Measuring the Complexity of Self-organizing Traffic Lights

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July 25, 2013

We have developed in recent years self-organizing mechanisms for traffic light regulation (Gershenson, 2005; Cools et al., 2007; Gershenson and Rosenblueth, 2012b), which considerably outperform traditional control schemes.

We applied recently proposed measures of emergence E, self-organization S, and complexity C based on information theory (Gershenson and Fernández, 2012; Fernández et al., 2013) to the simulation and mechanisms described in Gershenson and Rosenblueth (2012a), using the city traffic model proposed in Rosenblueth and Gershenson (2011). In particular, we focussed on the information properties of traffic light switch intervals (I_{swi}), car intervals at intersections (I_{cii}), and car intervals at streets (I_{cis}).

In this abstract, we mention preliminary results for the different dynamical phases found in our model for two traffic light control methods: *green-wave* and *self-organizing*.

For the *green-wave* method, since traffic lights are periodic, all switching is regular, and thus $E_{swi} = C_{swi} = 0$ and $S_{swi} = 1$. All $S > E$, indicating a regular behavior. For the *intermittent* phase, $C_{cii} > 0.9$. Also, $C_{cis} \approx S_{cis}$. for the *gridlock* phase, since no cars move, the measures for car intervals are the same as for light switching.

For the *self-organizing* method, there are seven dynamical phases. The *free-flow* phase is characterized by all vehicles having a maximum velocity. All $C \approx 1$, especially at inter-

sections. For the *quasi-free-flow* phase, $C_{swi} > 0.95$, $C_{cii} \approx 0.6$ and $C_{cis} \approx 0.8$. The *intermittent* phase has three subphases. For the *underutilized* subphase, $C_{swi} \approx 1$, $C_{cii} \approx 0.3$ and $C_{cis} \approx 0.9$. For the *full capacity* subphase, where all intersections are being used at all times, there is a maximum $S_{cii} = 1$. Since switching periods become constant, $E_{swi} = C_{swi} = 0$ and $S_{swi} = 1$. $C_{cis} \approx 0.6$. In the *overutilized* subphase, measures are similar to the *underutilized* subphase. This might be because of a certain duality between vehicles and spaces in our abstract model of city traffic. The *quasi-gridlock* phase has $C_{swi} \approx 0.6$, $C_{cii} \approx 0.8$ and $C_{cis} \approx 0.8$. The *gridlock* phase has measures similar to those of the *green-wave*, although for a minimal, extremely high density range. In most cases, $E_{swi} > S_{swi}$, while $E_{ci} < S_{ci}$. This reflects an adaptability in traffic lights (except when full capacity, i.e. maximum flow) and an flexible organization for vehicles due to platoon formation.

From these preliminary results, it can be seen that the improved performance of the *self-organizing* method over the *green-wave* method is due to its high complexity for most situations, and maximum self-organization when maximum flow can be reached.

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