective. Developments in artificial intelligence, machine learning, and virtual technologies drive a paradigm shift in all sectors, including healthcare. Professionals without an understanding of these frontiers will not be successful; while more professionals will be needed to manage different frontiers of business intelligence careers in the healthcare sector. Interestingly, the Business School at the University of Colorado Denver has several courses and programs catering to the need. It should be a smart student's keen exploration to find and use them to shape a better future,"—advises Dr. Smith.

***We cannot agree enough at the HARC!***

## References

1. Dong E. Hongru Du and Lauren Gardner. 2020. An Interactive Web-Based Dashboard to Track COVID-19 in Real Time.30120-30121.
2. Lai S, Bogoch II, Watts A, Khan K, Li Z, Tatem A. Preliminary risk analysis of 2019 novel coronavirus spread within and beyond China. In:2020.
3. Castellanos S. COVID-19 Pandemic Underscored Importance of IT in Medical Research. 2020. Accessed 11/28/2020, 2020.
4. Khuntia J, Ning, X., Tanniru M. Theory and Pratice of Business Intelligence in Healthcare. United States: IGI Global; 2019.
5. Glover, F., Kochenberger, G., Ma, M. and Du, Y., Quantum Bridge Analytics II: QUBO-Plus, Network Optimization and Combinatorial Chaining for Asset Exchange, 4OR, Springer, 2020, (DOI: 10.1007/s10288-020-00464-9).