SHORT COMMUNICATION

TRANSWARM: A SUGARCANE TRANSPORT SIMULATION MODEL BASED ON BEHAVIOURAL LOGISTICS

MCDONALD BC[1], DUBE E[1] and BEZUIDENHOUT CN[2]

[1]*School of Computer Science, University of KwaZulu-Natal, Private Bag X54001, Durban, 4000, South Africa*
[2]*School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Private Bag X01, Scottsville, 3209, South Africa*
brendclyde@gmail.com dubee2@ukzn.ac.za bezuidenhoutc@ukzn.ac.za

Abstract

Transport logistics systems typically evolve as networks over time, which may result in system rigidity and cause changes to become expensive and time consuming. In this study a logistics model, named TranSwarm, was developed to simulate sugarcane harvesting, transport and mill-yard activities for a mill supply area. The aim was to (i) simulate produce flow, and (ii) allow individual working entities to make decisions, driven by rules and protocols, and based on their micro-environments. Noodsberg mill was selected for the case study because of low current levels of synchronisation. Growers were assumed to operate independent harvesting and transport systems causing inconsistent convergences at the mill. This diverse and fragmented system provided a suitable environment for constructing a model that would consider interactions between individual growers and their respective transport systems. Ideally, by assessing the micro-decisions of individuals and how these decisions influence the holistic supply chain, TranSwarm quantifies the impacts of different types of transport practices, such as changing vehicle speeds to reduce queuing at the mill. TranSwarm is visual, mechanistic and represents key entities such as roads, farm groupings and the mill. The system uses discrete events to create a dynamic and stochastic environment from which observations and conclusions can be drawn. This approach potentially allows stakeholders to identify key components and interactions that may jeopardise overall efficiency and to use the system to test new working protocols and logistics rules for improving the supply chain.

Keywords: sugarcane, transport, modelling, simulation, logistics, TranSwarm

Introduction

In today's modern world of integrated networks and complex system problems, simpler solutions often mean better solutions. Bonabeau *et al.* (1999) formalised the notion of Swarm Intelligence (SI), which is a complex systems simulation methodology used to study the individual behavioural patterns of different entities in a system and how they interact with each other. The use of SI, a system that initially may seem chaotic, could ultimately accomplish complex tasks through simplification (Liu and Passino, 2000). An ant colony is a good example in which, by following simple rules, the seemingly random movements of ants collectively accomplish difficult tasks.

The South African sugar supply chain is currently facing many challenges. The sugar price is low, while infrastructure and logistics costs are steadily rising. A component of the supply chain that can immediately be identified as highly important is transport. Sugarcane transport is comprised of a large and complex network of activities. At a single mill, transport can involve hundreds of operators and vehicles. Careful planning and co-ordination is ideally needed to avoid wasting resources, but in a multi-stakeholder environment this may not be easily achievable.

Banks (1998) showed that inept transport management and work protocols often lead to inefficient systems, and how small corrections to these systems could benefit industries. It is hypothesised that SI-based modelling can be tailored to a sugarcane transportation problem to research how complex tasks could be completed efficiently without centralised control. Ideally, the SI system should be able to correct itself and adjust appropriately when external influences affect the system. The objective of this research is, therefore, to design and evaluate a sugarcane transportation simulation system based on swarm intelligence.

Model framework

The Rockwell Arena v11.0 simulation software package was used to implement the model. This package was chosen because of its successful use in similar industry applications (Barnes, 1998; Diaz and Perez, 2000; Gaertner, 2004).

Software implementation followed the key design principles developed in the conceptual model. Arena facilitates a flowchart type methodology when a system is constructed, thus the components found within the conceptual model could be represented accordingly. Following this, a generic sugarcane transport logistics system, named *TranSwarm*, was developed. TranSwarm allows entities of sugarcane bundles to flow through the system, from farms to the mill, and includes queuing at the mill.

The conceptual model (Figure 1) is closely related to the actual flow that takes place. The model has been divided into two distinct parts, the *Grower/Farm* section and the *Miller/Mill-yard* section, labelled F_0 and M_0, respectively. The reason for this was to differentiate between the activities of the distinctive parties in the supply chain. Therefore, the grower is responsible for his/her farm (f_0), harvesting (h_0) and transport (t_0) activities, whereas the miller is responsible for mill-yard (m_0) activities.

When the model runs, all the variables, schedule times and queue structures are initialised appropriately using three simultaneous inputs. All inputs are contained within a MS Excel spreadsheet and are read into the model through f_0 and m_0. Inputs include, *inter alia*, daily sugarcane allocation (for harvesting), external farm data (e.g. number of vehicles, choppers, and/or other) and mill data (e.g. number of spiller cranes, hysters, and/or other).

When the inputs have been read, the daily allocation of sugarcane (entities) can start flowing from module to module. First, the sugarcane will reach the harvest module (h_0), where cane will be harvested according to an appropriate harvest technique. Secondly, the cane will be transported infield to a loading zone, where it will enter the transport module (t_0). Here the cane will be loaded onto the correct vehicles and transported to the mill. During the transition through these modules, various facts, statistics and information are gathered and compiled into reports and graphs.

When the vehicles leave F_0 they enter the road network, where they are assumed to travel along the shortest path to the mill and back. When vehicles reach the mill (M_0) they enter the mill-yard (m_0) and offload the cane, after which they return to the farm to load the next consignment. This cycle continues until cane at the loading zones has been replenished.

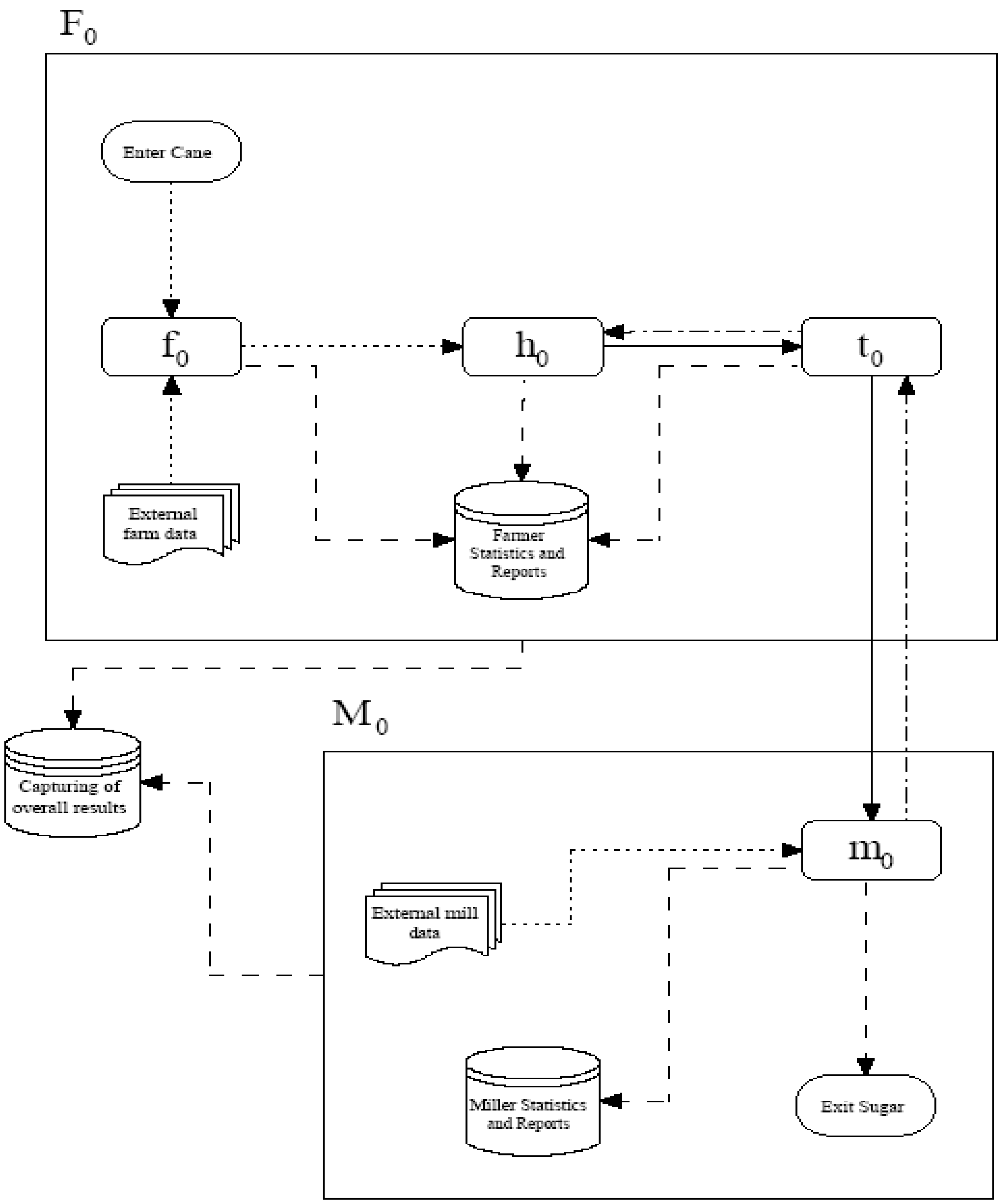

Figure 1. Conceptual diagram for the TranSwarm sugarcane logistics model.

Proposed case study

The region of interest is a small, culturally diverse community located north of Pietermaritzburg in KwaZulu-Natal province. In this area, known as Noodsberg, the cultivation of sugarcane is one of the primary agricultural activities. Noodsberg sugarcane transport configuration offers complex daily logistics challenges, which, through SI-based simulation, may be represented accurately enough to investigate different operating rules.

TranSwarm was configured for Noodsberg according to the current road and farm networks. The Noodsberg configuration comprises 153 major production units, serviced by 105 vehicles. Simulations include daily harvesting and extraction, loading zone dynamics, inbound and outbound vehicle movements, queuing at the mill, and offloading systems for both spiller and bundle cane systems. Figure 2 illustrates the graphical representation of the Noodsberg mill supply area as displayed in the Arena software.

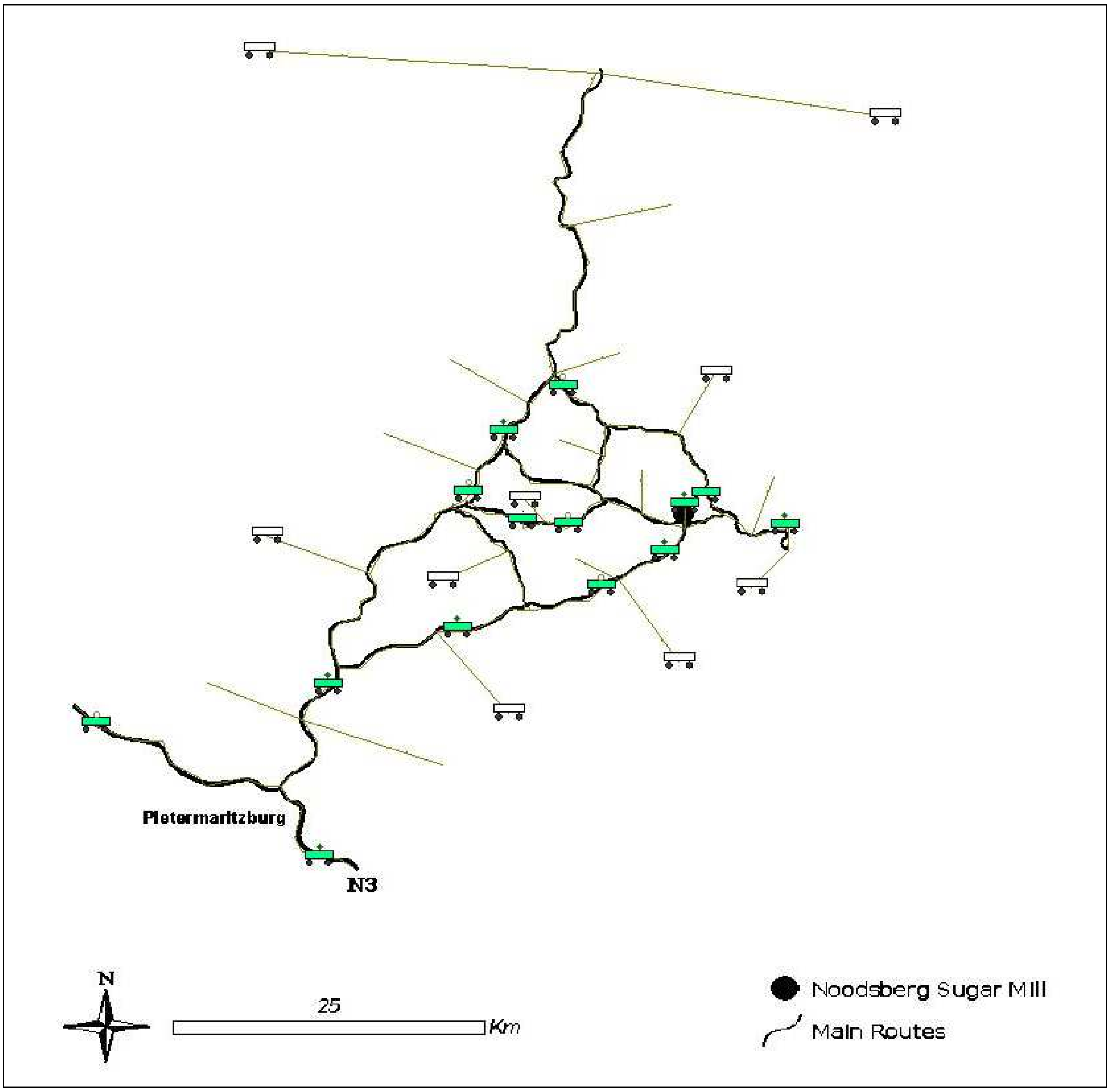

Figure 2. The *TranSwarm* configuration for Noodsberg. The Arena-based model includes production units, a road network, loaded and empty vehicles (shaded and un-shaded, respectively) and several processes at the mill.

Current research includes test results that validate the model under a benchmark scenario by comparing simulation outputs with observed system variables, such as cycle times, queue length and product flow rate. This confirms the model's validity, which provides a certain level of confidence when new scenarios are simulated. Future attempts will include simulation of external traffic to produce congested conditions, and alterations to swarm intelligence rules, such as vehicles speeding up or slowing down, and will analyse the impacts of these issues on overall system efficiency.

Acknowledgements

The Department of Transport (ECoTD bursary scheme) is thanked for funding this project. Stakeholders at Noodsberg mill are thanked for their advice, and their willingness to provide information and knowledge where required. Mr. Julien le Masson from ParisTech (France) provided valuable baseline information and simulation results that was used constructively in this study.

REFERENCES

Automation R (2007) http://www.arenasimulation.com/

Banks J (1998). *Handbook of Simulation Principles, Methodology, Advances, Applications, and Practice*. Engineering and Management Press. ISBN 0-471-13403-1.

Barnes A (1998). Simulation modelling of the sugarcane harvest to crush delays. MScEng Dissertation, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Bonabeau E, Dorigo M and Theraulaz G (1999) *Swarm Intelligence: From Natural to Artificial Systems*. Oxford University Press, UK. ISBN 0-19-513159-2.

Diaz J and Perez I (2000). Simulation and optimization of sugarcane transportation in harvest season. Winter Simulation Conference, Orlando, Florida, USA. Vol. 2: 1114-1117.

Gaertner D (2004) Natural algorithms for optimisation problems. Final Year Report, Imperial College, London, UK.

Liu Y and Passino K (2000). Swarm intelligence: Literature overview. Internal Report, Dept. of Electrical Engineering, Ohio State University, USA.