UNION SWITCH AND SIGNAL, INC.

On Time with Rail-Traffic Optimization Technology

Over 80 percent of raw materials and goods travel by rail at some point during shipment. Rail transport is prone to unexpected delays caused by routing conflicts, accidents, and power outages that inconvenience passengers and impair shipments between suppliers, manufacturers, and retailers. These delays play havoc with just-in-time delivery that manufacturers and distributors use to keep inventories low, and can increase costs. Punctuality is equally important for passenger trains: delays are a primary barrier to increasing ridership. And because passenger and freight trains share 95 percent of the same track miles, any delay can affect much of the rail system.

COMPOSITE PERFORMANCE SCORE
(Based on a four star rating.)
★ ★

Problems with Existing Optimization Approaches

Traditional optimization software employs a linear decisionmaking process whereby a single solution is reached. Traditional optimization techniques generally seek a single solution, such as maximizing profit or reducing cost. Each change in the environment (e.g., train delays or equipment fault) triggers the optimization system to start again from scratch to search for a new solution. This approach is both time-consuming and unrealistic for effective use in planning real-time train movement. In contrast, standard planning of train movement requires several objectives to be addressed simultaneously, e.g., minimizing the cost of crews and minimizing lateness.

Union Switch and Signal Company Sees Opportunity in University Research

Prior to applying to the ATP, Union Switch and Signal, Inc. (US&S), a leading supplier of equipment to the railroad industry, was working with a Carnegie Mellon University (CMU) research team on technology for improving the safety and viability of railroad equipment. In that process, US&S became familiar with optimization research that was going on at CMU. US&S saw an opportunity to build on the research by CMU to break through the technical challenges of optimization for rail traffic scheduling. The optimization research underway at Carnegie Mellon was referred to as the “Asynchronous Teams, or A_Teams technology.” Shortly after discovering the A_Teams work at Carnegie Mellon, US&S invited Sarosh Talukdar, a CMU professor of electrical and

US&S saw an opportunity to build on the research by CMU to break through the technical challenges of optimization for rail traffic scheduling.

Better tools for railway traffic planning could improve the rate of on-time arrivals.

PROJECT HIGHLIGHTS

PROJECT:
To adapt and extend a distributed multiagent-based optimization technology developed by Carnegie Mellon University (CMU) for use in railway traffic planning.

Duration: 1/15/95-1/14/97

ATP Number: 94-01-0063

FUNDING (in thousands):

ATP	$2,000	67%
Company	967	33%
Total	2,967	

ACCOMPLISHMENTS:
US&S researchers, working closely with university researchers at CMU, adapted and extended a technology to simulate real-time movement planning for railroads. The project:

- developed the basic tools and knowledge needed to construct and implement a better optimization system for railroad use;
- developed two different software programs which implement the technology: Real-time Central Traffic Controller, a real-time movement planning software; and Offline Railroad Operations Planner, software allowing railroads to evaluate alternative track layouts and routing plans;
- secured funding from a class 1 railroad (one of the six largest North American railroads) to pilot-test the technology; and
- achieved a potential 50 percent improvement in rate of on-time arrivals over the use of traditional command-and-control software.

COMMERCIALIZATION STATUS:
Efforts by US&S to commercialize work on the optimized traffic planner were focused on two software packages, each with specialized applications: the Real-time Central Traffic Controller and the Offline Railroad Operations Planner. The Real-time Central Traffic Controller is intended to provide optimized routing plans to central office controllers. The Offline Railroad Operations Planner provides recommendations that can increase the capacity and throughput of a railroad line, e.g., it can identify a bottleneck in a railway line and suggest solutions to increase throughput at the trouble spot. The software has performed well in pilot tests conducted in collaboration with a railroad, but had not been commercialized as of the time of the study.

OUTLOOK:
The commercialization of the two software packages is contingent on the ability of US&S to enter into cooperative development arrangements with prospective railroad customers. These customers can provide necessary data to perform additional tests and funding to support continued development of the software. There are several factors supporting a favorable outlook for commercialization: two software programs have been developed; the initial test results were strong; and the railroad companies have demonstrated interest. At the time of the study, however, uncertainties remained about the willingness of the railroad companies to provide the necessary follow-through support for commercialization.

Composite Performance Score: ★ ★

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computer engineering, to its offices to learn about potential applications of A_Teams technology to rail traffic planning. A-Teams offered a number of attractive features over traditional optimization approaches.

A_Teams technology employs multiple software agents. The agents are autonomous pieces of software that incorporate decisionmaking programs, memory, and the ability to communicate with each other. These agents work together as a team, each contributing its individual problem-solving expertise to provide solutions. The agents operate on a population of solutions, continuously improving the population by altering the solutions and then evaluating each solution against the rest of the population.

One advantage of A_Teams is that it allows optimization to be divided up into many subtasks—each of which is addressed by teams of agents, allowing for alternative schedules to be determined more rapidly. The flexibility of operations and adaptable architecture help to break up the optimization problem into agent subtasks. Thus, the A_Teams technology enables the handling of more complex problems than the existing technology can handle. In the case of railroads, this might include routing more trains over more tracks, whereas traditional movement planning systems are able to plan the movement of only one train at a time.

Another advantage of A_Teams is that it enables more rapid adaptation to alternative schedules because of changes in the environment (e.g., a track blocked by an accident) and does not require a total reassessment. Teams of agents react to local changes and make appropriate adjustments, testing the new solution by comparing it with the existing pool of solutions. In addition, the A_Teams is a modular approach, which allows networks to be upgraded and modified merely by changing the population of agents. This is important because incompatibility between different generations of software has been a particularly troublesome problem for railway decision-support software: upgrading has meant the complete replacement of software systems.

The university's modular problem-solving software appeared to offer potential for railroad routing, but not without additional research. US&S wanted to exploit the opportunity, but lacked the internal resources to mount the required research effort alone.

With ATP's Support, US&S Adapts and Extends the A_Teams Approach

In 1995, the Advanced Technology Group (ATG), an R&D unit of US&S, proposed a research project to adapt and extend the A_Teams approach to make it suitable for rail traffic planning. The proposal scored high in technical and economic merit, and US&S received a $2 million award for research from ATP. The company contributed a cost share of $967,000 to the project.

The technical goals of the project centered on developing a distributed optimization approach to railroad routing, and adapted and extended Carnegie Mellon's A_Teams modular problem-solving approach. The research had three major components: 1) decomposing a scheduling problem into subtasks to be pursued by agents, 2) developing a messaging protocol for communication among subtasks, and 3) specifying programming agents to respond to information received.

Technical Goals Reached

Researchers at US&S made substantial progress in developing the necessary infrastructure. They developed the basic tools and knowledge needed to construct better A_Teams systems, including libraries of code needed for agent construction, mathematical optimization models, system components, and application interfaces to allow components of the system to work together.

The simulations demonstrated a 50 percent improvement in the rate of on-time arrivals...

Researchers at Carnegie Mellon University were contracted to investigate potential organizational designs for individual A_Teams software agents and groups of agents. In addition, they provided expert advice on how the system could be designed to allow software agents to communicate with each other in real time.

Pilot Testing on Trains

Efforts by US&S to commercialize work on the optimized traffic planner are focused on two applications. The "Real-time Central Traffic Controller" is software for real-time movement planning that is intended to provide optimized routing plans to central office controllers. The "Offline Railroad Operations Planner" is simulation software that will allow railroads to evaluate alternative track layouts and routing plans. It provides recommendations that can increase the capacity and throughput of a railroad line. For example, it might identify a bottleneck in a railway line and suggest laying double track to increase throughput at this trouble spot.

...US&S was seeking to form cooperative development alliances with class 1 railroads.

Toward the end of the project, funding was secured from a class 1 railroad (one of the six largest North American railroads) to pilot-test the technology. US&S researchers performed simulations of real-time movement planning using data from the railroad, including typical schedules, track layout, speed limits, and patterns of movement (e.g., periods of acceleration and deceleration). The simulations demonstrated a 50 percent improvement in the rate of on-time arrivals, a key performance goal, when compared to the performance of traditional command-and-control software.

Unfortunately, the railroad company that was supporting the pilot-testing was acquired by another railroad company, and its new management, preoccupied with consolidation, discontinued support for the project. The company's management has since reconsidered its decision, and, at the time of this study, was negotiating a new arrangement with US&S. In addition, US&S at that time was seeking to form cooperative development alliances with other class 1 railroads.