

Traffic Lights Control using swarm-based algorithms

Riccardo Belletti

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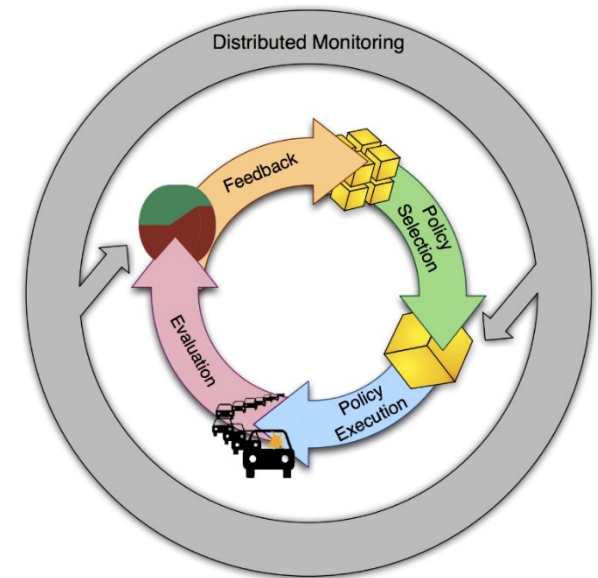
Main local partners:



Main objective

COLOMBO

- Design and implement a self-organizing, adaptive, distributed and monitoring-aware approach to traffic light control:
 - Based on info coming from V2X communication (not yet implemented);
 - Automatically selecting the proper policy;
 - Receiving feedback on its choice;
 - For low penetration rates.

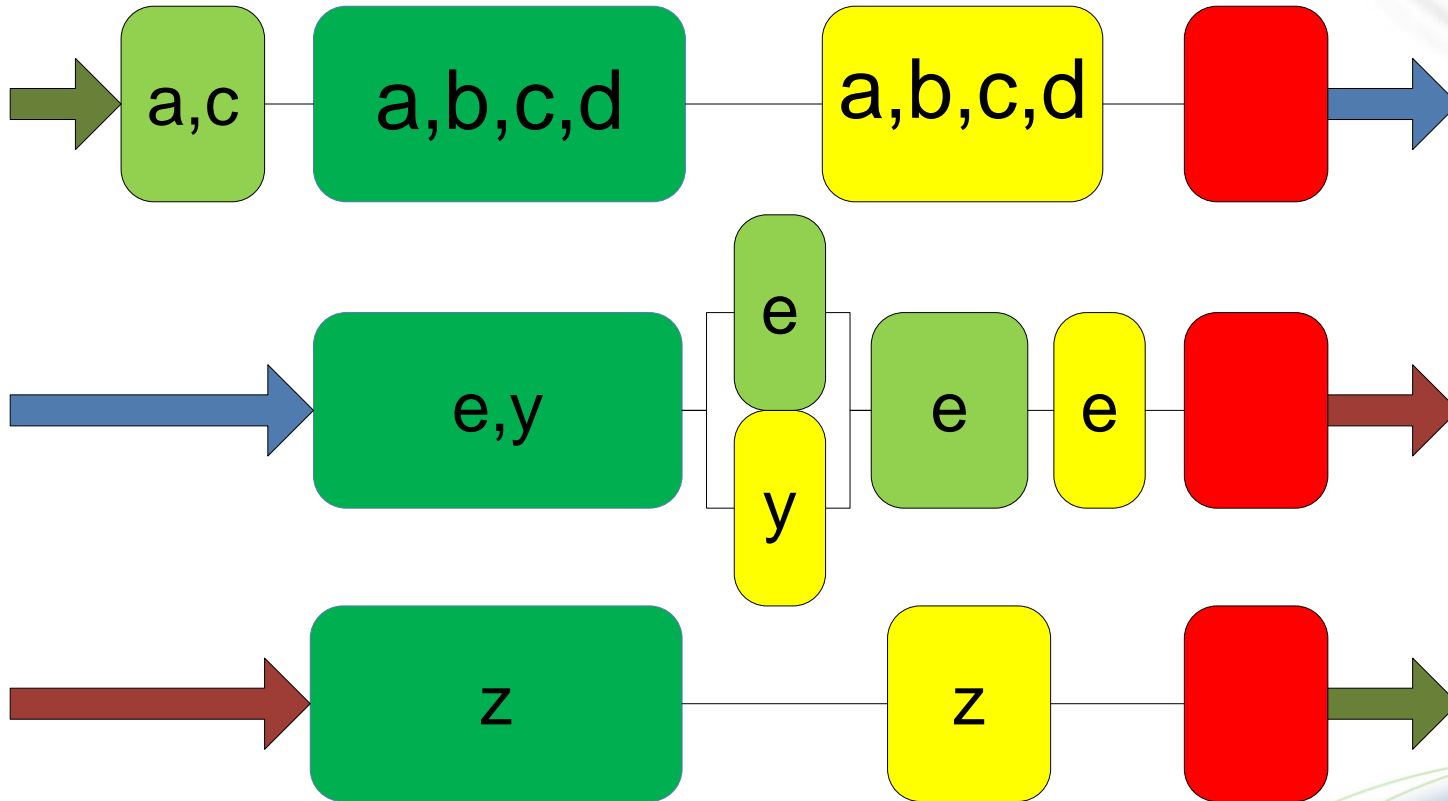


Agents

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- Every intersection controlled by an agent that has:
 - **Interface:** to acquire data from sensors or from monitoring;
 - **Low level policies:** base functionalities;
 - **Policy selection algorithm:** based on swarm intelligence concepts;
 - **Plan:** describes operational requirements.

Traditional execution COLOMBO



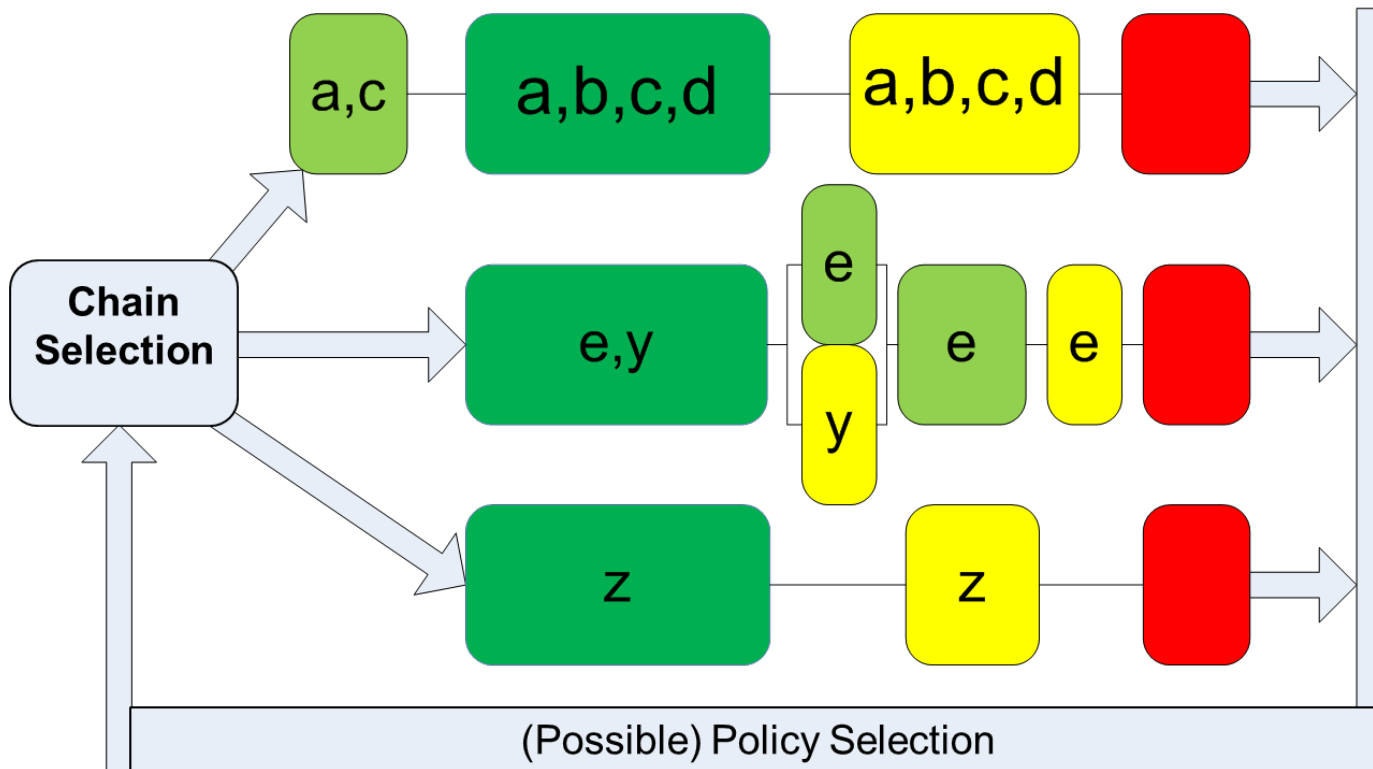
Glossary

COLOMBO

- **Stage:** a possible configuration of red, yellow, green lights;
- **All Red stage:** a configuration with only red lights;
- **Chain:** an ordered sequence of stages;
- **Types of stages:**
 - **Target/Commit:** the first and the last stage of a chain;
 - **Decisional/Transient:** stage with a variable or fixed duration;
- **Policy:** a criteria used to determine when it's needed to end a decisional stage and switch to the next one.

Plan executed

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Policies

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- Different traffic situations need different policies → Policy specialization:
 - Low traffic;
 - Average traffic;
 - High traffic;
 - Congestions & burst.
- Simple reactive rules.

Pheromone

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- Pheromone as traffic indicator:
 - Every car leaves a virtual pheromone trail on the road and the intersection (agent) manages his roads of competence;
 - Proportional to the level of congestion;
 - Better than simply counting vehicles;
 - Support to the policy selection.

$$\varphi_l(k + 1) = \beta \cdot \varphi_l(k) + \gamma \cdot v(l, k); \varphi_l(0) = 0$$
$$v(l, k) = \text{MaxSpeed}(l) - \text{MeanVehicleSpeed}(l, k)$$



Stimulus functions COLOMBO

- Specialized policies for every traffic conditions;
- Agent is pushed to chose a policy;
- Each policy has its own stimulus function.

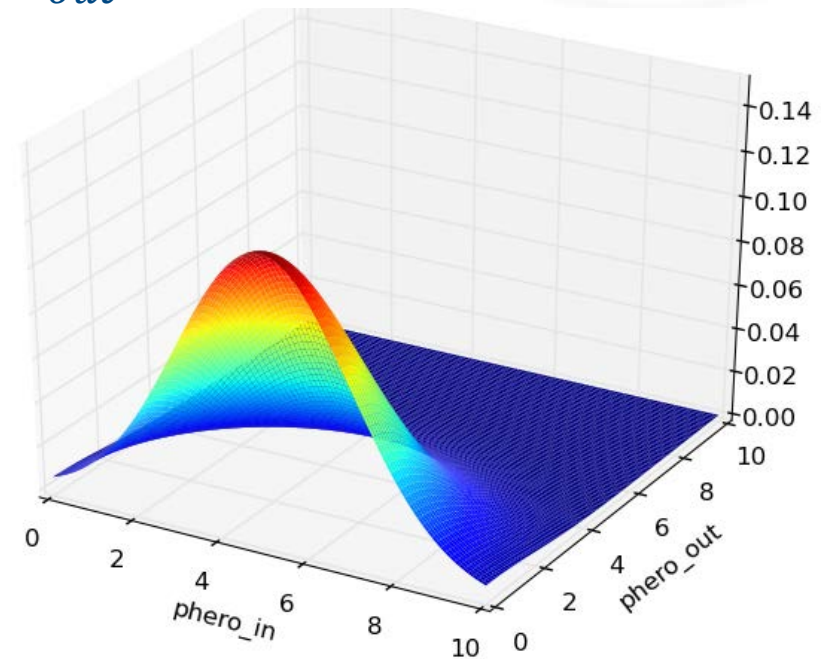
$$s_{i,j}: [0, \varphi_{max}] \times [0, \varphi_{max}] \rightarrow \mathbb{R}^+$$

$$\iint_{[0, \varphi_{max}] \times [0, \varphi_{max}]} s_{i,j}(\varphi_{in}, \varphi_{out}) d\varphi_{in} d\varphi_{out} = 1$$

Stimulus functions COLOMBO

$$S_{i,j}(\varphi_{in}, \varphi_{out}) = \frac{1}{V} e^{-\frac{(\varphi_{in} - \mu_{in})^2}{2\sigma_{in}^2} - \frac{(\varphi_{out} - \mu_{out})^2}{2\sigma_{out}^2}}$$

- Gaussians approximate well experimental results



$$\mu_{in} = 5; \mu_{out} = 0; \sigma_{in} = \sqrt{4}; \sigma_{out} = \sqrt{4}$$

Selection criterion **COLOMBO**

- Probabilistic selection is needed;
- Stimulus do not concur directly to the policy selection;
- Conditioned to the sensitivity toward a given policy;

$$P(i, j) = \frac{T_{\theta_{i,j}}(s_{i,j})}{\sum_j T_{\theta_{i,j}}(s_{i,j})}$$

$$T_{\theta_{i,j}}(s_{i,j}) = \frac{s_{i,j}^2}{s_{i,j}^2 + \theta_{i,j}^2}$$

- Agents specialize their behavior through reinforcement learning of the θ sensitivities:
 - Insensible to low stimulus and small traffic changes

Phase policy

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- The current chain is terminated as soon as another chain has reached a traffic threshold;
- Respects the minimum duration constraint of the current decisional stage.
- Adequate in **medium-low traffic** situations, where this early termination will not make the lights switch too often.
- If no chain reaches the threshold, then the current stage is kept on indefinitely, ignoring the maximum duration parameter.

Platoon policy

COLOMBO

- The current chain will be terminated only if:
 - the minimum duration of the decisional stage has elapsed AND
 - some other chain is above the threshold AND
 - there are no other vehicles in the current chain lanes OR the maximum duration has elapsed.
- No chain switch unless other lanes are requesting the green light.
- In **intense traffic situations**, each decisional stage will execute for the maximum allowed time (that greatly influences the performances).

Marching policy

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- This policy is adequate when the **traffic looks too intense** from all directions to take any online decision regarding the input lanes.
- Two possible approaches:
 - either use a static duration for decisional stages (current implementation) OR
 - consider the output lanes, do not allow traffic to lanes that are too heavily loaded (future work).

Congestion policy COLOMBO

- This policy is used when **all the output lanes are congested** and there are vehicles waiting in the intersection.
- To avoid gridlocks, all input lanes are inhibited, i.e. the current executing chain is terminate following the pre-defined plan to the commit stage, then no other chain is activated until the congestion has been solved.

Future work

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- Automatic parameter tuning:
 - very important for good performances;
 - initial experiments very successful but extremely time consuming;
 - now performed by ULB;
- Low penetration rates:
 - Approach: train the stimulus function on the monitored traffic;
 - Resort to static if no traffic is perceived.