RESEARCH

Inside IISE Journals

This month we highlight two articles in *IISE Transactions*. The first article focuses on how to tailor clustering of heterogenous data and how that practice helps reduce the spread of infectious disease outbreaks. The authors investigated a novel clustering procedure for handling frequency data, which is to interpret the process of clustering that characterizes a unique discrete distribution. This reformulation enables the construction of an efficient polynomial-time algorithm that guarantees global optimality, and the tailored clustering significantly reduces misclassifications when applied to identifying screening strategies that mitigate the spread of infectious diseases. The second article attempts to provide an understanding of the possible effects of competition in terms of consumption and economic welfare for providing water services. The authors studied two types of competition – one based on an attraction model for water providers within a public-private partnership and another involving quantity competition within a spot market. The authors found that spot-market competition does not necessarily result in greater levels of supply, nor in a lower price, and that a public-private partnership could be preferable. These articles will appear in the August 2022 issue of *IISE Transactions* (Volume 54, No. 8).

How tailored clustering approaches reduce the spread of infectious disease outbreaks

Hrayer Aprahamian

Hadi El-Amine

Cluster analysis is one of the most adopted unsupervised learning methods with uses that arise in various applications, some with a significant impact on human lives. While several off-the-shelf clustering techniques exist, many of these techniques perform poorly for specific problem types. This is largely attributed to three factors: First, existing approaches are based on approximate schemes with no guarantees. Consequently, the resulting recommendations can deviate, sometimes substantially, from global optimality. Second, there is no clear way of selecting between existing approaches, leaving practitioners in the dark as to which technique to adopt. Third, these techniques do not account for specific problem structure which, if taken advantage of, can improve solution performance.

In their work, "Optimal Clustering of Frequency Data with Application to Disease Risk Categorization," Texas A&M University assistant professor Hrayer Aprahamian and George Mason University assistant professor Hadi El-Amine investigate novel clustering procedures that are tailored to handle a specific type of data, frequency data, that commonly arises in numerous applications. The tailored approach provides many advantages over conventional procedures by exploiting the structure of the problem. Although the work is specific to frequency data, their results are independent of the application, which greatly broadens its usability.

The authors achieve this by interpreting the process of clustering a dataset as a procedure that characterizes a unique discrete distribution. This novel interpretation allows them to extract valuable statistical information, which they embed within an optimization framework. To solve the resulting challenging combinatorial optimization problem, the authors construct a scheme that casts the clustering problem as a tractable network problem. This reformulation scheme enables the construction of an efficient polynomial-time algorithm that guarantees global optimality.

The authors demonstrate the use of the developed methodologies through an application that aims to identify screening strategies that mitigate the spread of infectious diseases. In this context, the population needs to be clustered into risk categories in a manner that maximally highlights their heterogeneity. Doing so provides practitioners a tool that not only identifies optimal categories, but one that enables the construction of custom screening approaches.

Their results reveal that the considered approach con-

sistently outperforms current practices by significantly reducing misclassification while using the same amount of resources. Such results underscore the value of tailored optimization-based approaches in addressing complex real-world challenges.

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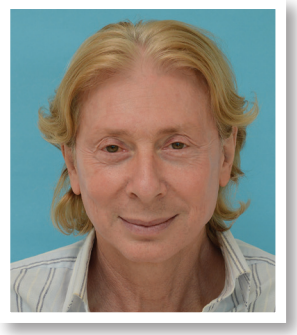
Using a dynamic model to decide if public-private partnership is preferable to spot market competition for water services

Water consumption is increasing due to worldwide population growth, the urbanization of countries around the globe and the demand for a higher quality of life. Actually, water joined gold, oil and other commodities traded on Wall Street, highlighting worries that the life-sustaining natural resource may become scarce across most of the world.

In many countries, policymakers face the dilemma of how to respond to increasing physical water scarcity. Therefore, considerable effort has been expended in improving the productive efficiency of the water sector using a variety of methods, including concentration, competition for the market, competition in the market and cooperation. Thus far, however, these strategies have only been implemented in a limited way and the consequences of introducing them remain unclear.

In their work, "Water scarcity and welfare: Regulated Public-Private Supply Chain Versus Spot-Market Competition," chaired professor Konstantin Kogan, postdoctoral student Dmitry Tsadikovich and associate professor Tal Avinadav, all from Bar-Ilan University in Israel, attempt to understand the possible effects of competition in terms of consumption and economic welfare. They contrast the standard monopolistic approach to supplying water with two different types of competition. One type is based on an attraction model for water providers within a public-private partnership, while the second type involves quantity competition within a spot market.



Konstantin Kogan

Unlike the case of quantity competition, which implies dynamic pricing, the public-private supply chain is characterized by a state-regulated price that is fixed over the period of the contract and that is set at a level to just recover the associated distribution costs of the public entity.

Dmitry Tsadikovich

Tal Avinadav

The authors derive dynamic equilibrium replenishment and inventory policies to show that, contrary to expectations, spot-market competition does not necessarily result in greater levels of supply, nor in a lower price, than does a regulated supply chain. In particular, if the distribution cost is relatively low, then by encouraging a public-private partnership, the public entity (municipality or state utility company) can ensure higher consumer surplus compared to a spot market.

On the other hand, increasing the distribution cost and hence the regulated price is likely to diminish the differences between the two market types. In such a case, managing water supplies for the municipality by means of a spot market would become advantageous. Specifically, it would help the public entity to manage the risk of shortages and better align supply and demand.

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This month we highlight two articles from *IISE Transactions on Healthcare Systems Engineering* (Volume 12, No. 2). The first article measures the total patient value received from creating a mix of cases for surgeons of varying levels of experience. The goal is to maintain a high level of patient outcomes but counterbalance caseloads to allow less experienced surgeons to improve their skills. The second article gathers information from surveys with patients and caregivers to aid in the design of a wearable dialysis device. Such a device could provide increased quality of life for patients suffering from renal disease if user-centered design principles are applied to take patients' needs and perspectives into account throughout the product development process.

How surgical units can leverage the diversity in surgeons' experience levels to improve patient outcomes

Renato de Matta of the University of Iowa College of Business.

While the observance of hospital treatment guidelines and protocols is critical for good medical outcomes that directly offer value to patients, a surgeon's case mix could also be a critical factor impacting patient outcomes. When difficult cases are mostly seen by experienced surgeons, less experienced surgeons miss the opportunity to improve their skills. However, when less experienced surgeons see too many difficult cases, it could produce poor patient outcomes.

Renato de Matta of the University of Iowa College of Business examines this trade-off in his paper, "Patient-Centric Surgeons Case Mix Problem." He shows how the diversity in experience level of surgeons complements a surgical unit in a way in which good patient outcomes from experienced surgeons counterbalance the average but improving patient outcomes from less experienced surgeons, while less experienced surgeons gain more experience.

He formulates and solves an optimization model that finds the case mix of surgeons in a surgical unit that maximizes the unit's total patient value (TPV) per dollar expenditure on healthcare resources. Numerical experiments using laparoscopic colectomy data show workload balancing and patient self-selection of surgeon could reduce total patient value; if the number of patients seen by each surgeon is restricted, achieving excellent outcomes for high value surgeries by managing the learning that takes place improves TPV; a balanced mix of easy and hard cases produces higher TPV; and high demand uncertainty increases the mismatch between the value surgeons can deliver to patients and the value demanded by patients which lowers TPV.

Examples of practical applications of the model are: Planning the mix of patients seen by junior surgeons in residency programs at teaching hospitals; U.S. hospitals that accept diagnosis-related groups (DRG) based on reimbursements could plan their budget using TPV. An actual TPV that is higher than projected is an indication of good patient outcomes, which could result in cost savings and produce good financial performance for hospitals.

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Realizing the dream of a wearable dialysis device: What do patients and their care partners want?

Imagine that your schedule is structured around visiting a dialysis center two or three times a week for the rest of your life. Each visit requires you to spend four to six hours at the center connected to a stationary dialysis machine that cleans your blood.

This is the reality for most patients with end-stage renal disease (ESRD), the condition of irreversible kidney failure.

The in-center mode of dialysis therapy negatively impacts ESRD patients' quality of life such as impairing their mobility, independence and mental health. Because of these challenges and other difficulties resulting from the disease, many ESRD patients need the support of a care partner to assists with their healthcare needs and daily activities.

The Center for Dialysis Innovation (CDI) at the University of Washington (UW) is developing a wearable dialysis device to transform current dialysis therapies by allowing ESRD patients to undergo continuous dialysis wherever they are.

To design a wearable dialysis device patients are willing to use, it is important that researchers apply user-centered design principles. The user-centered design takes users' needs and perspectives into account throughout the prod-

uct development process.

In "What Patients and Care Partners Want in Designing a Wearable Dialysis Device: A Mixed-Methods Study," the human factors team at the CDI joins forces with Auður Anna Jónsdóttir, a doctoral student in industrial and systems engineering at UW; Larry G. Kessler, a professor in the department of health systems and population health at UW; Seung-Yeon Rim, a UW industrial and systems engineering graduate; and Ji-Eun Kim, an ISE assistant professor at UW.

By interviewing 24 ESRD patients and 12 care partners, the interdisciplinary team of researchers identified similarities and differences in ESRD patients' and care partners' preferences for the designs of a wearable dialysis device.

The findings from this study can help guide researchers in designing a patient- and care partner-centered wearable dialysis device.

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IISE Transactions (*link.iise.org/iisetransactions*) is IISE's flagship research journal and is published monthly. It aims to foster exchange among researchers and practitioners in the industrial engineering community by publishing papers that are grounded in science and mathematics and motivated by engineering applications.

IISE Transactions on Healthcare Systems Engineering (*link.iise.org/iisetransactions_healthcare*) is a quarterly, refereed journal that publishes papers about the application of industrial engineering tools and techniques to healthcare systems.

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