



# Self-organizing traffic lights

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### Traffic Sucks...

•Everyone is affected by it •Traffic rules, lanes, lights, codes, etc. mediate between cars to avoid conflicts •Traffic lights only one piece of the puzzle •Mostly static mechanisms •Need adaptation more than optimization...



# Self-organization



- •Many definitions, almost any system can be *described* as self-organizing (Gershenson and Heylighen, 2003; Ashby, 1962)
- •Elements *interact* to achieve global behaviour
- •Not imposed nor hierarchical
- Achieved dynamically with feedbacks
- •System adapts constantly to changes
- •Useful for complex unpredictable domains

# The Simulation





Multi-agent, using NetLogo
http://ccl.northwestern.edu/netlogo
Try it!

+http://homepages.vub.ac.be/~cgershen/sos/SOTL/SOTL.html

Control methods •"Marching" •All horizontal streets green or red •Red lights period p, green p-1, yellow 1. •"Optim" •Green wave to the southeast •"Cut-off" •Switch to green when waiting queue length >  $\lambda$ •"no-corr" •Random phases







# Self-organizing control methods

### • "Sotl-request"

•Each TL keep count  $\kappa_i$  of cars \* timesteps approaching only red light. When  $\kappa_i \ge \theta$ , switch lights, and reset  $\kappa_i$ 

Platoon formation promoted

•"Sotl-phase"

•Introduce minimum green phase  $\phi_{min}$ 

### •"Sotl-platoon"

•Don't switch if car(s) close to green light

•Do switch if *many* cars approach green light

### First results

10x10 streets, torus on, 2dirs, 50% vertical, 50% southbound, 50% eastbound, p = 83,  $\theta = 41$ ,  $\varphi_{min} = 20$ , keep-plt=4, cut-plt=3, cutqueue=3



#### Average speeds



#### Percentage of stopped cars



### Average waiting times



#### Robustness of full synchronization



### Second results

•10x10 streets, **no torus**, **4dirs**, 50% vertical, 60%southbound, 75%eastbound,  $P_{turn}=0.1$ , p = 83,  $\theta = 41$ ,  $\varphi_{min} = 20$ , keep-plt=4, cut-plt=3, cut-queue=3

#### **Average speeds**



#### **Percentage of stopped cars**



#### Average waiting times



#### Average cars



# Discussion (1)



- •Sotl methods much better because they are *sensitive* to changes in traffic flow.
- •Formation of platoons can be seen as a reduction of *variety* (Ashby, 1956, Ch. 11)
- •"functional" modularity (Simon, 1996, pp. 188-195)
- •Reduction of *entropy* (non-random distribution of cars)
- •Induction of platoon formation, not imposed

Discussion (2)



•Sotl gets rid of cars asap •Long queue formation less probable •*Sotl* are *synergetic* (Haken, 1981) •Mediate competition for resources (space) •Minimize "friction" •No direct communication, but stigmergic •Similar to ants, *sotl* exploit their environment •Cars are environment of traffic lights •Cars and traffic lights co-control each other

### Adaptation or Optimization?

•Optimization good for static problem domain •For changing domains, better use self-org., since it seeks for solutions *actively* •*Sotl* "creative" (seek solutions themselves) •All traffic lights are *mediators* •Non-adaptive are more "autocratic" •Adaptive are more "democratic"

### Practicalities



•*Sotl* cheap and distributed •Improve incoming traffic e.g. from freeways •Pedestrians can easily be included •Also vehicle priority (just add weights) •Traffic lights not panacea •e.g. Roundabouts good for low traffic, low density areas (Fouladvand et al, 2004)

### Unattended issues

- •Final test in real situations, but good results so far
- •Explore parameter space for different densities
- •More realistic simulations
- •Multi-lane & non-homogeneous streets, lane changing, different driving behaviours
- •Compare with other methods
- •Difficult: complicated, or proprietary



Devise similar methods to promote "optimal" sizes of platoons for different densities
What would be "optimal"?

### Conclusions



- •3 simple *sotl* methods, very good performance •"Aware" of changes in environment Induce formation of platoons •Platoons coordinate traffic lights stigmergically •Full synchronization •Future in distributed, non-cyclic, selforganizing traffic lights
- •Promising results so far...