Constraint Recognition, Modeling, and Visualization in Network-Based Command and Control

Rogier Woltjer, Kip Smith, Erik Hollnagel

Linköping Institute of Technology

<rogwo@ida.liu.se>

I-152, 11th ICCRTS, September 27, 2006

Cambridge, UK

© Rogier Woltjer, 2006

Outline

- Distributed collaborative command and control
- Constraints
- Method for the recognition of constraints
- Representation of constraints
- Implications
- Future research

© Rogier Woltjer, 2006

Distributed Collaborative Command and Control

- Command and control (C2) process
- Management of a crisis situation
- Task:
  - Cooperative control of a dynamic and complex situation
- Network-based organization

© Rogier Woltjer, 2006

Network-Based Command and Control

- Staff will no longer relay orders down the hierarchy
- A “flat” network organization
- High-performance information grid
- Filtering, aggregation, and presentation of data/information by computer systems

- How can this be accomplished?

© Rogier Woltjer, 2006

Research Hypotheses

- The description of joint behavior in terms of constraints is useful.
- Representing constraints enhances control and performance.

© Rogier Woltjer, 2006

Research Hypotheses

- This work develops a method and several alternative representations of constraints that
  - enable the recognition of constraints,
  - illustrate how constraints shape behavior, and
  - may be used in the design of representational aids (displays) with the purpose of enhancing control.

© Rogier Woltjer, 2006

What is a Constraint?

A constraint is either a limit on goal-directed behavior, or an opportunity for goal-directed behavior, or both.

Constraints …

- have both restricting and facilitating roles
  - specify the opportunities for behavior
  - reduce variability
- shape human action
- facilitate the exercise of control
- propagate

© Rogier Woltjer, 2006

Constraints in Command and Control

Persson (1997) identified constraints concerning:

- Resources
- Time
- Organization
- Rules
- Procedures
- Mission
- Socio-cultural factors
- Communication
- Language

We will treat:

- Spatial and temporal resource constraints

© Rogier Woltjer, 2006

Method for Constraint Recognition

1. FRAM analysis of the distributed command and control team's task.

2. Identification of the essential variables.

3. Representation of constraints in state spaces.

© Rogier Woltjer, 2006

Logic of the Experiment

- We manipulated spatial and temporal resource constraints.
- By doing this, we presented a range of opportunities for action.
- We measured essential variables.
- This makes it possible to test the utility of our constraint recognition method and, thus, document how constraints shape behavior.

© Rogier Woltjer, 2006

Experimental Procedure

- We applied the method for constraint recognition to the C3Fire microworld.
- 4 groups of 8 persons engaged in the task of fighting the simulated fire
  - Swedish men
  - between the ages of 19 and 37 (mean 24.6)
  - not professionally trained in command and control

© Rogier Woltjer, 2006

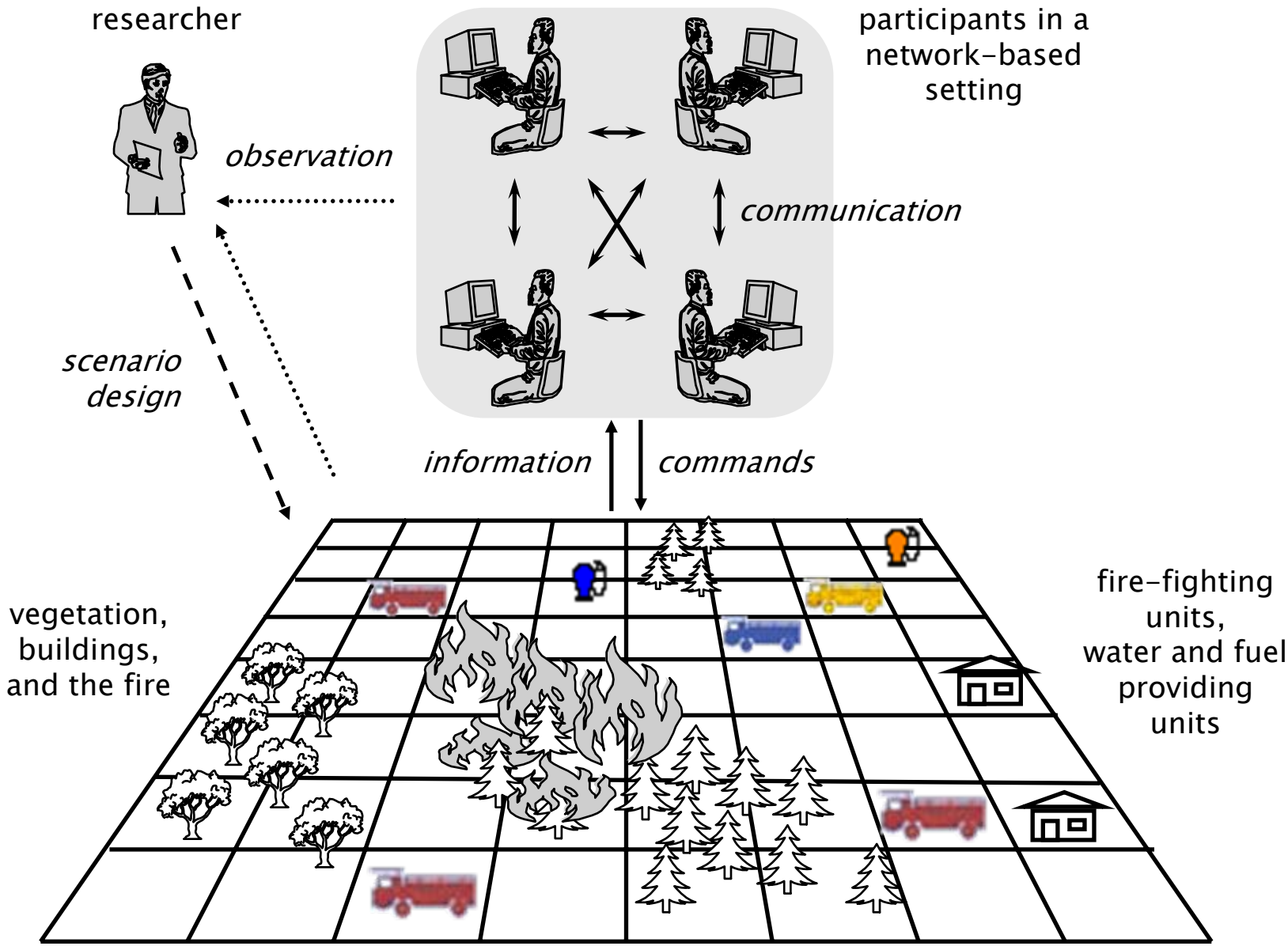
Microworlds

- Experimental platforms that simulate parts of real-world work environments
  - between laboratory and field study: balancing experimental control and veridicality
- Properties:
  - complexity
  - dynamics
  - polytely
  - intransparency

(Brehmer & Dörner, 1993; Brehmer, 2005)

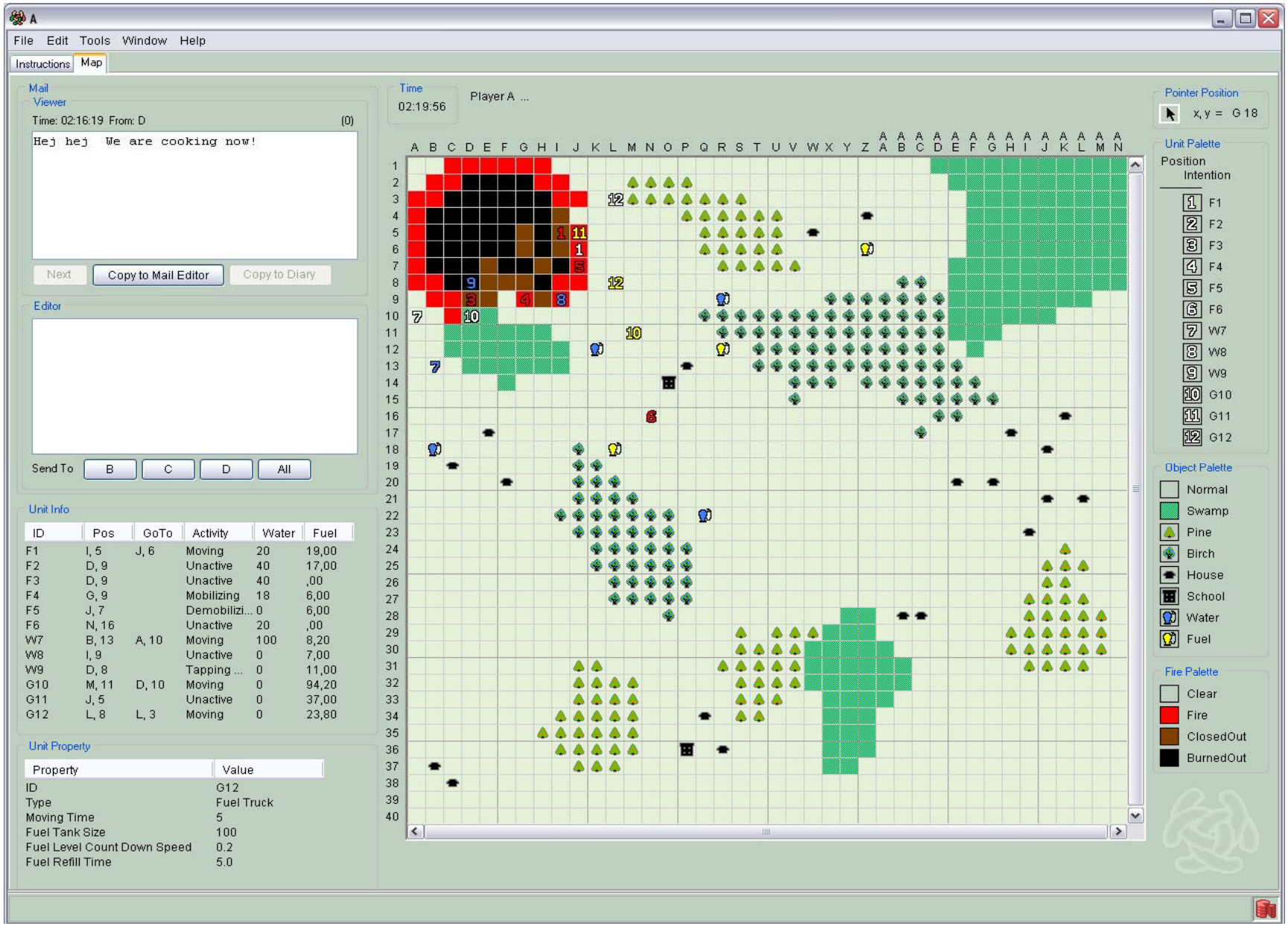
© Rogier Woltjer, 2006

C3Fire Overview



C3Fire Interface

C3Fire (Granlund, 2002)



Method for Constraint Recognition

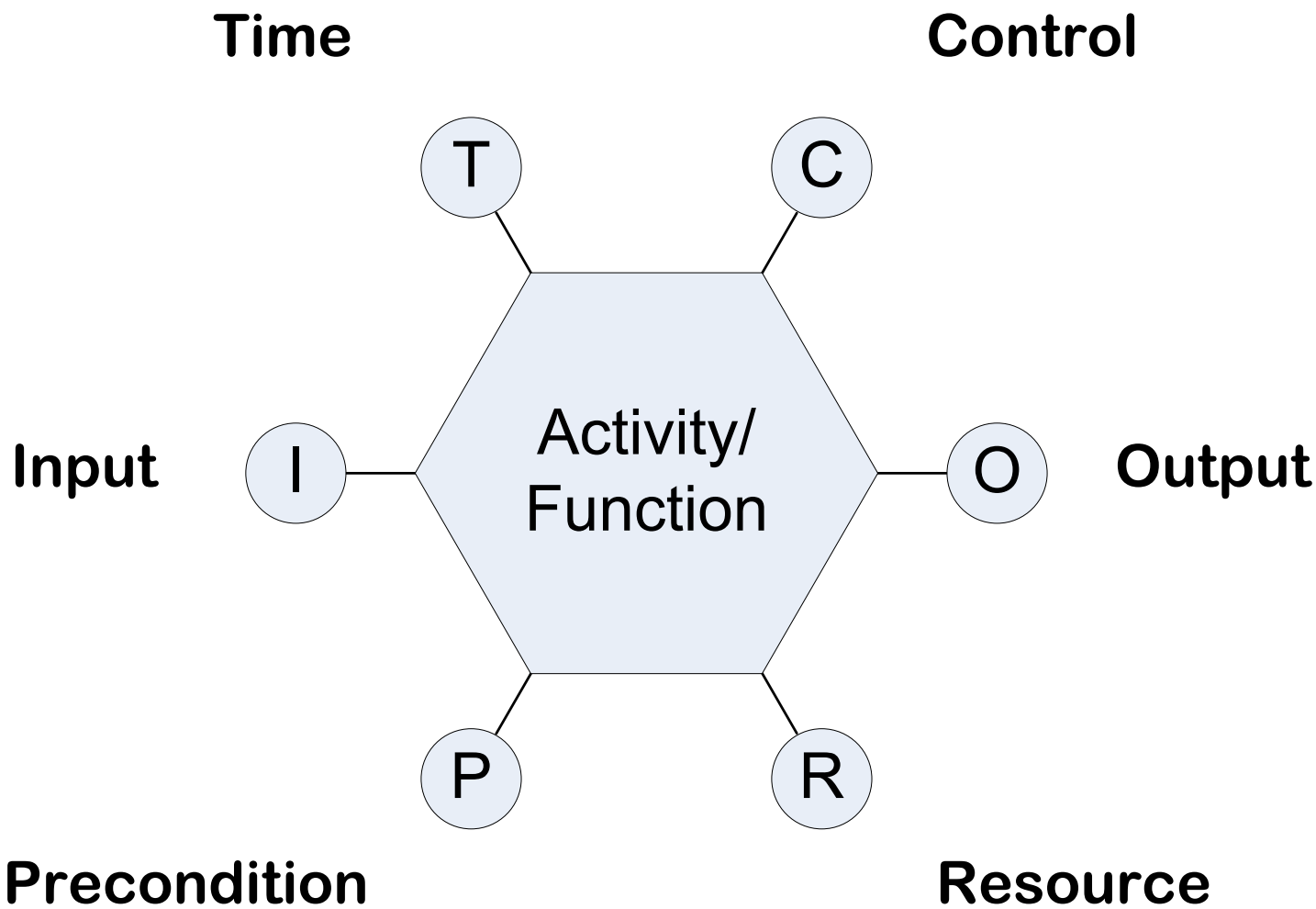
1. FRAM analysis of the distributed command and control team's task.

2. Identification of the essential variables.

3. Representation of constraints in state spaces.

© Rogier Woltjer, 2006

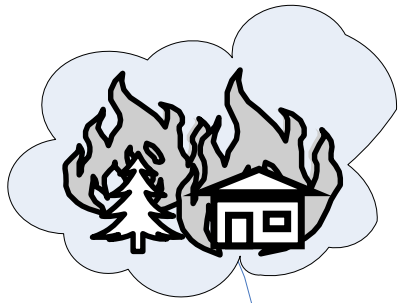
FRAM Functional Unit (Module)



© Erik Hollnagel, 2006

C3Fire Function Example

Staff members control fire trucks' movements



Fire truck collocated with fire

T

C

Truck dynamics

I

Fire truck moves to fire location

O

Fire truck

P

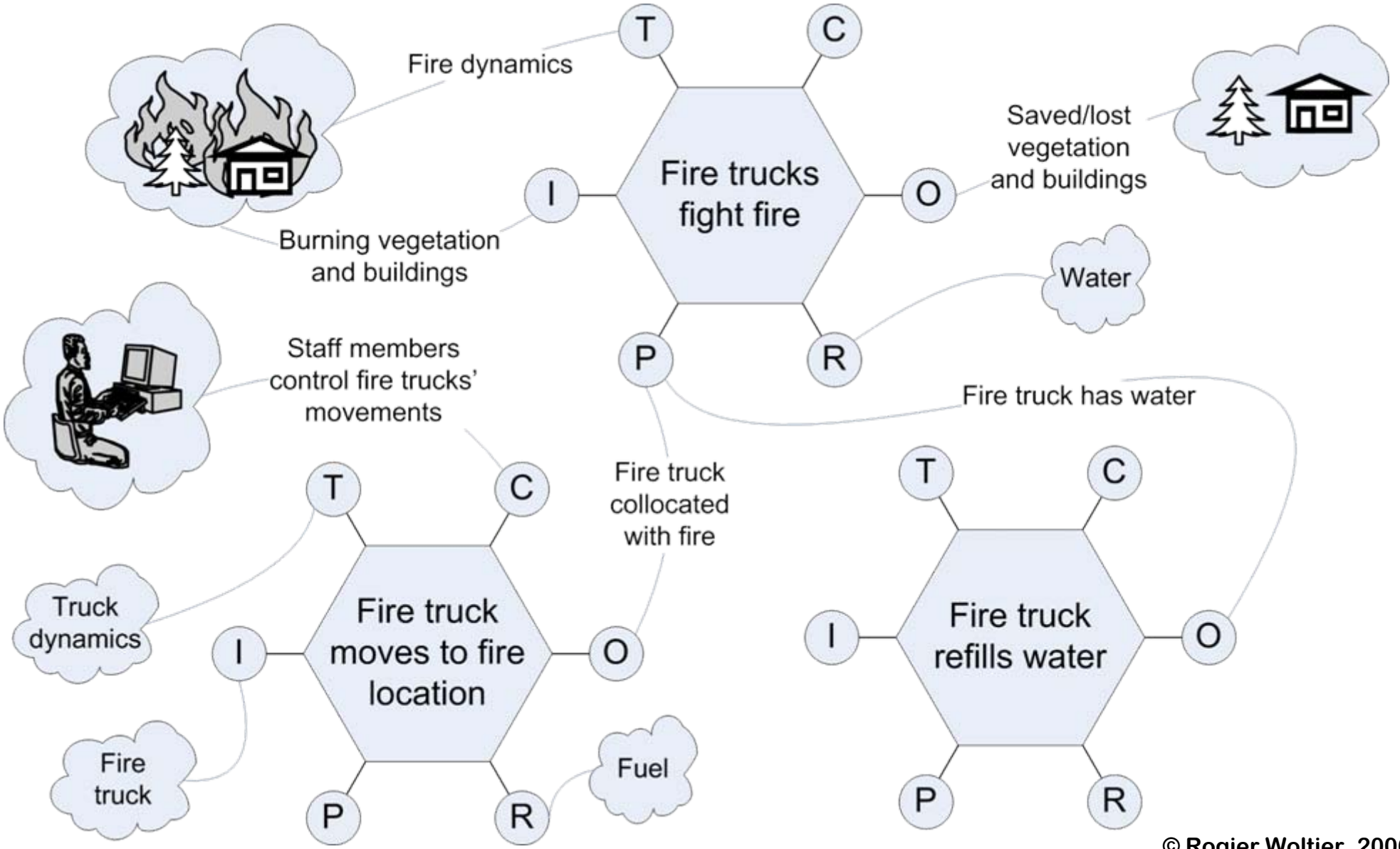
R

Fuel

© Rogier Woltjer, 2006

CSE LAB

C3Fire Links Between Functions



© Rogier Woltjer, 2006

FRAM & Essential Variables

Fire truck refills water from water truck	*Description*	*Essential variables*
Input	fuel truck, water, water truck	coordinates of fuel and water trucks
Output	increased water level of fuel truck	water level of fuel truck
Preconditions	water and fuel trucks collocated, water truck has water	coordinates of fuel and water trucks, time between them, water level of water truck
Resources		
Time	refill dynamics	Rate of increase of fuel truck's water level when refilling
Control		

© Rogier Woltjer, 2006

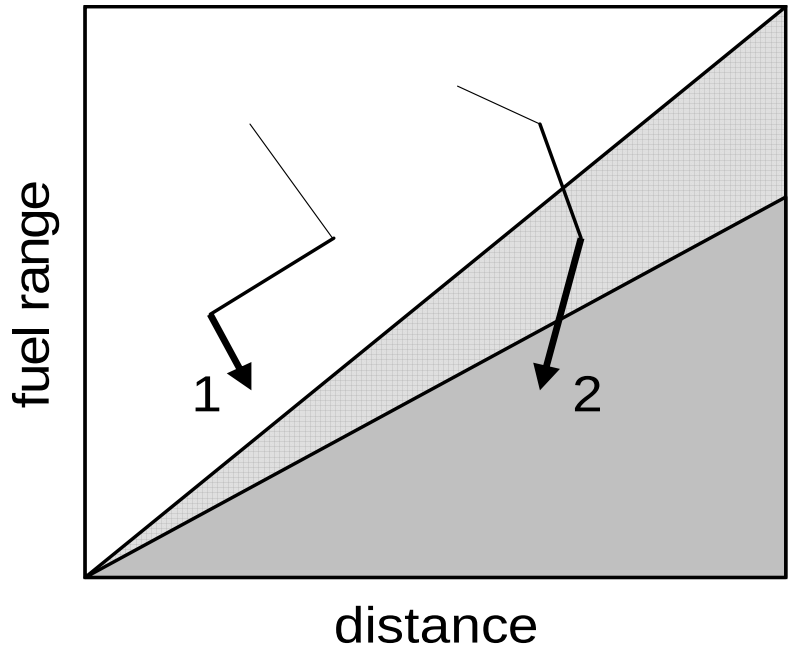
State Space Representation

Three steps:

a. **Juxtapose essential variables to form a multidimensional state space**

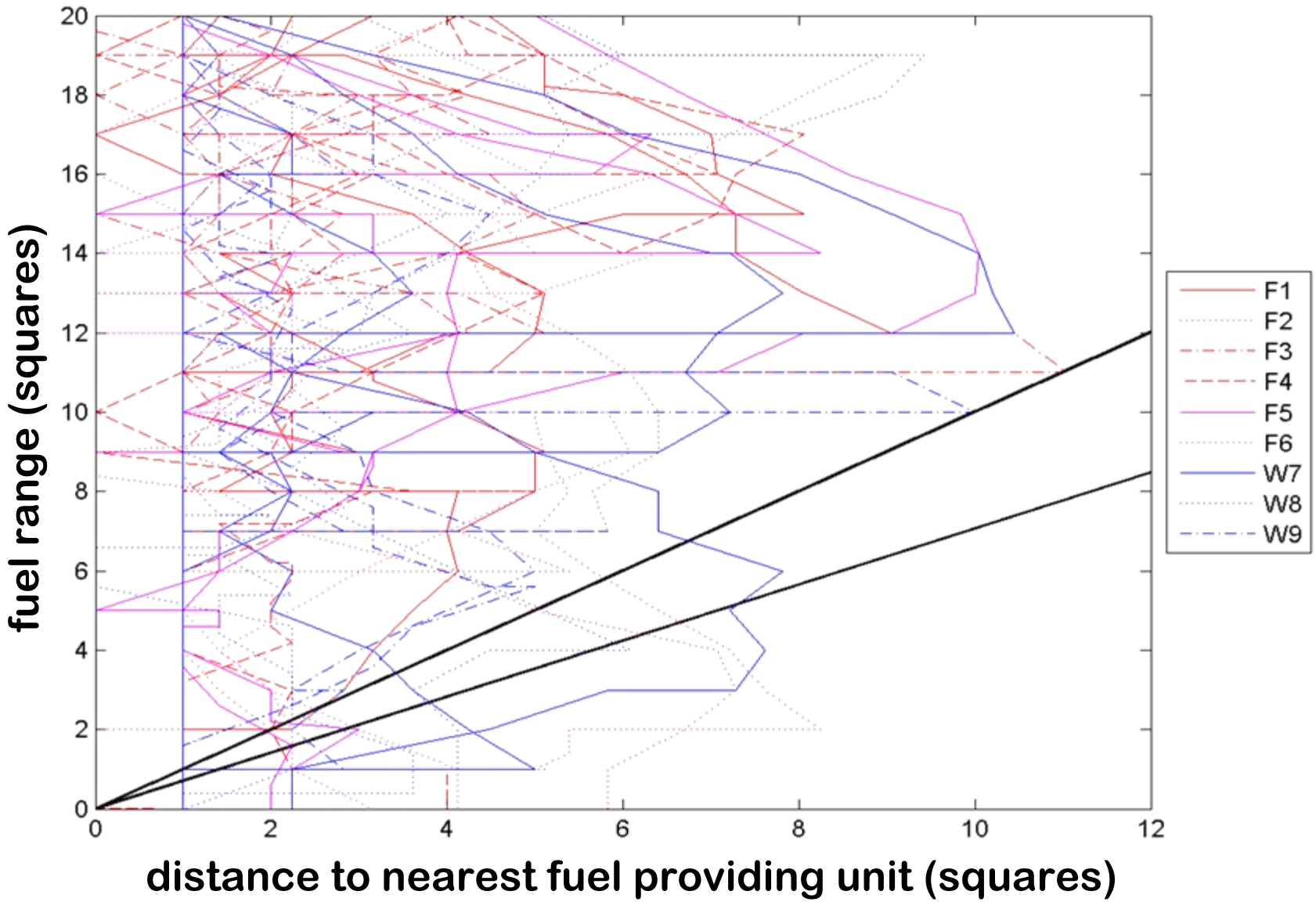
b. **Sample the values of the essential variables**

c. **Compare the sampled data to thresholds in the state space to identify the current opportunity for action.**



© Rogier Woltjer, 2006

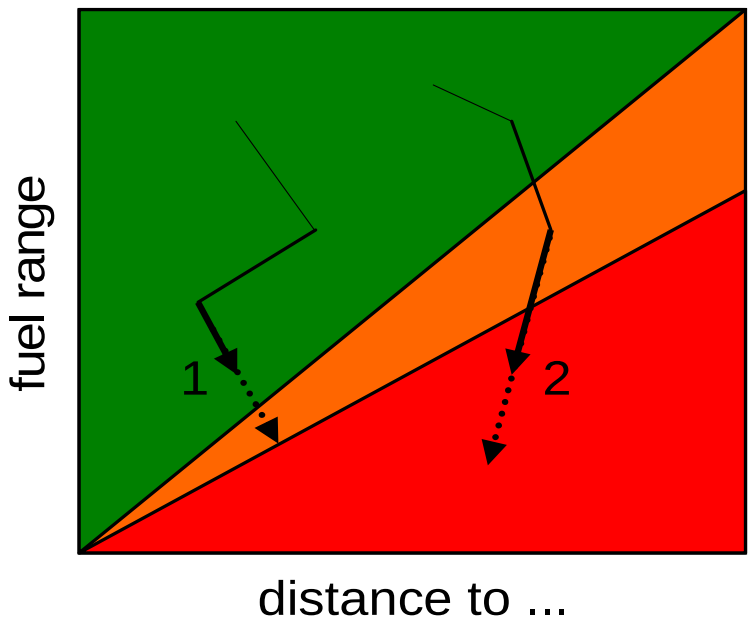
Results: State Spaces

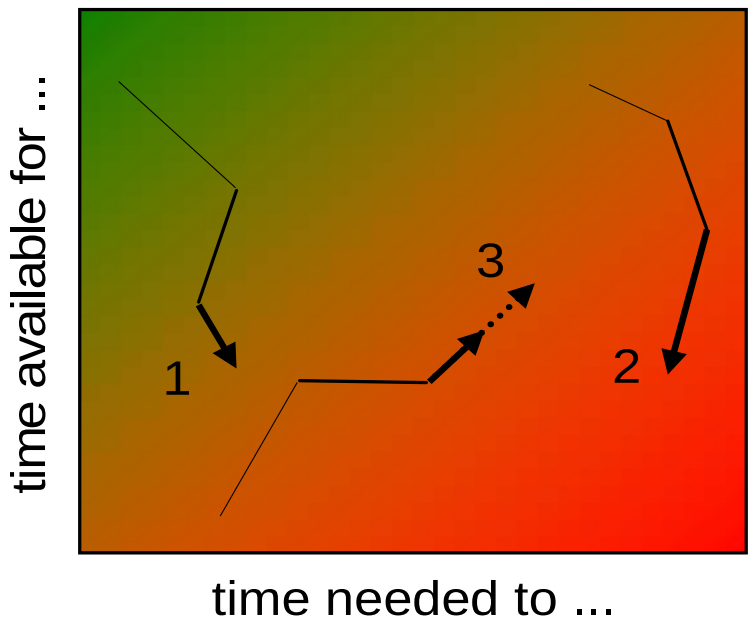


© Rogier Woltjer, 2006

Implications

- State spaces illustrate behavior in relation to constraints.
- State spaces may let their observer interpret the value of essential variables in a goal-directed context.

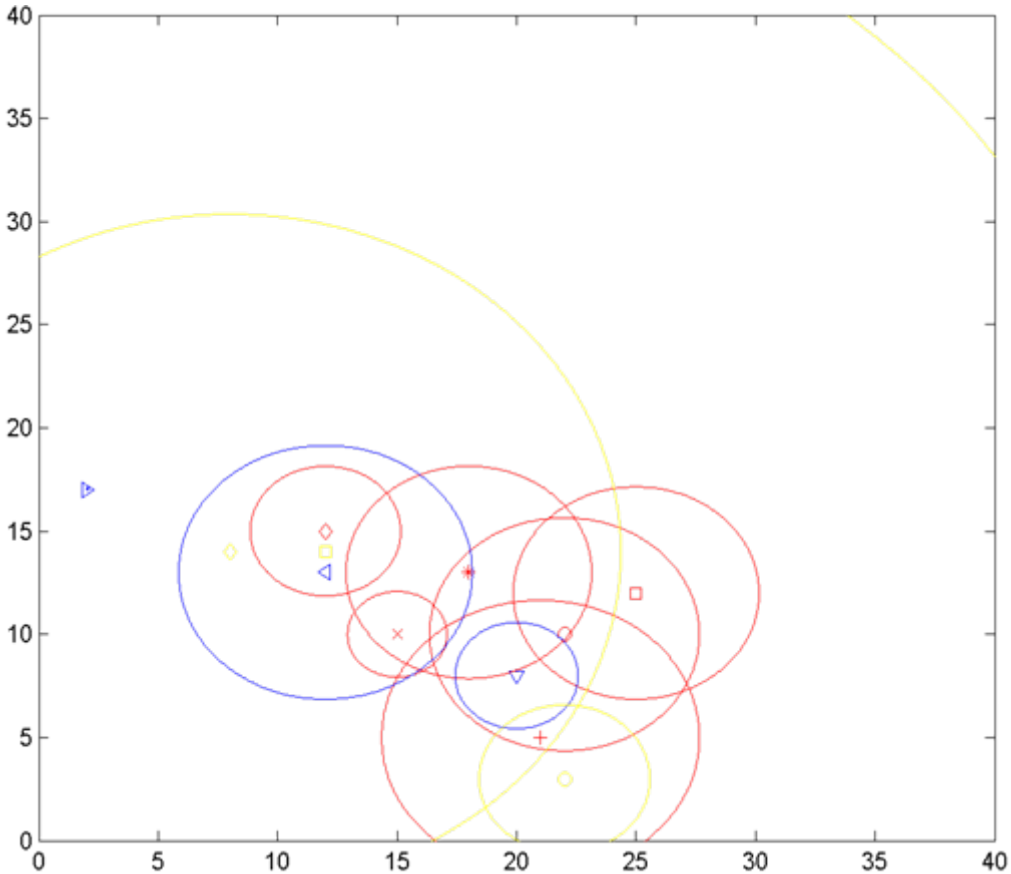




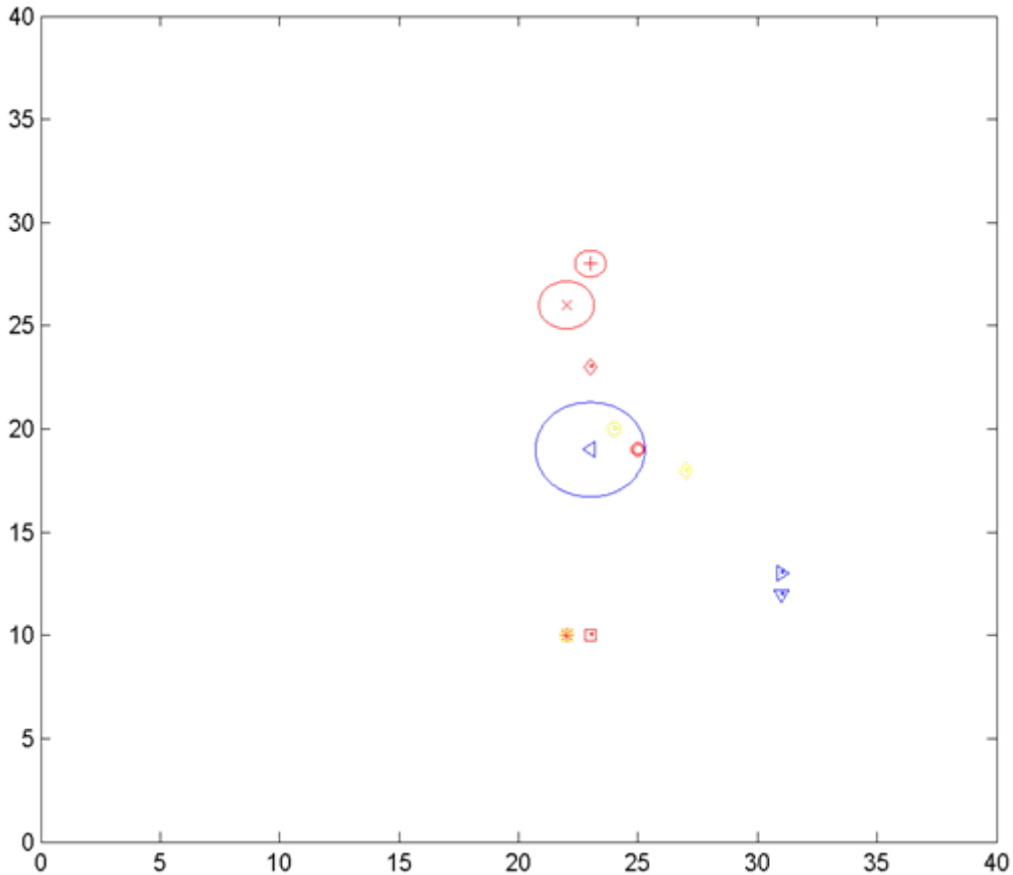
© Rogier Woltjer, 2006

CSE LAB

Results: Fuel Range Visualization



t=30s



t=930s

- Representation of constraint 'fuel range' on an XY-coordinate (map) display

© Rogier Woltjer, 2006

Implications

- Displays based on state space and other representations of constraints have the potential to
  - inform a commander's understanding of the process to be controlled, and
  - direct action that may enhance control.
- By making constraints more salient, designers of C2 systems should be able to help commanders to gain control over dynamic situations.

© Rogier Woltjer, 2006

Ongoing Research

- Refine, generalize, and test the method for constraint recognition in a C2 wargame
- Generate a specification of requirements for its implementation in C2 settings

© Rogier Woltjer, 2006

Thank you for your attention!

- Questions, comments?

- Point of contact:

  Rogier Woltjer <rogwo@ida.liu.se>

© Rogier Woltjer, 2006