INDUSTRIAL ENGINEER

Engineering and management systems at work

Engineers who make a difference

From developing sustainable power for watercraft to providing economic opportunities for the disenfranchised, industrial engineers are building a better world

JANUARY 2016 VOLUME 48 : NUMBER 1: $17.50

Value stream analysis for lean facility design

How many employees do you really need?

New manufacturing focus at New Mexico State

Old military aircraft require high maintenance

RESEARCH

Inside IIE Journals

This month we highlight two articles on transportation scheduling and logistics. The first article develops an approach for incorporating multiple sources of information from intelligent transportation systems to provide computationally efficient, real-time route planning for vehicles in dynamic traffic networks. The second article develops algorithms for scheduling the shipping of parts from an intermediate distribution center to production facilities so the parts arrive "just in time." These articles will appear in the February 2016 issue of *IIE Transactions* (Volume 48, No. 2).

Are we there yet? Exploiting massive amounts of traffic data for route planning

Intelligent transportation systems (ITS) employ a variety of technologies from smart traffic signal control systems to advanced applications that integrate live data and feedback from different sources (e.g., data from mobile phones). ITS provide a rich source of historical and real-time data that can enable efficient vehicle route planning. The real-time data also can inform route planners about how events such as extreme weather and road accidents affect traffic network dynamics.

Route planners are used in many systems, including dispatch centers of emergency responders and trucking companies, navigation systems and mobile

Ratna Babu Chinnam (from left), Mark Nejad and Lena Mashayekhy collaborated with Anthony Phillips to design a vehicle routing algorithm that used intelligent transportation systems.

navigation applications. If route planners effectively incorporate ITS data, vehicles can avoid congested areas.

However, developing efficient algorithms for vehicle routing on time-dependent networks is a major challenge due to scale and dynamics of traffic data. And most current applications require significant data pre-processing and computing memory.

The problem of vehicle routing under ITS is investigated in "Hierarchical Time-Dependent Shortest Path Algorithms for Vehicle Routing under ITS." In this paper, Mark Nejad from the University of Oklahoma, Lena Mashayekhy from the University of Delaware, Ratna Babu Chinnam from Wayne State University and Anthony Phillips from Ford Motor Co. propose a hierarchical time-dependent vehicle routing algorithm. Their proposed algorithm exploits community structure of traffic

Anthony Phillips is a senior technical leader at Ford Motor Co.

networks. Community structure refers to the occurrence of densely connected groups of nodes. Exploiting hierarchical community-based representations of road networks, the algorithm recursively reduces the search space in each level of the hierarchy to speed up the search for effective routes dramatically.

Using data from road networks in Detroit, New York and San Francisco, the authors also demonstrated the computational efficiency and accuracy of their proposed algorithm. The algorithm finds routes in real time on large-scale networks without having to store a large number of pre-calculated shortest paths and lower bounds. A key property of their proposed algorithm is the fact that it does not require a lot of memory. This property makes the algorithm more suitable to be incorporated in vehicle route planners.

CONTACT: Mark Nejad; mark.nejad@ou.edu; Assistant Professor, School of Industrial and Systems Engineering, University of Oklahoma, 202 W. Boyd St., Room 124, Norman, OK 73019-1022

Just in time, from time to time

These days, JIT supply of final assembly is often regarded as a matter of course, especially in the automotive industry, where the JIT principle was born. The plethora of parts, modules and subassemblies required for building cars these days, on the one hand, and the notoriously scarce space on the shop floor, on the other hand, make more inventory than the absolute minimum barely conceivable.

However, in spite of the undeniable benefits of JIT, the increasing delivery costs that go hand in hand with a frequent, small-lot supply must not be forgotten. So something like "just in time, from time to time" must have come to the mind of professors Nils Boysen and Simon Emde from Friedrich-Schiller-University of Jena and professor Dirk Briskorn from the University of Wuppertal when being presented with the following problem of a large German automobile producer.

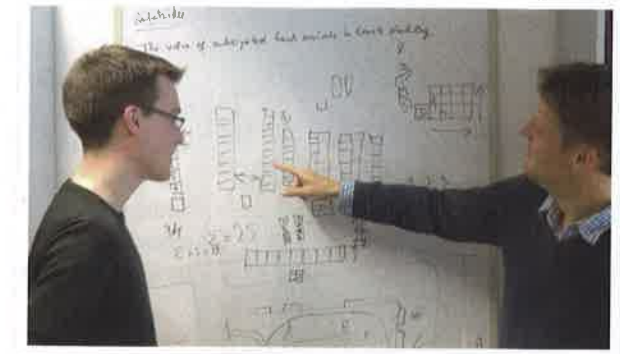
The OEM receives parts from all over the world, especially from Eastern Europe and the Far East. The lead-time for these distant suppliers is too long to enable a concerted JIT supply chain. Thus, to avoid excessive parts inventory, the OEM built an additional distribution center (DC) to store parts intermediately from distant suppliers for the OEM's nearby plants.

Three to four days ahead of production, when the production sequence of cars in one of the OEM's plants is fixed definitively, this sequence is communicated to the DC, where the required parts are sorted and stored in transport containers.

These containers need to be transported from the DC to the OEM plant by trucks that have a fixed capacity. The deadline of each container leaving the DC is defined by the production slot in which the first part is assembled. In this setting, the OEM aims at a delivery schedule that trades off the benefits of JIT supply with the transportation costs of the trucks.

In their paper "Just-in-Time Vehicle Scheduling with Capacity Constraints," the German researchers investigate the OEM's scheduling problem in detail and provide suitable optimization procedures. Their algorithms clearly outperform the simple spreadsheet solutions currently used by the OEM.

CONTACT: Nils Boysen; nils.boysen@uni-jena.de; +49 3641-943100; Chair of Operations Management, Friedrich-Schiller-University Jena, Carl-Zeiss-Str. 3, D-07743 Jena, Germany



Simon Emde (left) and Nils Boysen discuss their work.

The most recent issue of *IIE Transactions on Healthcare Systems Engineering* (Volume 5, Issue 4) contains five articles covering a range of healthcare systems problems and solution methods. Brief summaries of two of the articles are given below. The first discusses how an integer program can be used to help manage the deployment and redeployment of ambulances. The second describes the use of sensors and data mining techniques to provide a low cost, noninvasive way to predict early stage Parkinson's disease.

Timely and effective emergency response is no accident

Emergency medical service (EMS) organizations provide vital services, but an often overlooked challenge for these incident responders is the struggle to stay afloat financially. The reality is that many EMS outfits battle to survive fiscally while they are saving lives.

In "A Multi-Period Dynamic Location Planning Model for Emergency Response," doctoral student Jianing (Jenny) Zhi and professors Burcu B. Keskin and Sharif H. Melouk of the University of Alabama aim to minimize the total operational cost of an EMS organization while maintaining acceptable response times. The researchers collaborated with Chris Byrd, operations supervisor at NorthStar Paramedic Services of the Tuscaloosa/Birmingham region, while designing a new, four-tier, dynamically changing response network. The new network considers EMS supply centers, hospitals, potential responder locations and predicted incident locations.

This work was motivated by the lack of cost perspective in existing EMS research. EMS providers typically use a limited number of ambulances to respond to incoming calls. They dispatch a set of ambulances to the incident scene depending on incident severity. Uncertain arrival times of emergency calls impact the ability of ambulances to cover the service area, especially with respect to service restrictions that have been imposed. A major concern for EMS providers relates to the failure of responding to incidents within a defined service time requirement, which leads to excessive penalty costs for the providers and leaves the public vulnerable. Of course, sustained low service performance by an EMS provider may result in the loss of a responder service contract.

Using an integer programming approach, the researchers created a resource planning and network design model with a focus on minimizing total operational cost, all while meeting the service requirements. Operational cost components include transportation cost, delayed response penalty cost and deferral penalty cost. Unique to this research are considerations of penalty costs for delayed and deferred responses and using supply centers as a source for responder and dispatch locations.

Research by Burcu B. Keskin (from left), Chris Byrd and Sharif H. Melouk aimed to help emergency medical service organizations survive financially.

Jianing Zhi co-authored "A Multi-Period Dynamic Location Planning Model for Emergency Response."

This research quantifies the impact of network size, ambulance fleet size, differing incident occurrence patterns and time-dependent incident frequency on service quality and total cost. One of the most interesting investigations relates to a payback analysis that could justify acquiring new emergency response resources. The planning model helps practitioners evaluate when procuring additional resources, compared with reallocating existing resources, may be a justifiable strategy.

CONTACT: Burcu B. Keskin; bkeskin@cba.edu; (205) 348-8442; 355 Alston Hall, ISM Department, The University of Alabama, Tuscaloosa, AL 35487-0226

What can body movement tell us about brain health?

Mobility is critical to human interactions, whether it involves how we move the muscles in our face to smile or our arms to hug a loved one. Unfortunately, some people lose certain cells in the brain that are important for normal movement, leading to significant motor dysfunction. Whereas directly observing the inner workings of the brain may be challenging even when using today's advanced technologies, what goes on in the brain may be observable indirectly by focusing on the things that the brain controls, such as our hands and legs.

One established technique for measuring indirectly how well our brain is controlling our motor functions is attaching physical sensors to different body parts that execute motor functions (e.g., hands, arms, etc.). This approach, however, requires securing many sensors to multiple body positions and using special cameras to track the sensors. Furthermore, the placement of the sensors is time-consuming, somewhat embarrassing for the participant, and the cameras are rather expensive. Instead of wearable sensors that indirectly measure the brain's functions relating to mobility, what if similar data could be captured using off-the-shelf, nonwearable sensing systems?

In the article "A Data Mining Methodology for Predicting Early Stage Parkinson's Disease Using Non-Invasive, High Dimensional Gait Sensor Data," Pennsylvania State University researchers Conrad S. Tucker, Yixiang Han, Harriet Black Nembhard (industrial engineering), Wang-Chien Lee (computer science and engineering), Mechelle Lewis, Nicholas Sterling and Xuemei Huang (neurology) collaborated to explore the feasibility of using a single nonwearable, depth-sensing camera system to capture individuals' gait patterns. Just as a human can see the difference in how people walk, researchers were able to train a computer algorithm to use the movement data captured by the nonwearable sensor to differentiate Parkinson's disease patients from controls.

This research has the potential to advance early-stage detection of neurologically induced movement disorders in nonclinical settings, such as the comfort of one's home. Such techniques could serve as a decision support system for physicians and healthcare providers seeking to empower patients by focusing on wellness and preventive medicine.

CONTACT: Conrad S. Tucker; ctucker4@psu.edu; (814) 865-7580; The Pennsylvania State University, 213-N Hammond Building, University Park, PA 16802-1401

Conrad S. Tucker presented his team's work at the annual Center for Integrated Healthcare Delivery Systems workshop.

Ronald Askin is a professor and director of the School of Computing, Informatics and Decision Systems Engineering at Arizona State University. He is editor-in-chief of IIE Transactions *and a fellow of IIE.*

John W. Fowler is the Motorola Professor and Chair of the Department of Supply Chain Management in the W.P. Carey School of Business and a professor of industrial engineering at Arizona State University. He is editor-in-chief of IIE Transactions on Healthcare Systems Engineering.

About the journals

IIE Transactions is IIE'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.

IIE Transactions on Healthcare Systems Engineering is a quarterly, refereed journal that publishes papers about the application of industrial engineering tools and techniques to healthcare systems.

To subscribe, call (800) 494-0460 or (770) 449-0460.