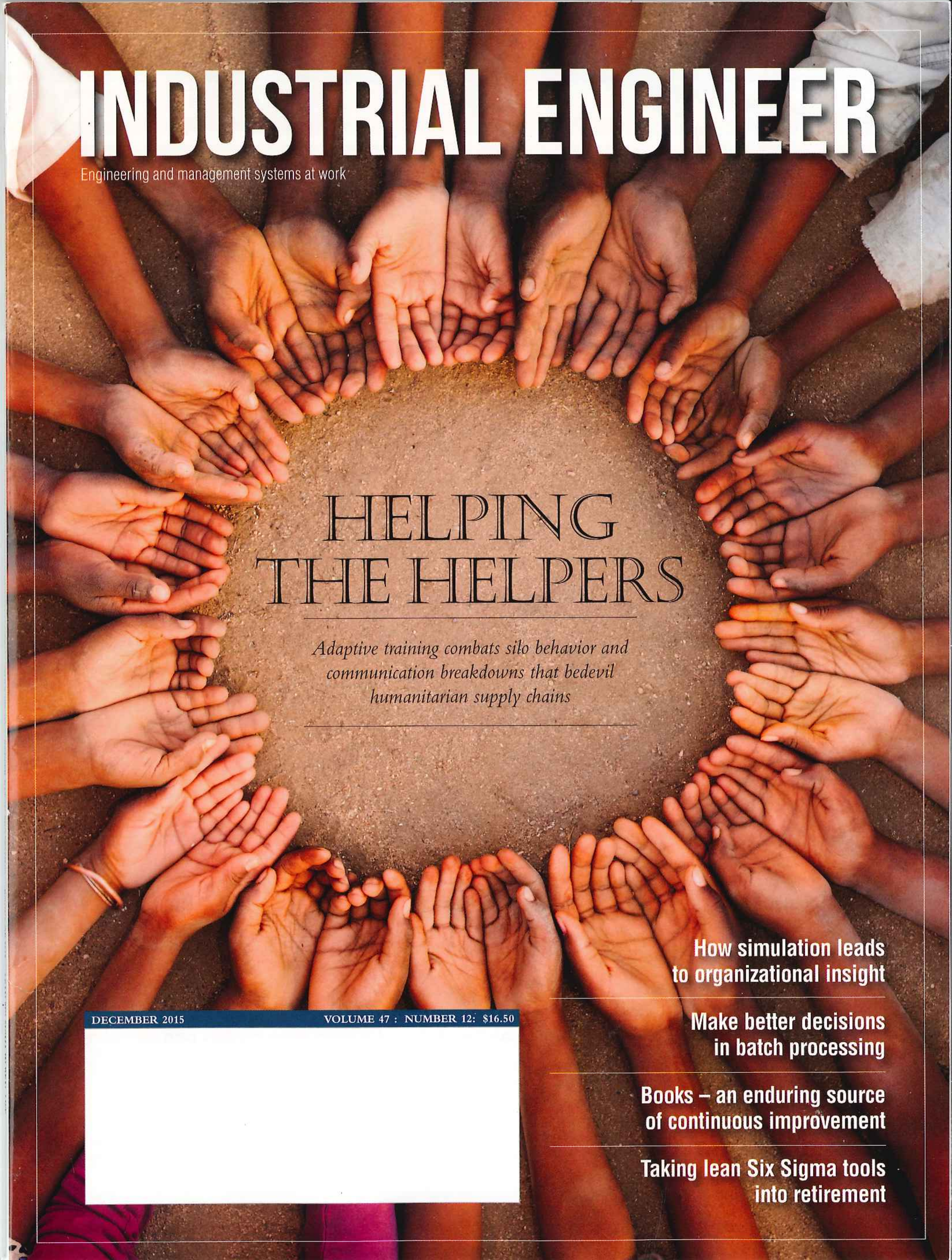
INDUSTRIAL ENGINEER

Engineering and management systems at work



HELPING THE HELPERS

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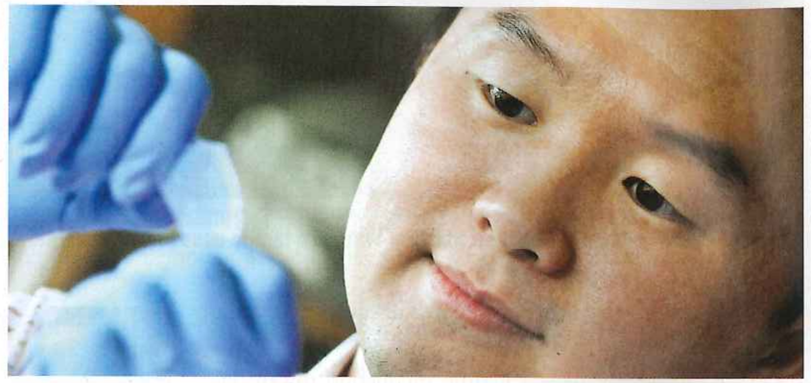
RESEARCH

Inside IIE Journals

This month we highlight two articles on quality and reliability engineering. The first article develops an approach for incorporating expert knowledge into forecasting. The approach is shown to work in a tissue engineering context for modeling scaffold degradation. The second article integrates demand forecasting with inventory management for spares provisioning. The objective is to improve forecasts of spare parts for inventory planning for repairable systems with occasional technology upgrades. These articles will appear in the January 2016 issue of *IIE Transactions* (Volume 48, No. 1).



Jian Yang, who is developing novel biomaterials, co-authored "Constrained Hierarchical Modeling of Degradation Data in Tissue-engineered Scaffold Fabrication."

Let's generate predictions that are practically meaningful

In the practice of predictive modeling, expert knowledge must be incorporated in the prediction to make the results practically meaningful for the studied application.

One typical example is the prediction of degradation in tissue-engineered scaffold fabrication. The scaffold is degradable biosubstrate for growing cells, which plays a critical role in the development of engineered tissues or organs. In scaffold fabrication, efforts are made to achieve designed degradation properties of products in the human body. According to expert knowledge, the degradation of scaffold monotonically increases with time, while the rate of degradation, i.e., acceleration, decreases over time.

However, due to the setup in degradation measurement, the data may violate the required properties and lead to meaningless predictions no matter how powerful the prediction method.

This problem is investigated in "Constrained Hierarchical Modeling of Degradation Data in Tissue-engineered Scaffold Fabrication" by Li Zeng in the Department of Industrial and Systems Engineering at Texas A&M University, Xinwei Deng in the Department of Statistics at Virginia Tech and Jian Yang in the Department of Bioengineering at the Pennsylvania State University. The interdisciplinary team developed a constrained hierarchical modeling approach to characterize the complex relationship of scaffold degradation and affecting factors, including time and process variables. The model can conveniently incorporate expert knowledge such as monotonicity in the form of constraints on model parameters.

The case study applies the constrained hierarchical modeling approach to a dataset from a novel tissue-engineered scaffold process and compares its performance with popular existing methods. It reveals that this approach generates meaningful and accurate predictions that cannot be obtained from other methods. Another advantage of this approach is that its results have easy interpretations, which can provide valuable insights to help practitioners understand and improve their process.

This approach has broad applicability in process design and modeling in manufacturing and other fields where expert knowledge on the process exists and should be taken into account during data analysis to produce practically meaningful, desirable and useful solutions.

CONTACT: Li Zeng; lizeng@tamu.edu; (979) 458-2352; Department of Industrial and Systems Engineering, Texas A&M University, 3131 TAMU, College Station, Texas 77843

Managing inventory risk so asset owners aren't stuck with obsolete spare parts

Airline, metro bus, trucking, electric utility and other asset-rich companies operate large numbers of similar, repairable assets. Failed parts or subsystems are replaced by what are commonly called line replacement units (LRUs).

In order to ensure high system availability and improve system reliability over time, recurring and critical failures are addressed by improving the reliability of LRUs through new design or material. This means that subsequent acquisitions of these repairable systems will come with upgraded LRUs, and the corresponding old LRU will become obsolete. Asset owners are faced with the trade-off in carrying a sufficient number of LRUs to meet the availability requirement and running the risk of being stuck with LRUs that aren't usable.

In "Reliability Analysis and Spares Provisioning for Repairable Systems with Dependent Failure Processes and Time-Varying Installed Base" by Xiao Liu of IBM Research and LC Tang from the National University of Singapore, an integrated approach combining reliability analysis and inventory planning is proposed for optimally setting stock levels of various LRUs while maintaining high overall fleet availability and mitigating the risk of carrying obsolete stock.

One salient feature of the proposed framework is that it addresses the dynamics of the complex demand process through statistical modeling and data analysis.

In practice, the demand process is not stationary because of the potential reliability growth or deterioration of LRUs over maintenance cycles and from the time-varying installed base, that is, the entire set of systems in use.

Interestingly, studies have shown that the size of the installed base closely follows the product life cycle. The installed base often increases during the initial phase due to market expansion, reaches the maximum level within the mature phase and starts decreasing during the end-of-life phase. Advances in information technology, such as the Internet of Things, make it feasible to collect historical failure data and project the future installed base expansion.

Hence, instead of managing inventory risks based on strong mathematical assumptions imposed on the demand process, the proposed framework allows the spares provisioning to be driven by real-time updated demand forecasting. The user-friendly software package, which is available from the authors, makes the proposed framework readily applicable in industry.

Xiao Liu (left) and professor LC Tang shared their research at an international conference.

CONTACT: Xiao Liu; liuxiao314923@gmail.com; IBM T.J. Watson Research Center, 1101 Route 134 Kitchawan Road, Yorktown Heights, New York 10598; or Loon-Ching Tang; isetlc@nus.edu.sg; 6516-6648; Department of Industrial and Systems Engineering, National University of Singapore, 1 Engineering Drive 2, Singapore 117576

This month we highlight one article from the most recent issue of *The Engineering Economist* (Volume 60, Issue 3). In it, the authors introduce a closed-form solution to model the mortgage refinancing decision.

Modeling the mortgage refinancing decision

In a regime of falling interest rates, millions of homeowners and businesses will seek to refinance their mortgages to secure a lower rate. Most do this by relying on "guesstimates" or rules of thumb because financial analysis is somewhat tricky.

Elements of the decision include the after-tax costs of implementing the mortgage replacement, the anticipated holding period of the replacement mortgage and the present value of the after-tax savings of replacing a higher mortgage payment with a lower one.

In a zero-tax environment, or when a homeowner does not itemize mortgage interest, the problem is fairly simple. However, when taxes are considered, calculating the net present value of the mortgage refinancing decision becomes more tedious and difficult.

The computational problem is that the interest portion of both the current and replacement mortgage payments changes with each payment. For this reason the discounted net tax savings for each payment has heretofore in the literature been handled in a discrete manner. If each net monthly after-tax mortgage has to be calculated separately, the refinancing equation can comprise hundreds of terms.

The effect of taxes should be considered in the refinancing decision because, while the newer mortgage payments are lower, the interest tax deduction is lower as well. Because the net interest rate deduction changes every month, computations become difficult.

The approach thus far in the literature has been to use spreadsheets to discount the components of each monthly cash flow discretely. This approach will yield a correct net present value (NPV) for each situation it considers, but it is not an efficient method.

In "A Closed-Form, After-Tax, Net Present Value Solution to the Mortgage Refinancing Decision," professors Richard Followill and Brett Olsen of the University of Northern Iowa develop a concise equation that alleviates