Gridlock Warning and Resolvement at Signalized Intersections

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Abstract. *An adaptive urban traffic control system where traffic is captured by video sensors and analized by the real-time traffic control algorithm – CRONOS (ContROl of Networks by Optimization of Switchovers). This advanced ITS solution, detects gridlock situation and extends local traffic controllers clearance time in order to free the intersection center.*

Keywords: CRONOS, gridlock, video, real-time, control algorithm, intelligent transport systems

1 Introduction

CCTV image analysis can provide more comprehensive data about approaching traffic, then many existing traffic signal control methods relying upon loop detectors placed in particular points in the road.

A vision based detection method offers ease of installation and maintenance, reconfiguration of monitored tracks without traffic interruption, etc.

The gridlock warning system, marketed by the french company Citilog, provides an advanced ITS (intelligent transport system) solution by continuously optimizing the signal plan according to the actual traffic load at the intersection.

Changes to the active signal plan parameters are automatically implemented in response to the current traffic demand as measured by the video detection system.

Citilog's MediaCity system employs described characteristics and can be deployed locally at an intersection overlooking local traffic conditions, or remotely, at the traffic management center, operating in conjunction with the global traffic management plan.

2 The adaptive control algorithm

CRONOS (ContROl of Networks by Optimization of Switchovers) [1] is a real-time traffic control algorithm, that has been developed in the nineties at the Centre d'Etudes et de Recherches de Toulouse (CERT).

The algorithm tries to minimize the traffic criterion of total delay on the intersection over a time horizon of around one minute. It controls zones of several intersections in the same optimization process. The advantage is to be more coherent and to need traffic flow measurements only at the limit of the zone.

The algorithm defines in advance the cyclical and no stage approach. The intersection is defined as a set of safety constraints. Any solution that verifies these safety constraints is a possible solution for the algorithm. It uses priority video based measurements in order to have richer information than with inductive loops. The queue lenghts are measured directly and the situation inside the intersection is known.

The forecasting module of the algorithm receives traffic measurements obtained by image processing every second. The module forecasts, based on received information, arrivals of vehicles at the entry points of the zone over the whole horizon. This forecast is used by the simulation module in order to know what the zones arriving traffic could be expected.

The simulation module propagates the vehicles inside the zone, according to predefined traffic signal colors at each intersection. It uses the traffic measurements elaborated each second. The traffic flow is modeled along the links but also in the stocking zones inside each intersection

The aim of the optimization method is to look for the next optimal switchover of the intersection traffic signals that minimize a given criterion, from a given traffic signal state at the intersection.

Such optimization is based on successive trials where the solution giving the highest criterion value is modified until convergence. Its advantage is to have a polynomial computational time according to the number of controlled intersections. The consequence is to be able to control simultaneously (in the same optimization process) a zone of several intersections or a complex intersection with great number of traffic signals. [2]

3 Intersection definitions

The control method, describing traffic light at an intersection, is based on a group-based approach. The smallest entity are the traffic light groups of the intersection – a group is set of signals which control traffic streams.

F.Boillot [3] describes the intersection by a list of traffic light groups and by a set of safety constraints that are defining the intersections safety level. All constraints eliminating any not allowed intersection states (color duration or correlation between traffoc lights) have to be defined. These constraints are manually provided by the traffic engineer who should not mix safety and control aspects. The control part is carried out by a management tool.

Constraints that are concerning one group:

- minimal and maximal green duration (green duration of a group)
- minimal and maximal red duration

Constraints concerning two groups; *i* and *j*:

- minimal and maximal all-red duration for antagonist groups (duration between end of green of group *i* and antagonist group *j*)
- minimal and maximal „strict“ offset (duration between beginning of green of group *i* and the beginning of green of group *j*)
- minimal and maximal „non strict“ offset (duration between of green of group *i* and the beginning of green of group *j* – only if both groups are green simultaneously)
- correlation between the color *a* of group *i*, to the color *b* of group *j*, with minimal and maximal offstes at the beginning and at the end of the colors (if the color of group *i* is *a*, then the color of group *j* is automatically *b*, with offset ranges at the beginning and at the end of the colors *a* and *b*)

Constraints concerning three groups:

- authorized ordering between a triplet of mutually antagonist groups (*i*, *j*, *k*) (the triplet *i,j,k* can have this ordering: the green of *k* occurs after the green of *j* that occurs after the green of *i*).

4 Intersection gridlock detection

If the critical degree of saturation of one intersection in the system approaches the over-saturation limit, then the whole system will be affected due to the spillback from the over-saturated intersection. This phenomenon is commonly referred to as gridlock or “De facto red”. [4]

Figure 1. illustrates the gridlock on an arterial. Once gridlock occurs, the vehicles on the arterial are blocked and the coordination along the arterial breaks down. Meanwhile, the vehicles on the side street also cannot be discharged. Thus, the whole capacity of the upstream intersections drops down significantly. Moreover, at the upstream intersection, the queues begin to build up on both arterial and side streets. Gridlock tends to transmit the over-saturated state to neighbor intersections and cause severe congestion all over the road networks.

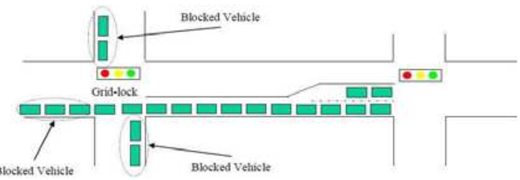

Figure 1: Gridlock on an arterial

There are two problems that might cause the gridlock at an intersection.

The first that the intersection along an arterial are so closely spaced that even normal traffic demand will generate queues that may build up to the end of the link during the red phase. This is a geometric problem, and not easily corrected by signal timing. It can, however, be alleviated by running the intersections as a pair, and allowing the traffic to proceed as if it were a single intersection.

The second problem is concerned with the signal timing parameters for the intersection and the arterial coordination. Signal timing plans could be a major factor in the spillback phenomenon. If the green time doesn’t allow for enough traffic to proceed through the intersection during the green phase, or the offset between the intersections is not set properly, the queue will continue to grow beyond the link storage capacity. The overall efficiency of the intersection operation could be improved by relocating the green times between different approaches and utilizing the wasted effective green time that some approaches might have.

The vehicle discharge rates and the effective green time loss are illustrated in Figure 2.

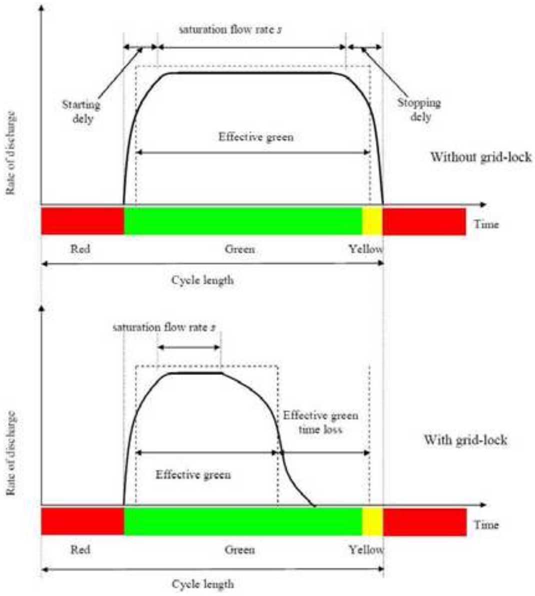

Figure 2: Vehicle discharge during a signal phase with and without gridlock

The gridlock detector is designed to communicate with the traffic controller to prevent queue from downstream link by blocking the upstream intersection, or on a one intersection gridlock, by blocking one stream to prevent queuing on the other one.

Figure 3. [5] Depicts an intersection where we can observe a real-life intersection were queue build-up deters the proper functioning of the intersection.

Figure 4. Depicts the intersection were the left turning vehicles build up into u queue

Figure 5. Depicts a situation where upstream left turning vehicles build up into a queue. The system differentiates between a real stopped vehicle from a continuous presence in a zone (a continuous presence may mean that vehicles are continuously passing but they are not blocked).

Figure 6. Depicts a warning message, where a high-risk gridlock situation is detected. The space occupancy of stopped vehicles is analyzed in real-time by the system within the left turn areas. The alarm is sent to the traffic controller every time space occupancy exceeds a predefined threshold within a predefined combination of antagonist areas

Figure 7. On detection, local traffic controller can extend its clearance time (full red phase) in order to free the intersection center. When no high-risk gridlock is detected, clearance time is set to a minimum in order to optimize the lights cycles.

The described system uses one to three cameras overlooking the intersection center, depending on the intersection complicity, and one video analyzer per intersection.

Figure 3: Real-life intersection

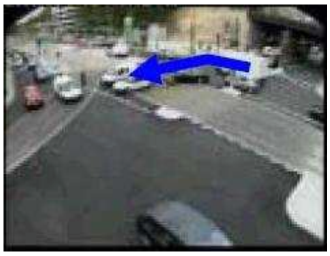

Figure 4: Downstream left turning vehicles queue build-up

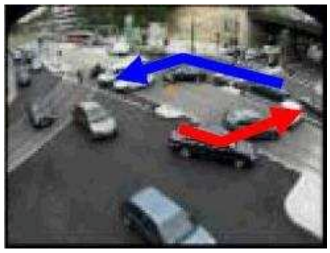

Figure 5: Upstream left turning vehicles queue build-up

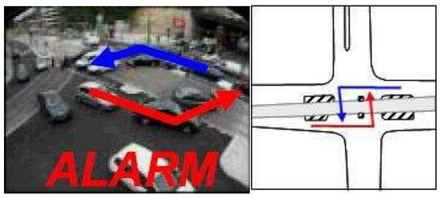

Figure 6: Intersection gridlock warning

Figure 7: Successful gridlock prevention

4 Conclusion

A real intersection description has been presented based upon the CRONOS (Control of Networks by Optimization of Switchovers) adaptive control algorithm.

The solution provides improved travel time reliability and minimized conflicts between road users.

Although the described intersection analyzer is interacting locally with the traffic controller, it can also be interconnected to the traffic control center.

The solution can also be employed in application like bus/tram priority management systems, where the public transportation priority has to be ensured in the sense that intersections won't be blocked for a long period of time.

References

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