Conceptual Model of a Self-Organizing Traffic Management Hazard Response System

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Introduction

- Recent natural disasters and terrorist attacks have sparked renewed interest in developing effective policies and strategies for evacuating densely populated areas
- Lack of analytical tools for dealing with such evacuations
Introduction

But currently…

• Progress in information technology and transportation science allows faithful simulations and testing of various what-if scenarios

• Cellular automata and evolutionary computation provide tools for designing effective traffic management strategies
Background: Cellular Automata

- One of the simplest mathematical representations of complex systems
- Useful idealizations of the dynamical behavior of various systems
- Models for complex systems and processes consisting of a large number of identical, simple, locally interacting components
- Discrete dynamical system simulators used to study pattern formation and self-organization processes
Background: Cellular Automata

Simplest 1D Cellular Automata
Background: Cellular Automata

1D Cellular Automata: Mechanism

a) initial configuration of cell values

b) 

c)
Background: Cellular Automata

2D Cellular Automata

Neighborhoods

- radius = 1
- radius = 2
- Moore neighborhood
- von Neumann neighborhood

Diagonal neighborhood
North-South neighborhood
East-West neighborhood

Iteration

step 0
step 1
step 2
step 3

step 12
step 13
step 14
step 15

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Background: Evolutionary Algorithms

- Use a population of individuals
- Individuals are points in search space
- Individuals are evaluated for their “fitness”
- Population dynamics:
  - New individuals (samples) are created from existing high fitness parents using operators like:
    - Crossover
    - Mutation
  - Existing low fitness individuals are deleted
Assumptions and Hypotheses:

• A typical transportation network can be understood as a complex system with many entities and actors, all pursuing their own somewhat limited objectives and acting with variable and limited information inputs.

• All of the actors in the system have actions they can take that are perceived to improve their own performance, or to advance their assigned operational objectives, and they often make decisions with little or no knowledge of the impacts of their decision on the performance of the overall system.
Assumptions and Hypotheses:

• The *emergent behavior* of the system and its subsystems is of great interest for finding effective technology and policy approaches to improving performance.

• *Systems operating in crisis mode exhibit self-organizing behavior*, so finding optimal operational strategies involves understanding and capitalizing on this attribute.
Self-Organizing Traffic Management System

Conceptual Model:

Simple model of an urban area to be evacuated

2D cellular automaton updating the traffic signal system
Self-Organizing Traffic Management System

- Cellular automata models of the traffic control system can be employed to determine evacuation strategies following terrorist attacks in a given urban area.
- The input for each evacuation scenario simulation consists of:
  - a configuration of vehicles (pedestrians will be introduced in later versions) in the urban area under consideration
  - a specific CA model of a traffic control system to be evaluated, and
  - pre-determined terrorist threat situation, i.e., locations and types of terrorist attacks.
Self-Organizing Traffic Management System

Conceptual Model Assumptions:

- Traffic signal state durations (phase lengths) are fixed and constant. A traffic phase length is an integral multiple of the model’s fixed time step, and cycle times are a product of the modeling results. The length of the time step is a modeling variable.

- Vehicles move only in marked lanes (i.e., not on the shoulders, sidewalks, or off-road areas), in the normal direction (i.e., not in opposing lanes, even if they are empty).

- The initial locations, destinations and travel paths of individual vehicles are given and constant, which determine the turning movement demand at individual intersections.
Implementation: System Architecture

- CORSIM
  Traffic Network Simulation and Determination of Measures of Effectiveness (MOEs)
  Fortran
  CORSIM Output
  CORSIM Input

- OUT File
  Complete description of a network simulation and MOE values

- TRF File
  Complete traffic network definition and simulation parameters

- Runtime Extension
  Real-time traffic network simulation control
  C++

- Java Native Interface (JNI)

- EMERGENT DESIGNER
  - ECJ
    Traffic signal system representation and optimization using evolutionary algorithms
  - Mathematica
    Cellular Automata Simulation
  - JLink
    Java

- Java I/O
  Fitness value(s)
Implementation: Visualization
Initial Conclusions

• Only a conceptual model presented
• Initial architecture of the system defined and implemented
• A simple demo version of the system presented - fine-tuning of the system required