RESEARCH

Inside IISE Journals

This month we highlight two articles in *IISE Transactions*. The first article contemplates whether it is possible to make effective use of complementary multimodality data for early detection of the Alzheimer's disease when the multimodality data is incomplete. The authors borrowed ideas from a popular machine learning approach, known as transfer learning, then worked with Banner Alzheimer's Institute and MS Technologies Inc. and tested their transfer learning method using the Alzheimer's Disease Neuroimaging Initiative datasets. The second paper addresses when to remanufacture and when to throw away high-value parts in a production system. The answer appears to depend on whether the part in question is generic or proprietary. The authors developed computational models that can weigh the return rate of used items against the demand rate of remanufactured items to attain the minimum long-run average cost of remanufacturing. These articles will appear in the September 2021 issue of *IISE Transactions* (Volume 53, No. 9).

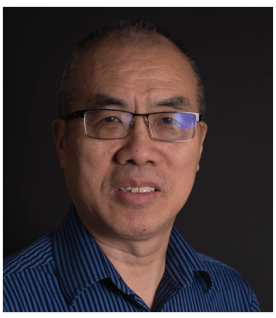
Machine learning-enabled integration of incomplete multimodality datasets for medical diagnosis and prognosis

Multimodality datasets in healthcare applications provide complementary information for disease diagnosis and prognosis. Consider what they might do for diagnosis of Alzheimer's disease, a devastating neurodegenerative disease that desperately needs a treatment solution. Combining complementary neuroimages such as those from structural MRI, FDG-PET and amyloid-PET holds great promise in enabling early detection. In practice, however, not every patient has undertaken that many diagnostic examinations that would make the multimodality data available. The reasons are multifold, including limited availability of expensive imaging equipment, restriction of certain insurance policies and/or a patient's own preexisting conditions forbidding such exams.

The question this research team sets to address is whether it is still possible to take advantage of multimodality data modeling and analysis in the presence of an incomplete dataset.

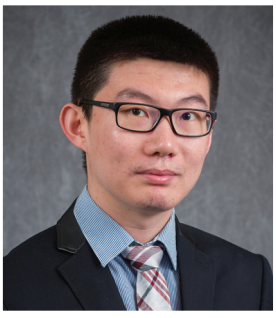
In the article "A Novel Transfer Learning Model for Predictive Analytics Using Incomplete Multimodality Data," doctoral student Xiaonan Liu and professor Jing Li from Georgia Tech, together with collaborators Kewei Chen and David Weidman, M.D., from Banner Alzheimer's Institute, Fleming Lure from MS Technologies Inc. and Teresa Wu from Arizona State University, built a predictive model for each subcohort of subjects with the same missing modality pattern. Their approach features a coupled model estimation process for different subcohorts, allowing for transfer learning to take place. The resulting algorithm is known as the incomplete-multimodality transfer learning (IMTL). It entails an interesting privacy-preserving capacity, permitting iterative communication between a global learner and the local learners residing within each subcohort, so that the collaborative model is trained without pooling data to a central repository across institutions.

The research team tested IMTL on diagnosis and prognosis of mild cognitive impairment, an early stage of Alzheimer's disease, at which point proper intervention has the potential of



Kewei Chen

Jing Li



Xiaonan Liu

Fleming Lure

David Weidman

Teresa Wu

slowing down the disease's progression. The data used in the test is incomplete multimodality neuroimages from the Alzheimer's disease neuroimaging initiative dataset. IMTL outperforms competing approaches remarkably, achieving 0.93 and 0.85 area under the curve accuracies, respectively, for detecting the pathology and progression of Alzheimer's disease. This research could facilitate accurate diagnosis and prognosis for patient cases with varying availability of image modalities and benefit particularly resource-limited populations or regions.

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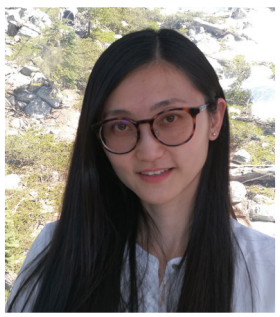
When to remanufacture parts and when to throw them away

Original equipment manufacturers in the automotive industry use both proprietary and generic automotive parts for assembly of their vehicles. Most of these proprietary parts, such as transmissions and engines, and generic parts, such as electronic control modules and alternators, can be and are, routinely remanufactured.

An important challenge in the context of automotive, as well as other similar high-value parts remanufacturing, is the mismatch between used item return and remanufactured item demand rates. If the return rate of used items is smaller than the demand rate of remanufactured items, then the underlying inventory and production planning problems can be addressed by specifying when a batch remanufacturing run should be executed.

For counterpart problems, however, where the return rate of used items is larger than the demand rate of remanufactured items, the underlying inventory and production planning problems need to be addressed by specifying when a batch remanufacturing run should be executed, as well as when a batch of used items should be disposed. While the former class of problems are encountered in the remanufacturing of proprietary automotive parts, the latter class, which are substantially more complex, appear in the remanufacturing of generic automotive parts.



Yi Zhang

Elif Akçalı

Sıla Çetinkaya

In their paper "An Analytical Investigation of Alternative Batching Policies for Remanufacturing under Stochastic Demands and Returns," Yi Zhang, a senior manager of data science at Maxim Integrated; Elif Akçalı, an associate professor and The Cottmeyer Family Innovative Frontiers Faculty Fellow at the University of Florida; and Sıla Çetinkaya, a professor and Cecil H. Green Professor of Engineering at the Southern Methodist University, propose several new batching policies inspired by shipment consolidation practices.

For the purpose of computing policy parameters, analytical models that are aimed at minimizing the long-run average expected total cost of remanufacturing are developed. Since the underlying cost expressions are not analytically tractable, easy-to-compute approximations that lead to closed-form expressions of policy parameters are proposed. A careful numerical investigation demonstrates that the resulting policy parameters are highly effective approximations.

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This month, we highlight two articles in *IISE Transactions on Healthcare Systems Engineering* (Volume 11, No. 2). The first examines how to measure workload concerns for surgeons to determine when they are approaching their capacity, including monitoring the physical strain of operating laparoscopic instruments. The team identified a novel workload instrument through surgical simulation for future validation. The second article addresses compliance with doctors' recommendations by diabetic patients in using antihypertensive medications. The authors developed a Markov decision process model to determine the impact of different levels of adherence to antihypertensive medication plans on the quality of life and the expected life years of diabetic patients. Results of the study may help physicians to motivate patients to become more adherent to life-saving medications.

Authors, from left to right, Bethany Lowndes, Bernadette McCrory, Kristin Chrouser and Susan Hallbeck; not pictured, Jiahui Ma.

Better, faster, safer? Reengineering surgical workload assessment

Becoming a surgeon is not for everyone! On top of the 12 years of postsecondary education, this highly competitive field is physically, mentally and emotionally challenging. As healthcare institutions of any size invest in their people, we must remember that each surgeon's training including specialty training and fellowships could easily cost approximately $1 million in direct costs. Even more important are the intangibles and indirect benefits of a surgeon, who is a superb diagnostician, team player, compassionate caregiver and excellent at the "sharp end."

After years of focusing solely on patient safety and quality outcomes, we recognize the critical importance of caring for our surgeons. They are often "operating machines" working long days but still providing the highest quality of care. Their hands that are contorted in laparoscopic graspers or their necks and backs bent awkwardly over the operating room table must be protected and rested to ensure the longevity of our surgical force. Far too often, our surgeons silently endure hand and wrist issues, neck and shoulder discomfort, low back pain, fatigue and burnout. This can lead to shortened careers and reduce patient access to life-saving procedures.

As healthcare moves toward ensuring providers are gratified and fulfilled by their work, we must not lose sight that surgery is fraught with occupational issues not easily solved with automation or technology. We need surgeons and data to support occupational accommodations and equipment redesign, and enable the entire surgical team to be better, faster and safer for everyone's well-being.

Four institutions are working together to solve these issues. What data – quick, yet valid – can help determine when a surgeon's workload exceeds capacity? The task load indices (NASA-TLX and SURG-TLX) have helped immensely, and yet based on analyses, both singularly are missing important factors. Yet in combination, we have uncovered important predictors that may lead to a novel instrument to assess specialized surgical techniques like laparoendoscopic single site surgery.

Jiahui Ma, a doctoral student in systems engineering, and her mentor, Bernadette McCrory, an assistant professor in industrial engineering, partnered with leading experts in the field of human factors and ergonomics – Susan Hallbeck of Mayo Clinic, and in surgery, Kristin Chrouser, M.D., chief of urology at the University of Michigan-Ann Arbor VA. A leader in surgical workload assessment, Bethany Lowndes of the University of Nebraska Medical Center, provided valuable insights into physician experiences in the OR.

The team identified a novel workload instrument through surgical simulation for future validation in their article "Developing a Subjective Instrument for Laparoscopic Surgical Workload in a High Fidelity Simulator Using the NASA-TLX and SURG-TLX."

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Diabetic patients should listen to their doctors and take their prescribed medicines

Patient adherence to medication plans plays a pivotal role in maintaining a desirable health level when it comes to chronic diseases. Patients with chronic diseases, such as diabetes, usually have difficulty adhering to medication recommendations since chronic care requires a comprehensive plan to control the primary disease and its complications. Individuals with diabetes must adopt a healthy lifestyle and use multiple types of medications to lower their blood sugar level and reduce the risk of comorbidities such as hypertension. Sometimes this situation becomes unmanageable when a person has to deal with other challenges throughout their life.

Saeideh Mirghorbani of Binghamton University along with Sharif Melouk and John Mittenthal, both from the University of Alabama, investigated these challenges in a paper "The Effect of Adherence on Antihypertensive Therapy Plans in Patients with Diabetes." The authors developed a Markov decision process model to determine the impact of different levels of adherence to antihypertensive medication plans on the quality of life and the expected life years of diabetic patients. This model considers the patient systolic blood pressure level, past and current cardiovascular complications, and the medications prescribed to shed more light on nonadherence and treatment success.

Results of this study may help physicians to motivate patients to become more adherent to life-saving medications and achieve

Saeideh Mirghorbani

Sharif Melouk

John Mittenthal

a health level that minimizes the risk of complications and comorbidities.

According to the study, using antihypertensive medications while maintaining an insufficient adherence level is more harmful than not using medications at all. This is due to the side effects of medications patients experience while not receiving the potential positive impacts from their regular, steady use. Additionally, maintaining an average level of adherence is more beneficial in the long run than changing adherence habits randomly.

The study also confirms that patients diagnosed at younger ages can attain the same quality of life if they are 100% adherent as those who do not have diabetes. The results further reveal that quality of life for a patient with high adherence may be at least twice as high as someone who has extremely low adherence and sparsely follows prescription recommendations.

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About the journals

IIISE 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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