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The advantages of fuzzy logic for traffic signal control

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Zurich, 6 February, 2001

Outline of presentation

- Background
  - Changing objectives for traffic signal control
- Prototype signal controller
  - Fuzzy logic modules
  - Optimisation using Multi-Objective Genetic Algorithm (MOGA)
- Some results

Background

- UTMC programme
- UK Government White Paper *"A New Deal for Transport: Better for Everyone"*
- Delphi study done by TORG

⇨ New objectives include

- priority to public transport
- improving conditions for vulnerable road users
- reducing traffic impact on air quality

3 generations of vehicle actuated signal control

- Crisp logic
  - “Gapping out”
- Single objective network control
  - SCOOT, SCATS
- Multi-objective network control
  - SCOOT+, SCATS+
  - Fuzzy Logic

Multi-objective network control

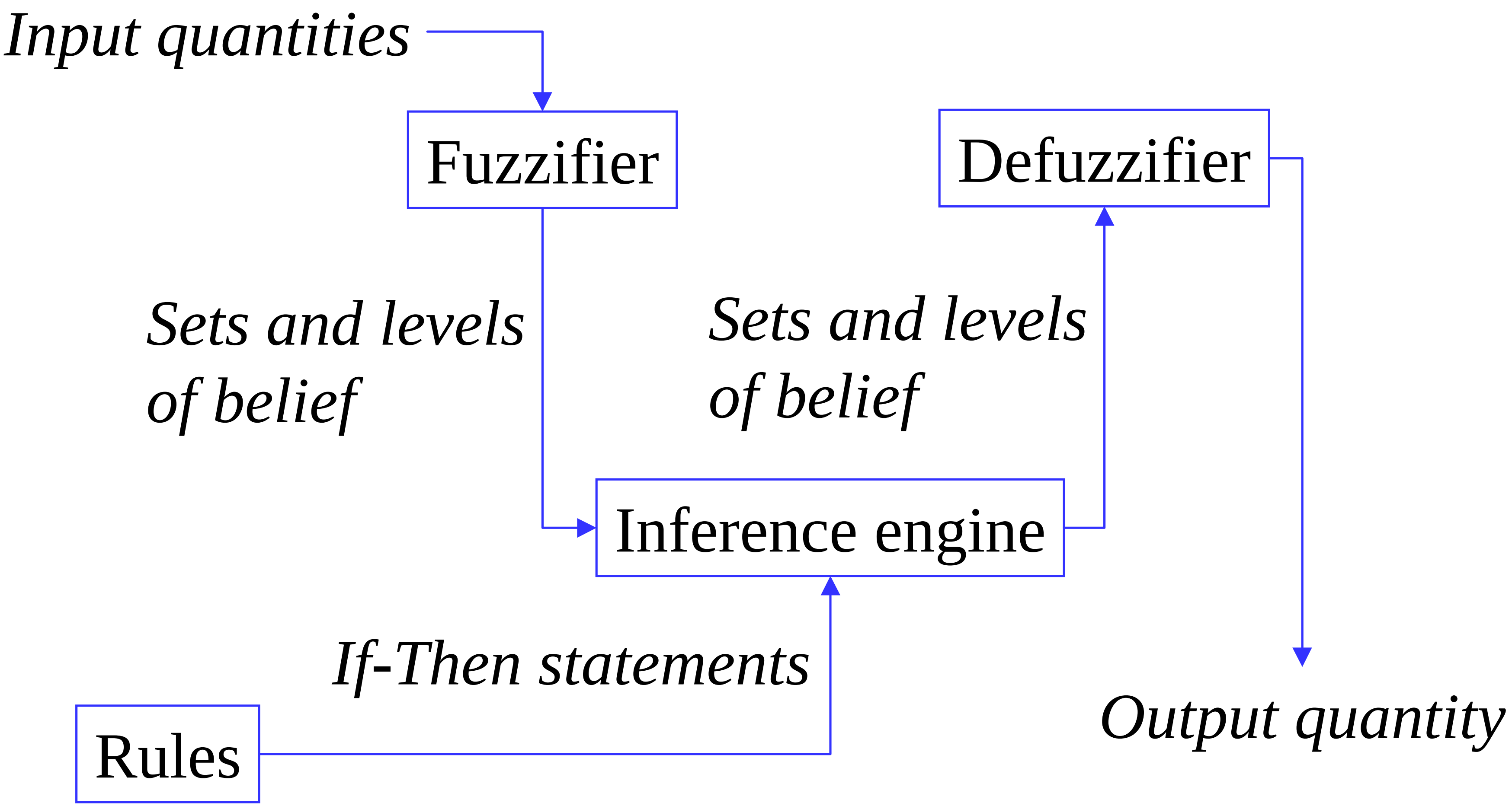
- Different junctions,different priorities
  - pedestrians
  - public transport
  - private transport
- Road space reallocation
  - pedestrianisation
  - bus lanes
  - “red routes” (no parking)

Road space reallocation

What is fuzzy logic?

- Quantification of *linguistic information* while allowing for *imprecision*
- Invented by Zadeh (1965), now used widely for *inference* and *control* problems
- “non-linear mapping of an input data (feature) vector into a scalar output” (Mendel, 1995)

Fuzzy logic system



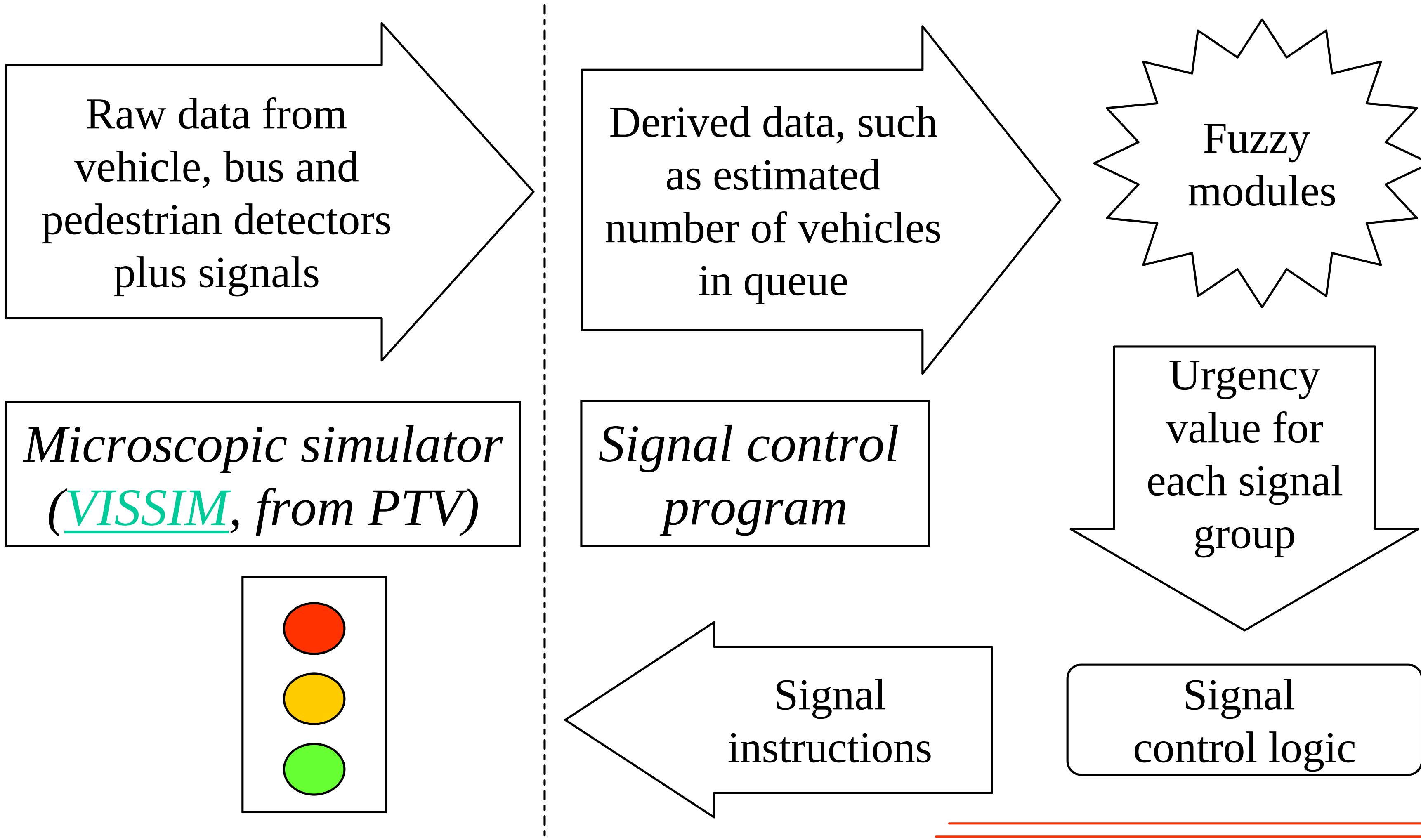
Past work in the field

- Pappis and Mamdani (1977) – seminal work
- Nakatsuyama et al (1983) – two junctions
- Chui (1992) - network
- Sayers, Bell, Mieden and Busch (1996) - urgency
- Nittymaki and Pursula (1997) – group-based control
- Landenfeld and Cremer (1997) – junction with spill back
- Niitymaki and Kikuchi (1997) – pedestrian crossing
- Niitymaki (1998) – bus priority
- Lee, Krammes and Yen (1998) – incident detection

Advantages of fuzzy logic

- Uses linguistic variables
- Allows imprecise/contradictory inputs
- Permits fuzzy thresholds
- Reconciles conflicting objectives
- Rule base or fuzzy sets easily modified

Simulation Environment: Dynamic Data Exchange on PC



Input data for signal controller

Vehicle

- Smoothed gap at stop line detector
- Smoothed gap at upstream detector
- Estimated queue
- Number of seconds since first vehicle arrived at stop line

Pedestrian

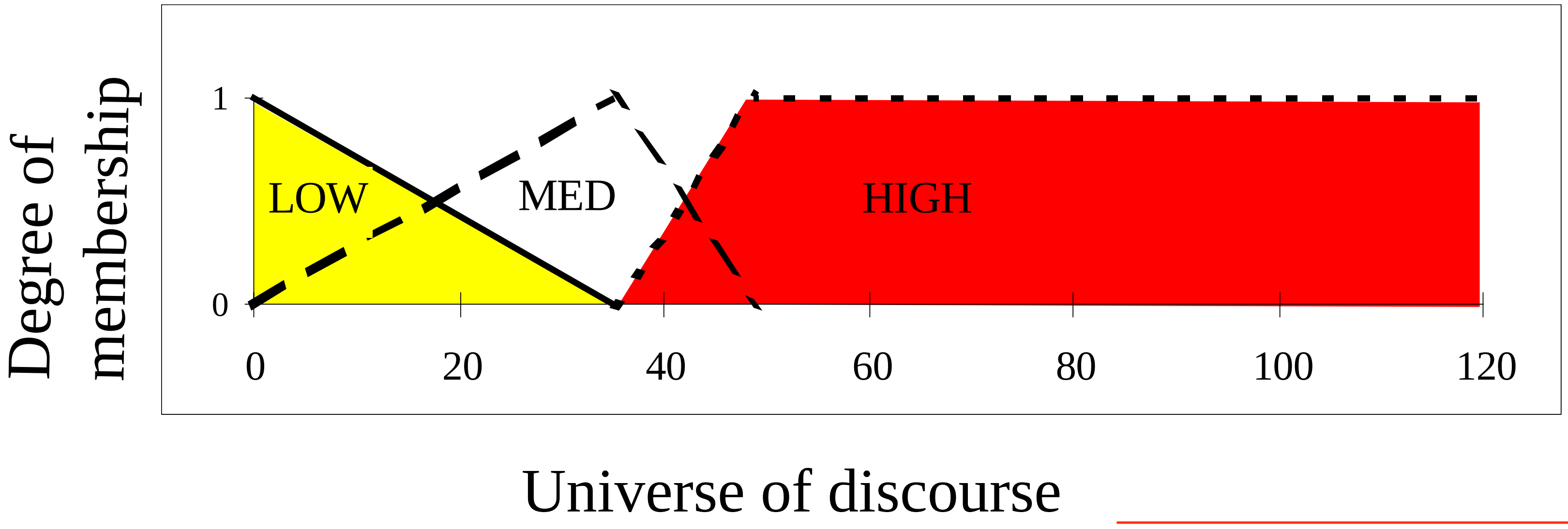
- Time since pedestrian request was received
- Time since last pedestrian green

Public Transport

- Deviation from scheduled arrival time
- Deviation from desired headway between buses

Fuzzy sets for input variables

- Simple triangular membership functions (3 or 4)
- 19 configurations defined
- Goal of optimisation is to find optimal configurations of fuzzy sets for all input variables



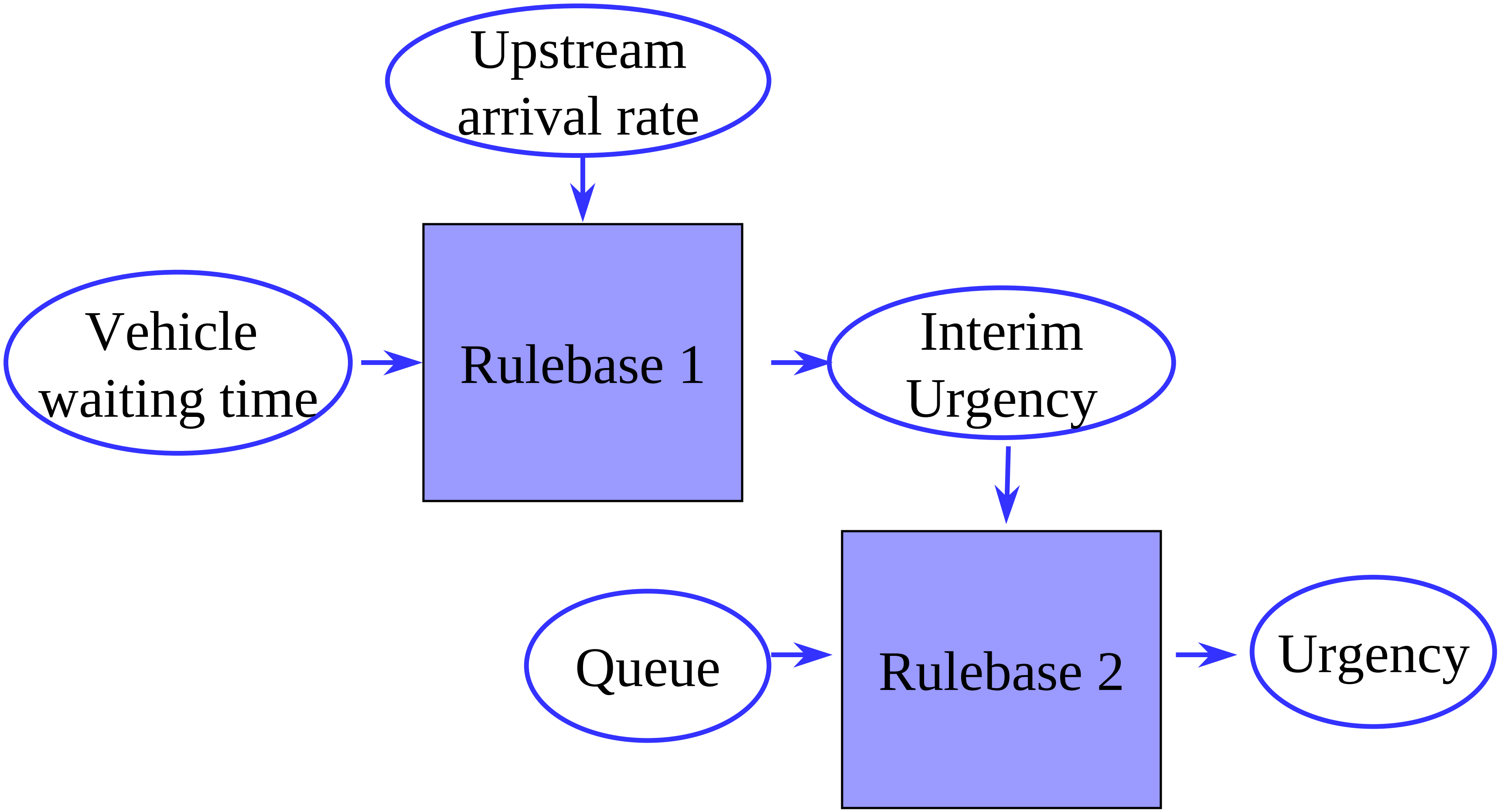
Rulebase for urgency when vehicle signal is red

Upstream Arrival Rate

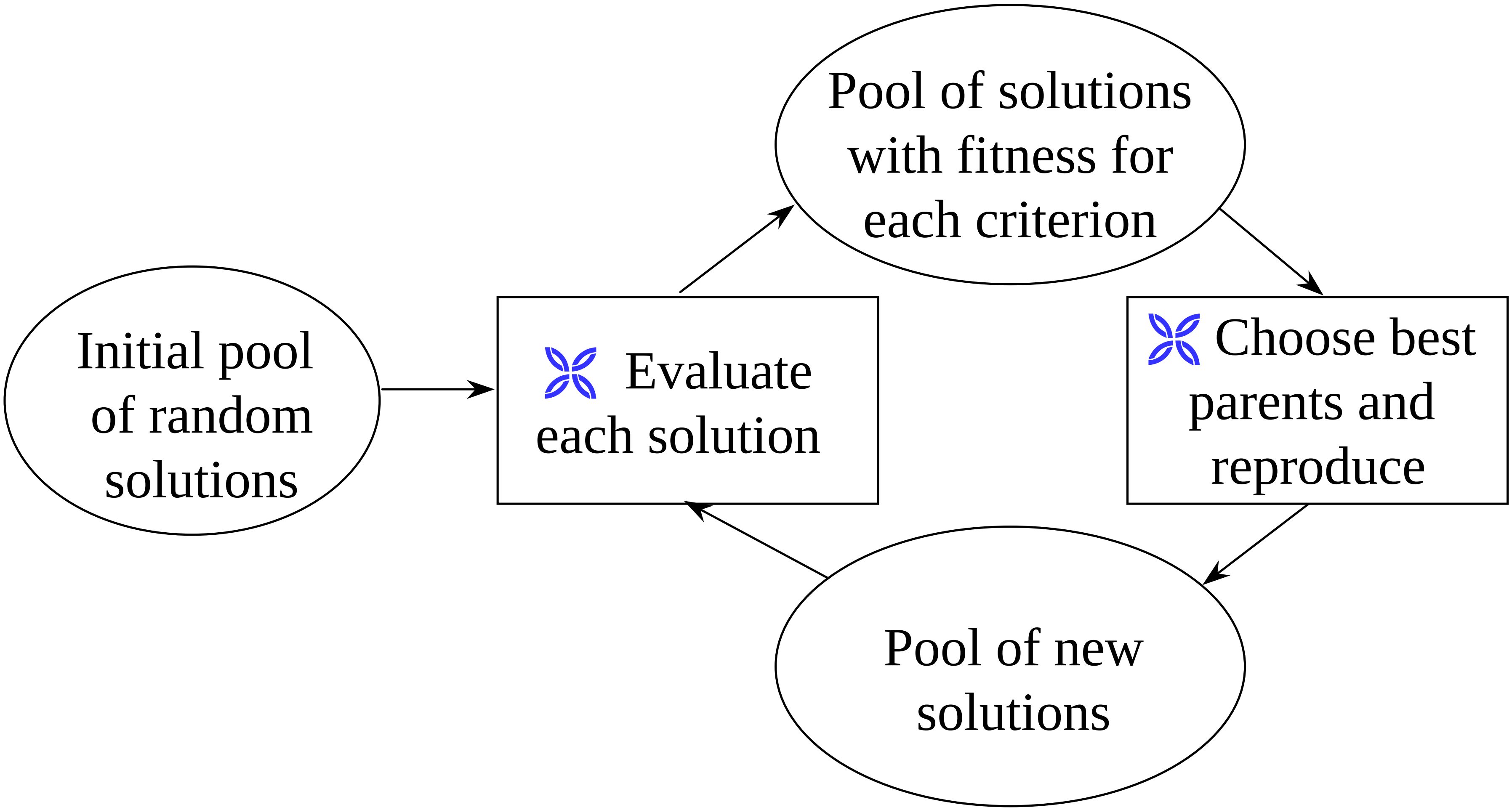
Vehicle waiting time	Low	Med	High
Low	M	L	VL
Med	H	M	M
High	VH	VH	VH

→ Urgency value

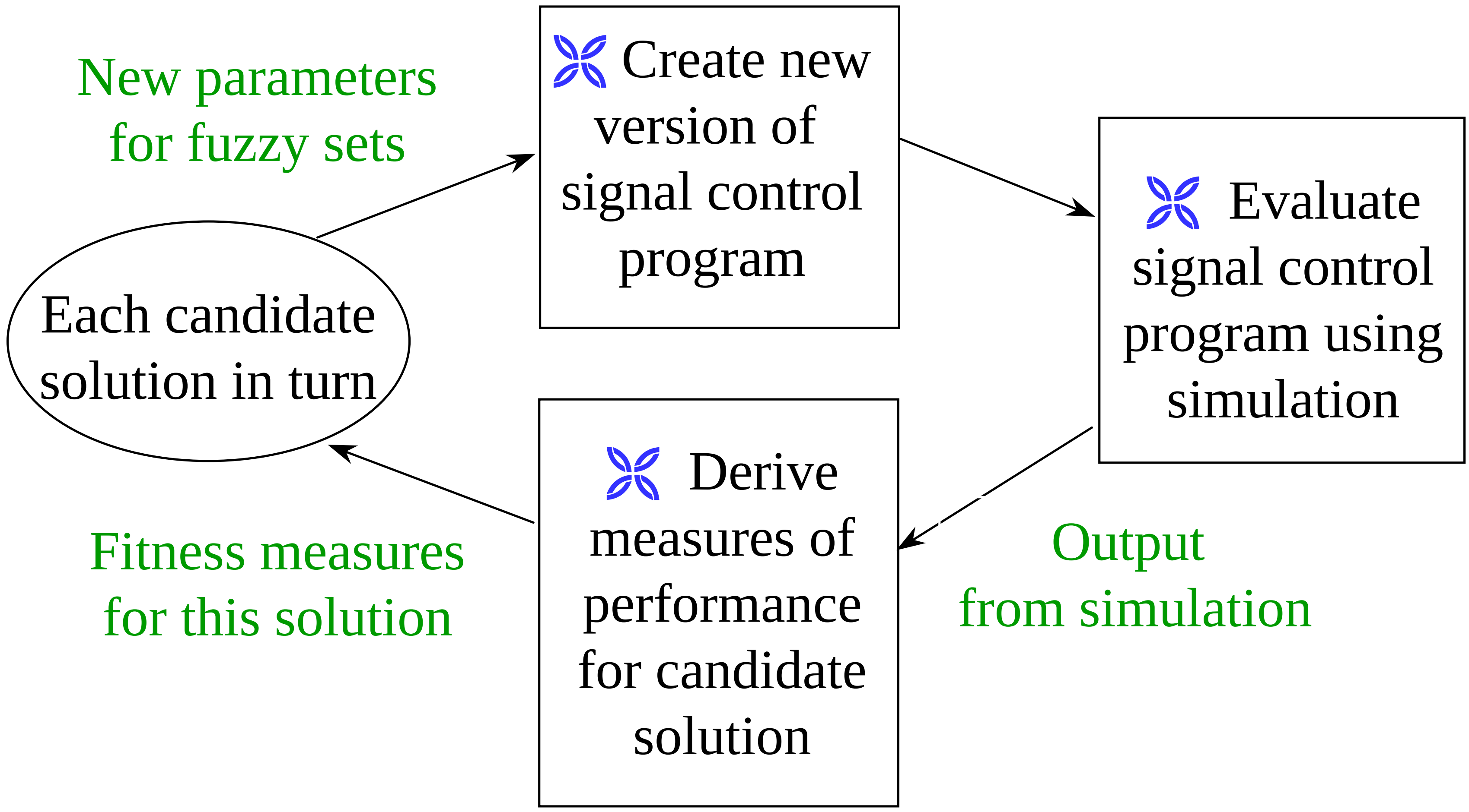
Sample fuzzy module



The MOGA process



Evaluation of each solution



Generating new solutions

Pool of solutions with fitness for each criterion

- Use Pareto rank and niching to select pair of parents
- Create new pair of solutions from parents by crossover and mutation

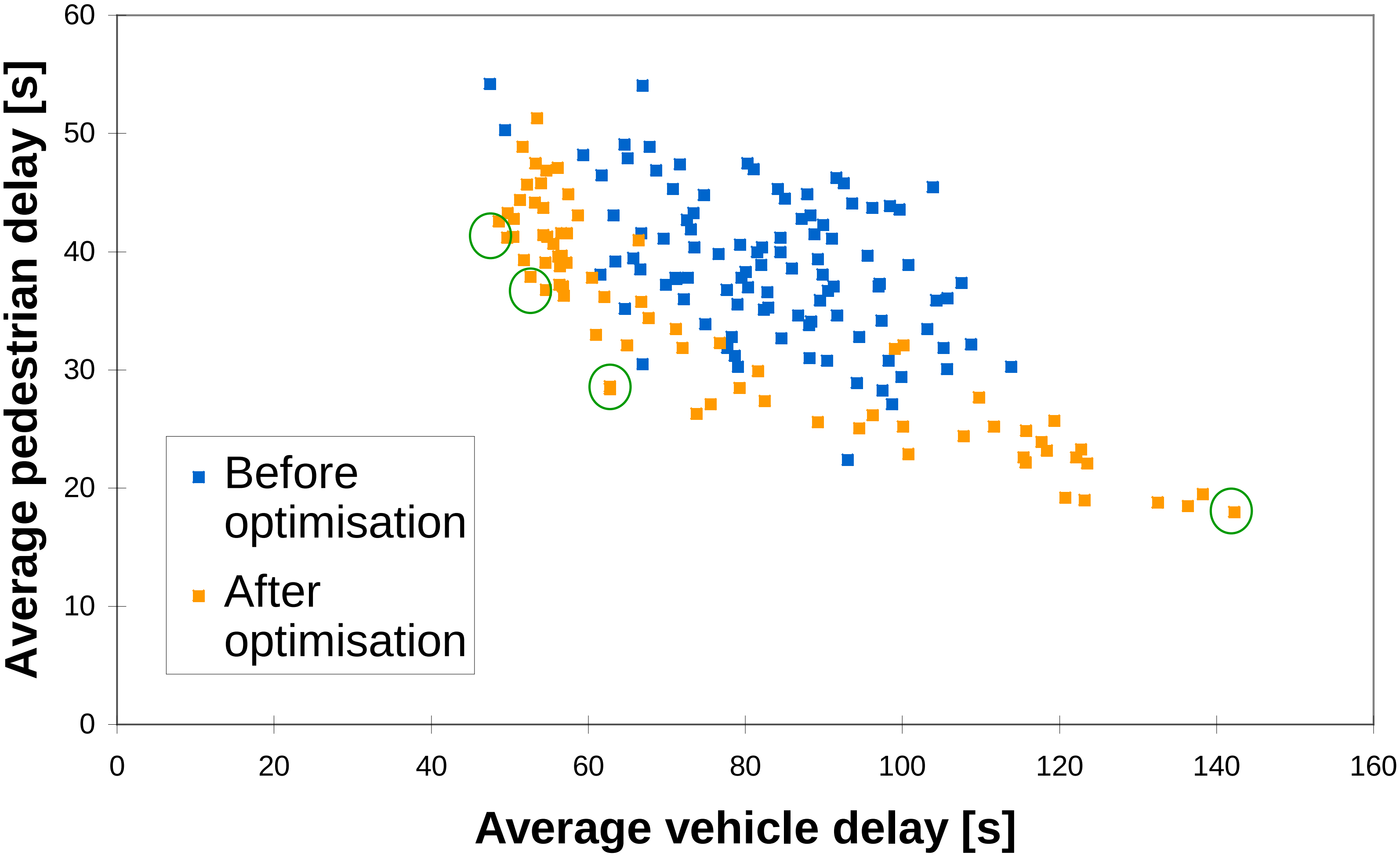
Repeated until the new pool is the same size as the old pool

Pool of new solutions

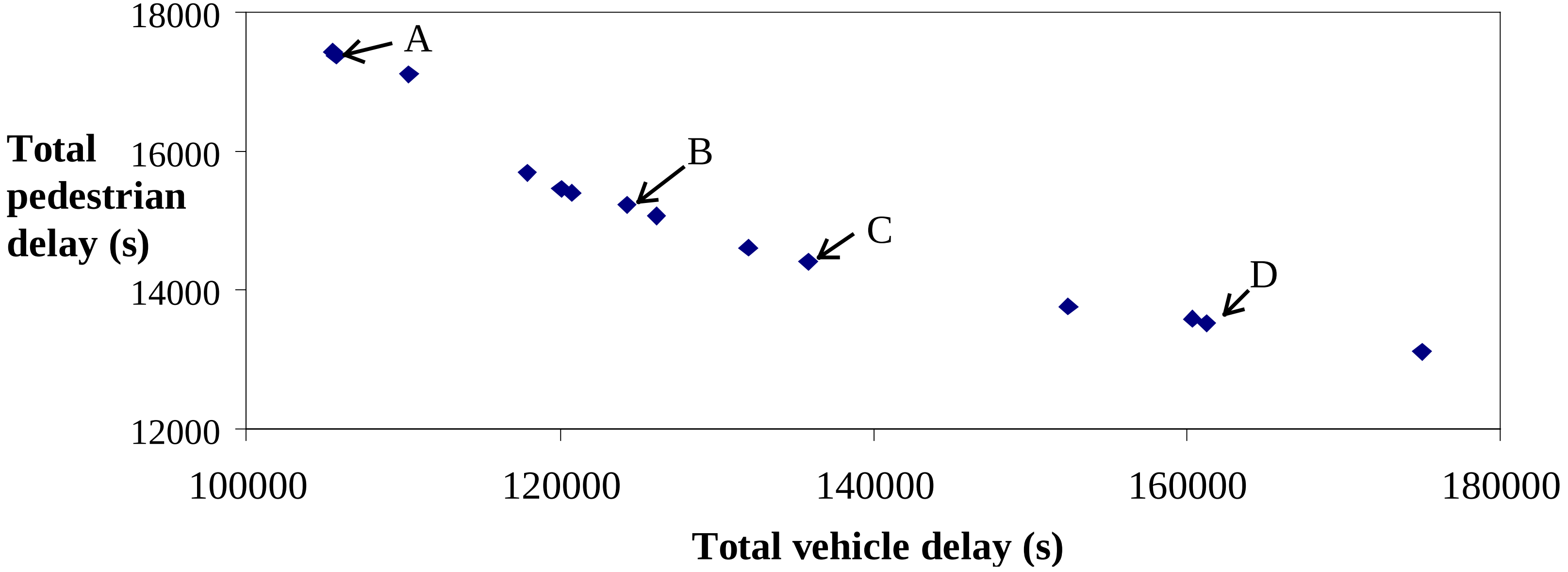
Evaluation criteria

- Vehicle-related criteria
  - Average vehicle delay
- Pedestrian-related criterion
  - Average pedestrian delay
- Bus-related criteria
  - Deviation from timetabled arrival (+/-)
  - Deviation from desired headway (+/-)

Typical result of optimisation

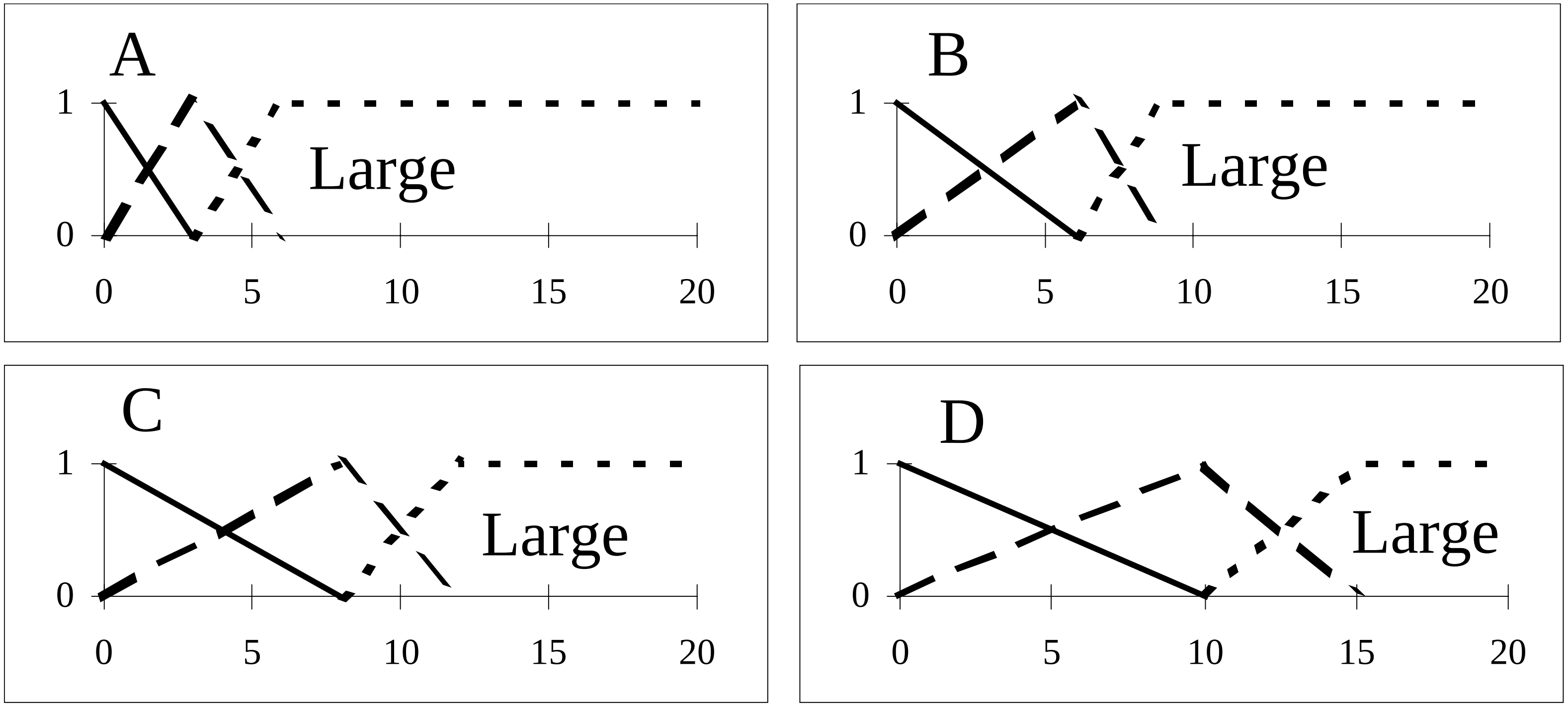


Pareto optimal frontier



- Each point shows performance of the controller conwith a certain configuration of input variable fuzzy sets
- The optimal sets cover a range of policy options, from vehicle-friendly (A) to pedestrian-friendly (D)

Optimal membership functions



- Fuzzy sets for Queue input variable for 4 points on preceding graph
- X-axis is the estimated number of vehicles on the approach

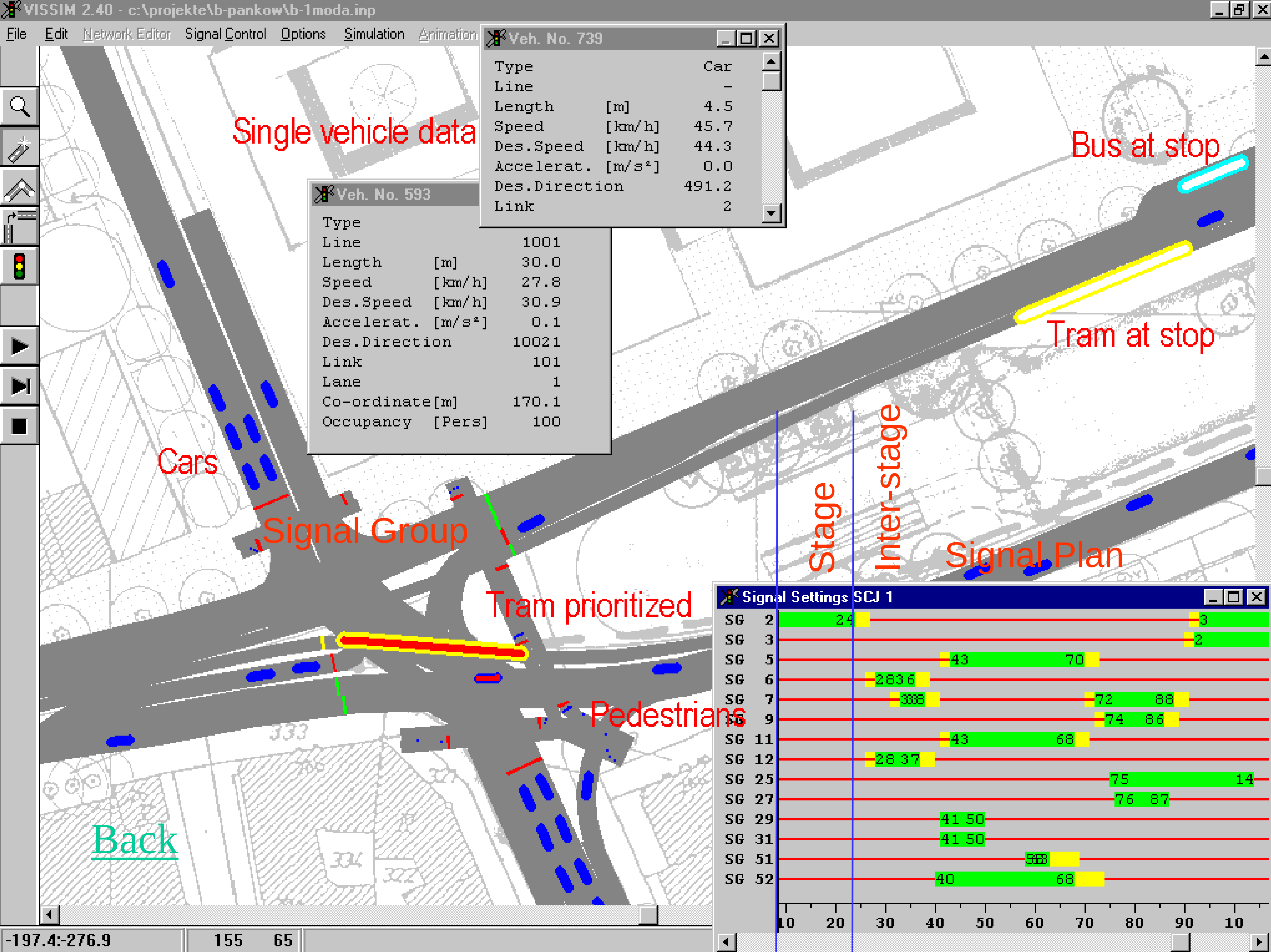
Conclusions and further research

- Urgency approach to fuzzy control promising
- MOGA plus simulation can optimise membership functions
- Conflicting objectives (pedestrian, car, public transport) reconciled
- Network control with differing local priorities
- On-going PhD research:
  - Fuzzy control for mixed traffic
  - Fuzzy control with incident detection

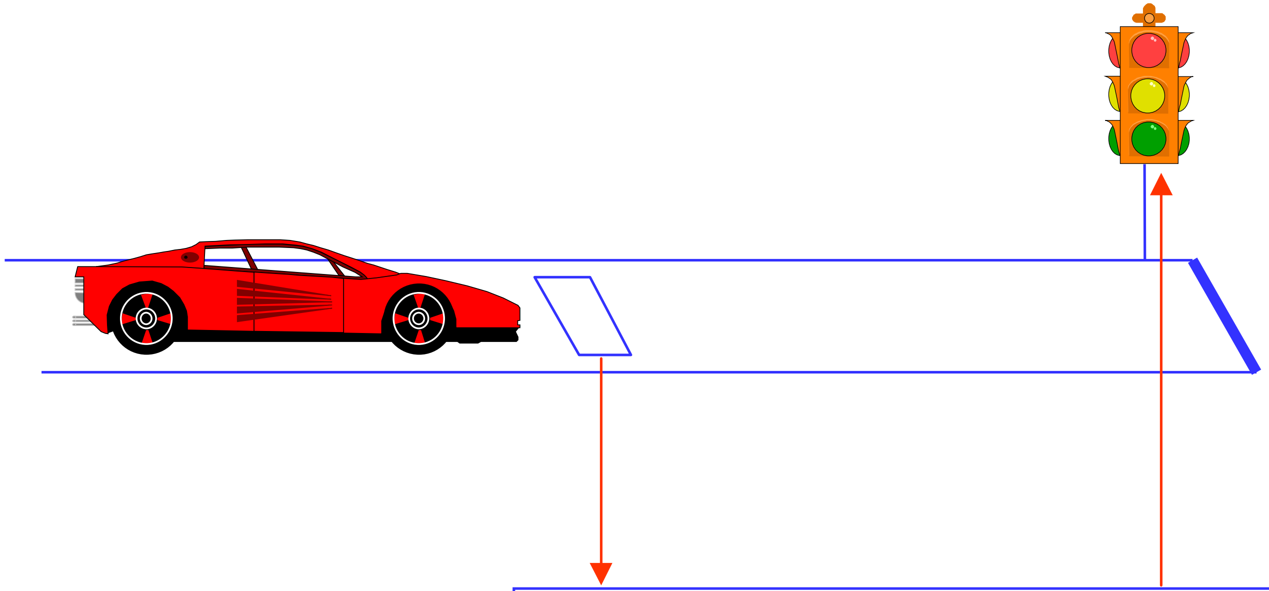
Acknowledgments

- EPSRC - funded project
- Siemens - SieFuzzy
- PTV - VISSIM simulator
- Andrew Hunter - SUGAL GA software
- Dr Jessica Anderson and Tessa Sayers (TORG)
- Jarkko Niittymäki (Helsinki) for advice

Thanks for listening!


VISSIM 2.40 - c:\projekte\b-pankow\b-1moda.inp
File
Edit
Network Editor
Signal Control
Options
Simulation
Animation
Veh. No. 739
Type Car
Line -
Length [m] 4.5
Speed [km/h] 45.7
Des.Speed [km/h] 44.3
Accelerat. [m/s²] 0.0
Des.Direction 491.2
Link 2
Veh. No. 593
Type
Line 1001
Length [m] 30.0
Speed [km/h] 27.8
Des.Speed [km/h] 30.9
Accelerat. [m/s²] 0.1
Des.Direction 10021
Link 101
Lane 1
Co-ordinate[m] 170.1
Occupancy [Pers] 100
Single vehicle data
Bus at stop
Tram at stop
Cars
Signal Group
Tram prioritized
Pedestrians
Stage
Inter-stage
Signal Plan
Signal Settings SCJ 1
SG 2
SG 3
SG 5
SG 6
SG 7
SG 9
SG 11
SG 12
SG 25
SG 27
SG 29
SG 31
SG 51
SG 52
10 20 30 40 50 60 70 80 90 10
Back
-197.4:-276.9
155 65

“Gapping out” logic

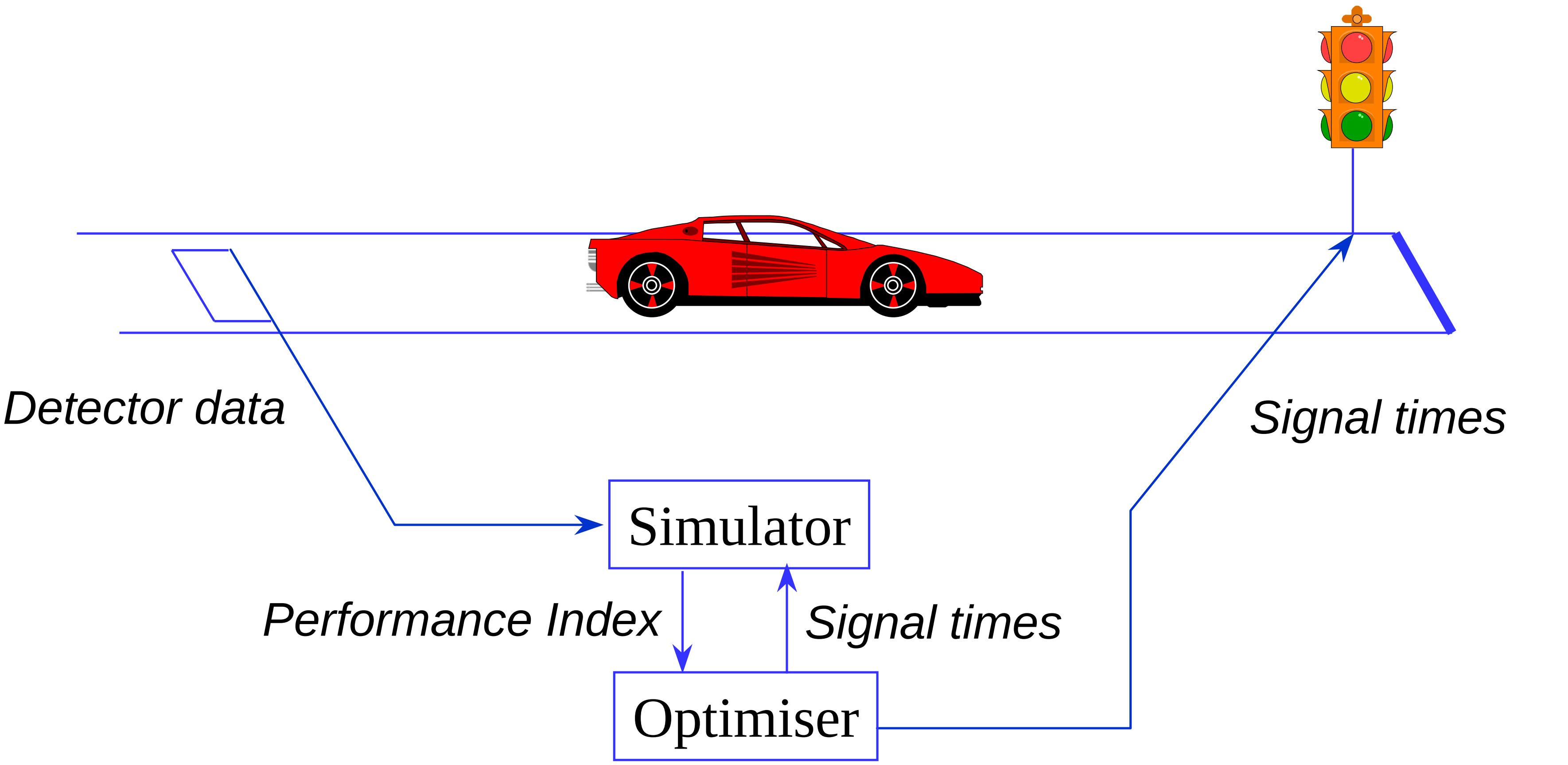


If GAP>3s *then* END GREEN

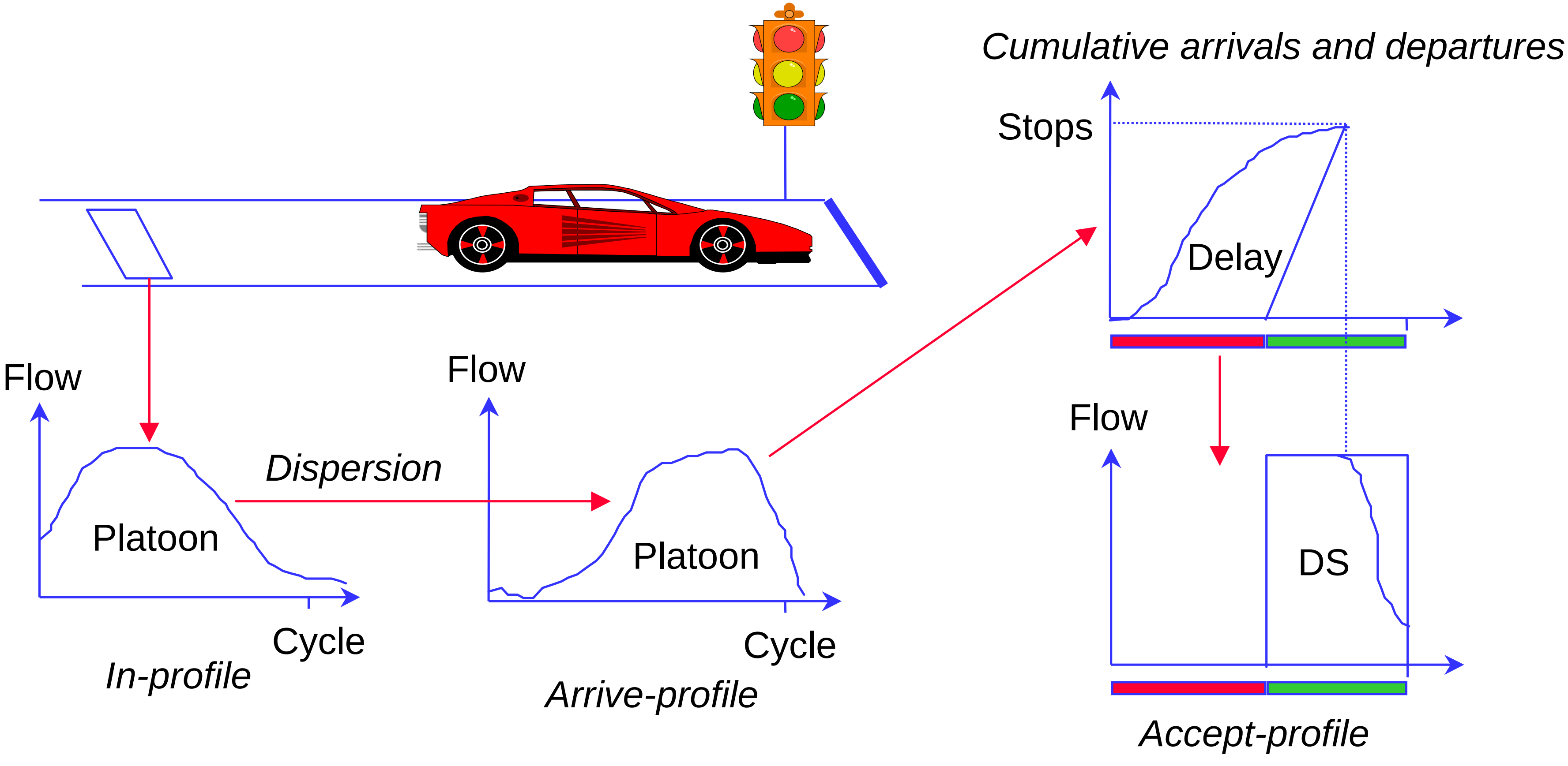
Back

SCOOT

Cyclic flow profile model

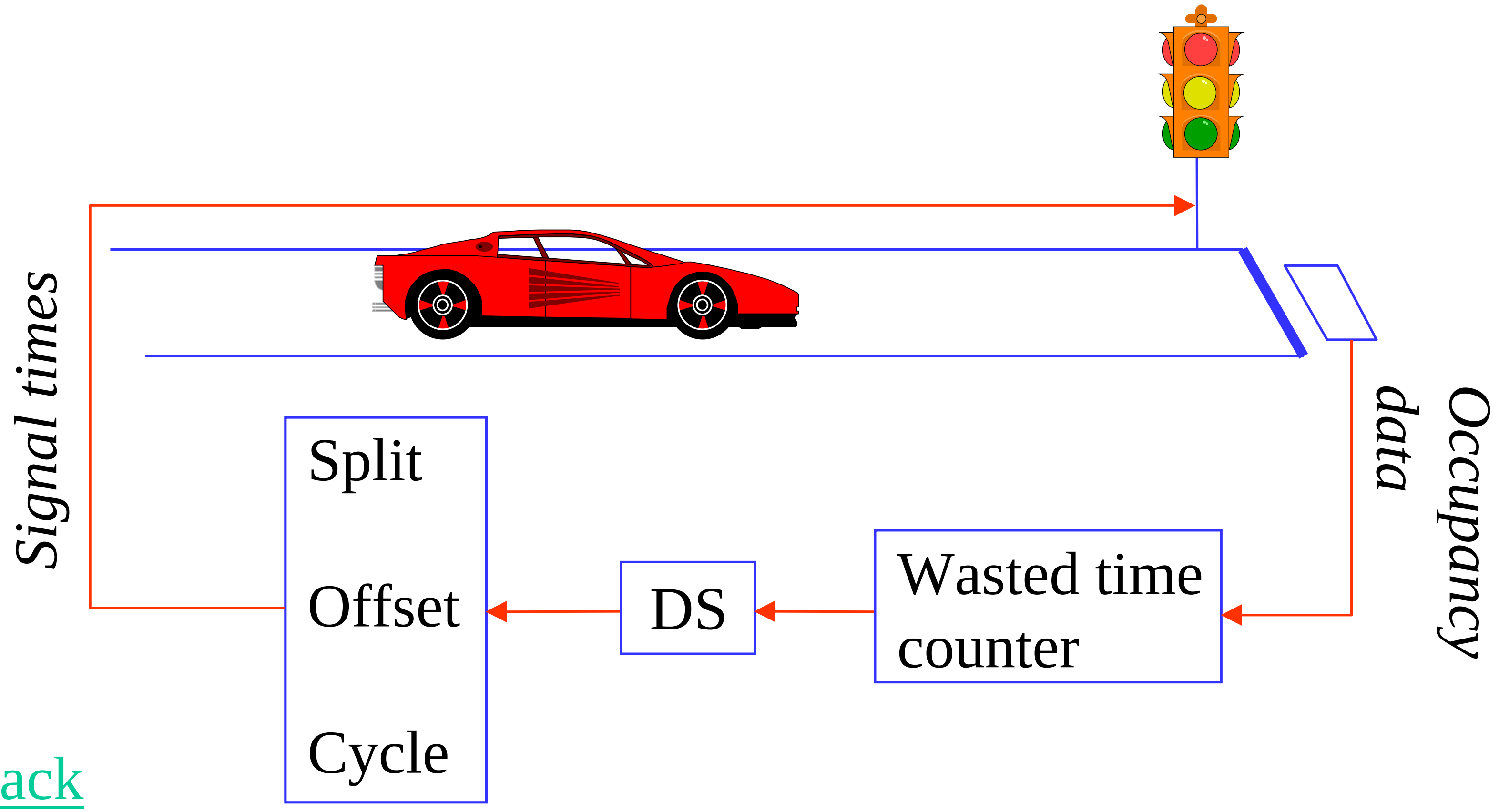


SCOOT
DS + equi-saturation + offset optimisation



SCATS

DS + equi-saturation + offset selection



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