ACTAM: Cooperative Multi-Agent System Architecture for Urban Traffic Signal Control

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Outline

- Introduction
- Objective of our Seminar
- Multi-Agent System in Traffic Signals
- ACTAM (Adaptive & Cooperative Traffic Light Agent Model)
- Traffic Signals
- Agent Technology
- Agent Learning in Multi-Agent System
- Experiment
- Results
- Conclusion of the paper
- Our Conclusion

Introduction

- Summary based on the paper: Chen, R.S., Ceh, D.K. & Lin, S.Y. (2005). ACTAM: Cooperative multiagent system architecture for urban traffic signal control. *IEICE Trans. Inf & Syst.*, vol. E 88, 119-125.

The paper mainly deals with:

- The use of Adaptive and Cooperative Traffic Light Agent Model (ACTAM) for decentralized traffic signal and control system
- The proposed architecture of ACTAM

Introduction

- Cooperation of multi-agents and prediction mechanism of proposed architecture
- Experiment and performance evaluation
- Results/Conclusions

Objectives of our Seminar

- To summarize how Multi-Agent system is being used in Traffic Control System
- To summarize the architecture of ACTAM and its mechanism of work
- To summarize the experiment done for the performance evaluation of ACTAM w.r.t fixed time signal
- To summarize the findings of the paper and our own conclusion based on the study

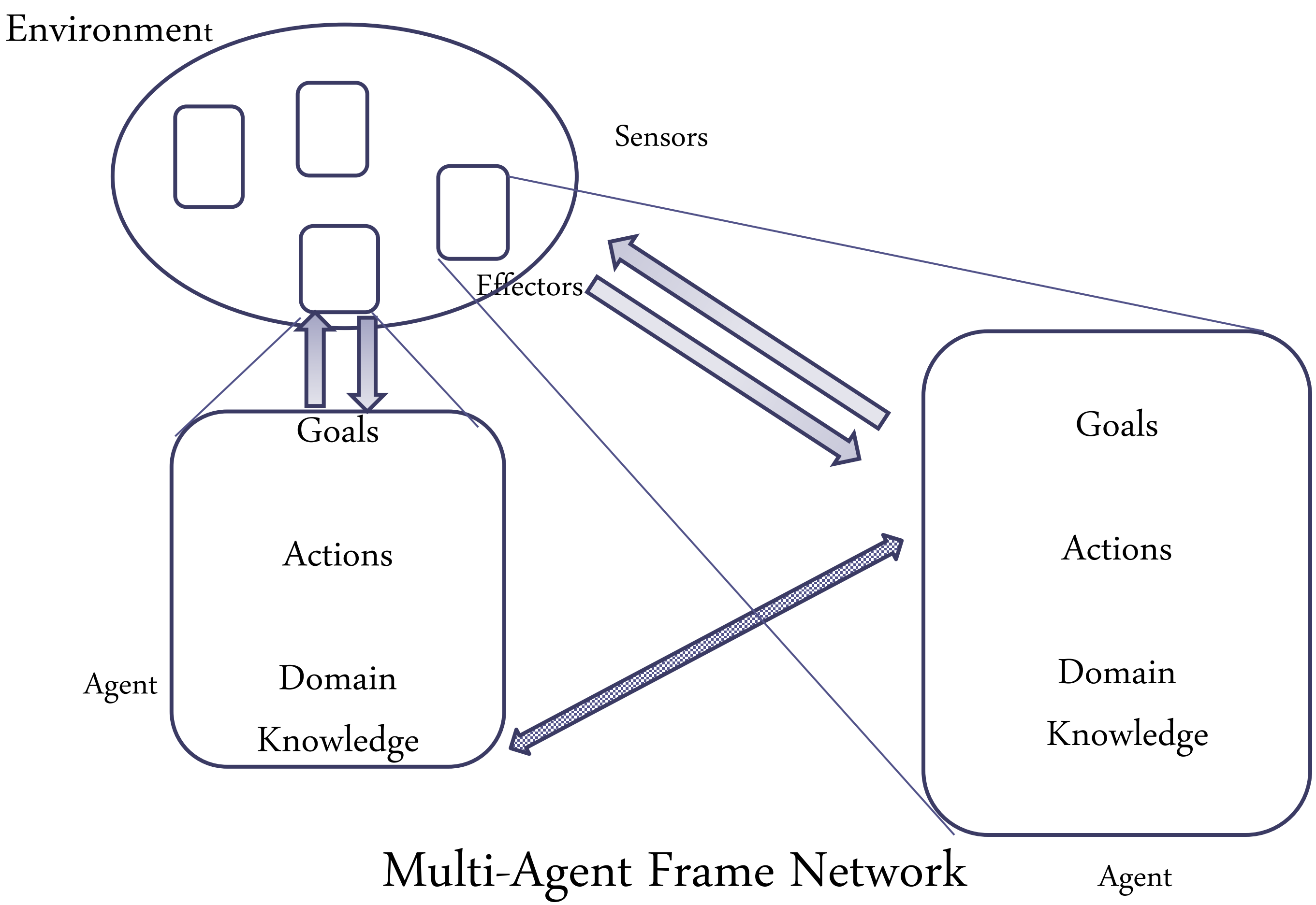
Multi-Agent System in Traffic Signals

- Problem: Reducing traffic congestion in urban roads
- Difficulties
  - Highly dynamic environment
  - Necessity for real-time information gathering and processing
  - Growing population has increased traffic congestion, rendering older traffic control models less effective
  - Traffic lights are geographically distributed and decentralized
  - All traffic signals affect each other

Multi-Agent System in Traffic Signals

- Proposed Solution: **ACTAM**
  - Adaptive and Cooperative Traffic light Agent Model
- ACTAM is a multi-agent system that utilizes the advantages of an agent model to solve the problem
- By using a multi-agent system, the designer can solve the issues by
  - Observing and acting on a dynamic environment
  - Gathering real-time data and executing real-time decisions
  - Fitting over a geographically distributed environment
  - Communicating and cooperating with each other for information that will make them more effective at reducing congestion

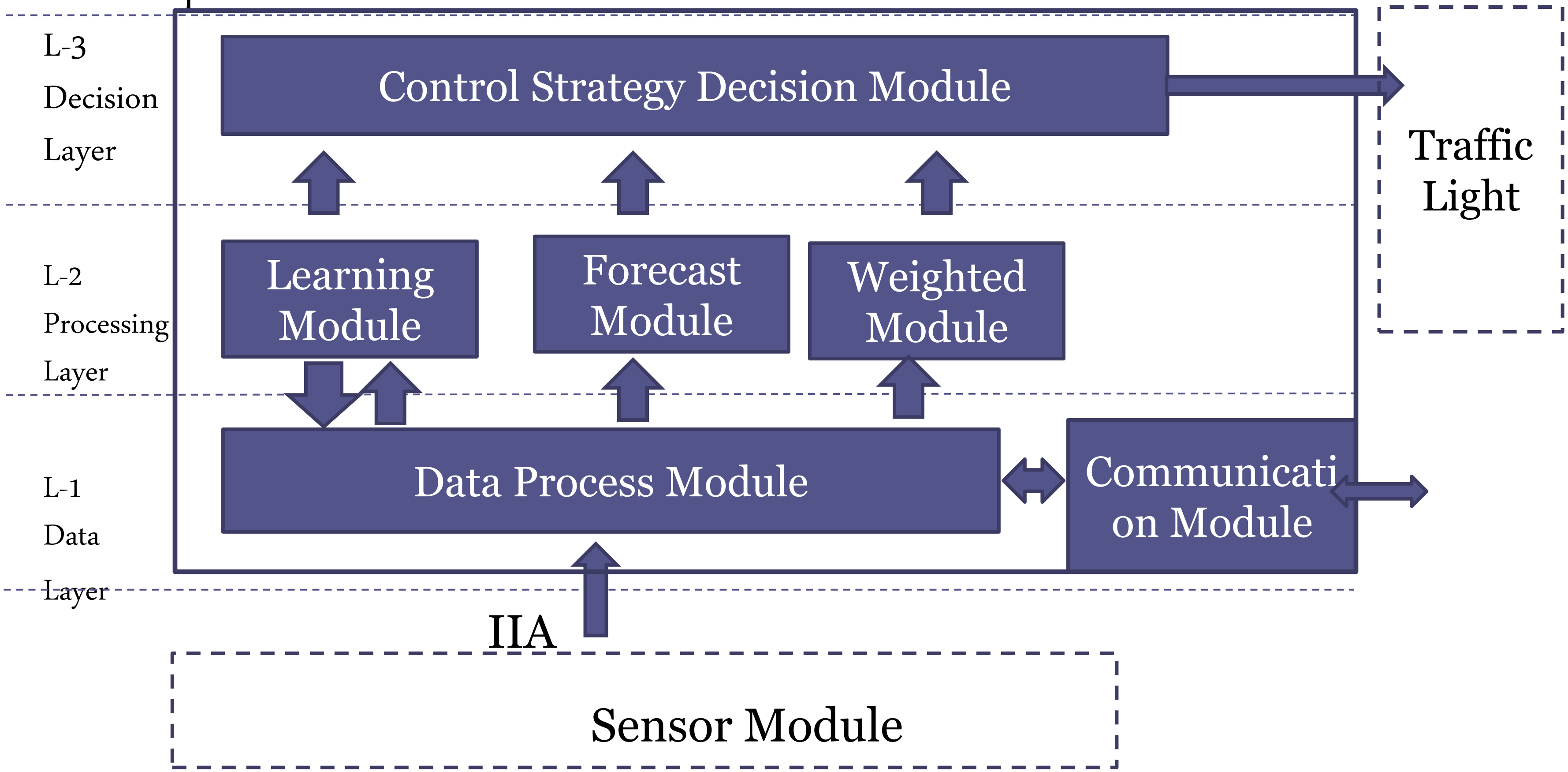
Multi-Agent System in Traffic Signals



Multi-Agent Frame Network

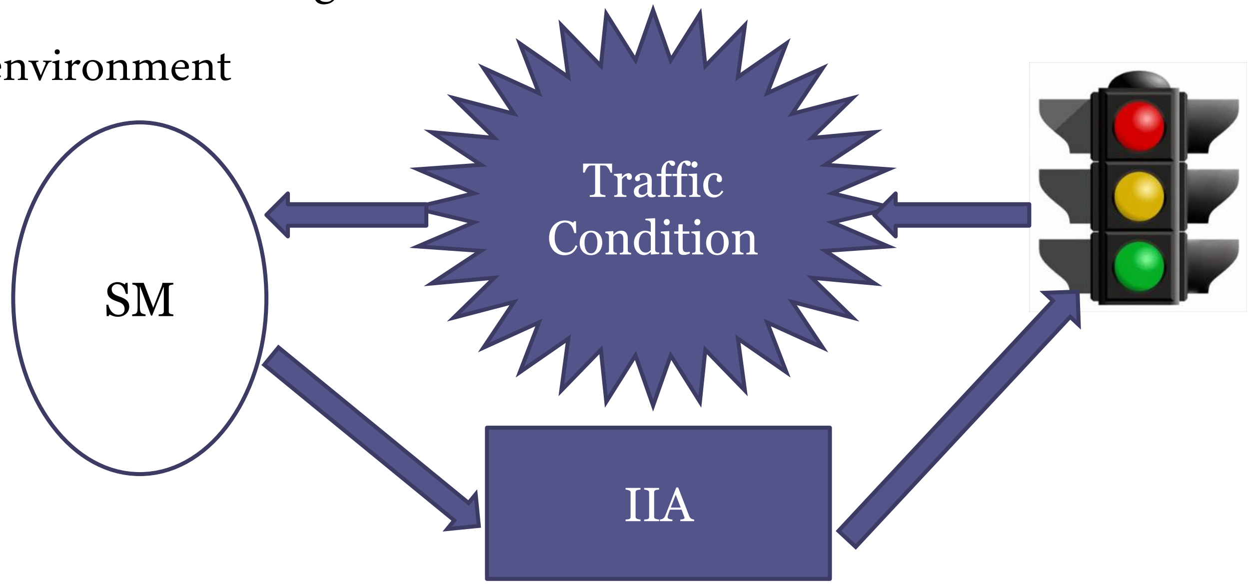
ACTAM

- Components of ACTAM



ACTAM

- Information Flow
  - Gathering of volume information
  - Processing and decision making
  - Actuation on environment



ACTAM

- Data Layer (IIA)
  - Comprises of Communication Module and Data Process Module
  - Communication Module: Agent interaction through KQML
  - Data Process Module: Storing Fixed + Calculated Data
    - Fixed Data: Serial number of intersections, distances, etc.
    - Calculated Data: Data from Learning Module

ACTAM

- Processing Layer (IIA)
  - Deals with the factors affecting traffic signal control strategies.
  - Traffic signal control strategies: Knowledge of past traffic flow data + Future vehicle number at the intersection + importance of each intersection
  - Processing layer comprises of
    - Learning Module: Used to achieve adaptation in models
    - Forecast Module : Forecasting future volumes
    - Weighted Module: Storing weighting result

ACTAM

- Decision Layer (IIA)
  - Gathers information of learning, forecast and weighted module .
  - Alters traffic control strategy through the modification of cycle, split and offset.

Signals

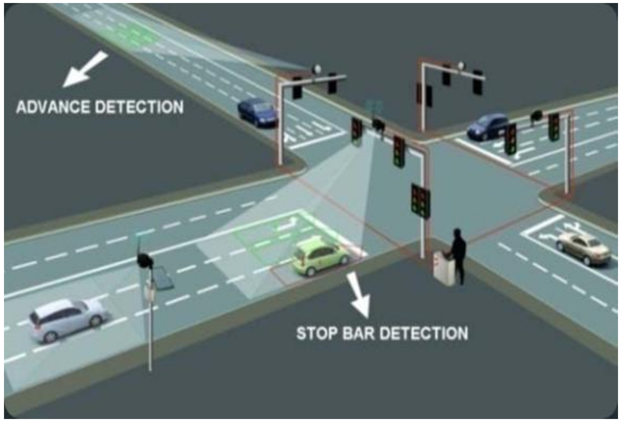
- Factors
  - Cycle length: Time required for a traffic signal (generally, 40s-120s) to circulate from some particular phase back to same phase.
  - Split: Segment of cycle length allocated for phase or interval
  - Offset: Time difference between same phase of traffic signals at adjacent intersection.
  - Headway: Time gap between two vehicles measured front to front or rear to rear.

Signals

- Types of Signals
  - Fixed Timed Signal Control: Uses fixed timetables as
    - Fixed cycle length
    - Fixed phase length
    - Not capable of handling fluctuating traffic volumes
  - Traffic Actuated Signal Control
    - Signal cycles, phases and intervals are defined with controllers and other devices
    - Green time is adjustment w.r.t the vehicle demand
    - Phase decision is based on the immediate arrival of the vehicles on the approach
    - It is myopic

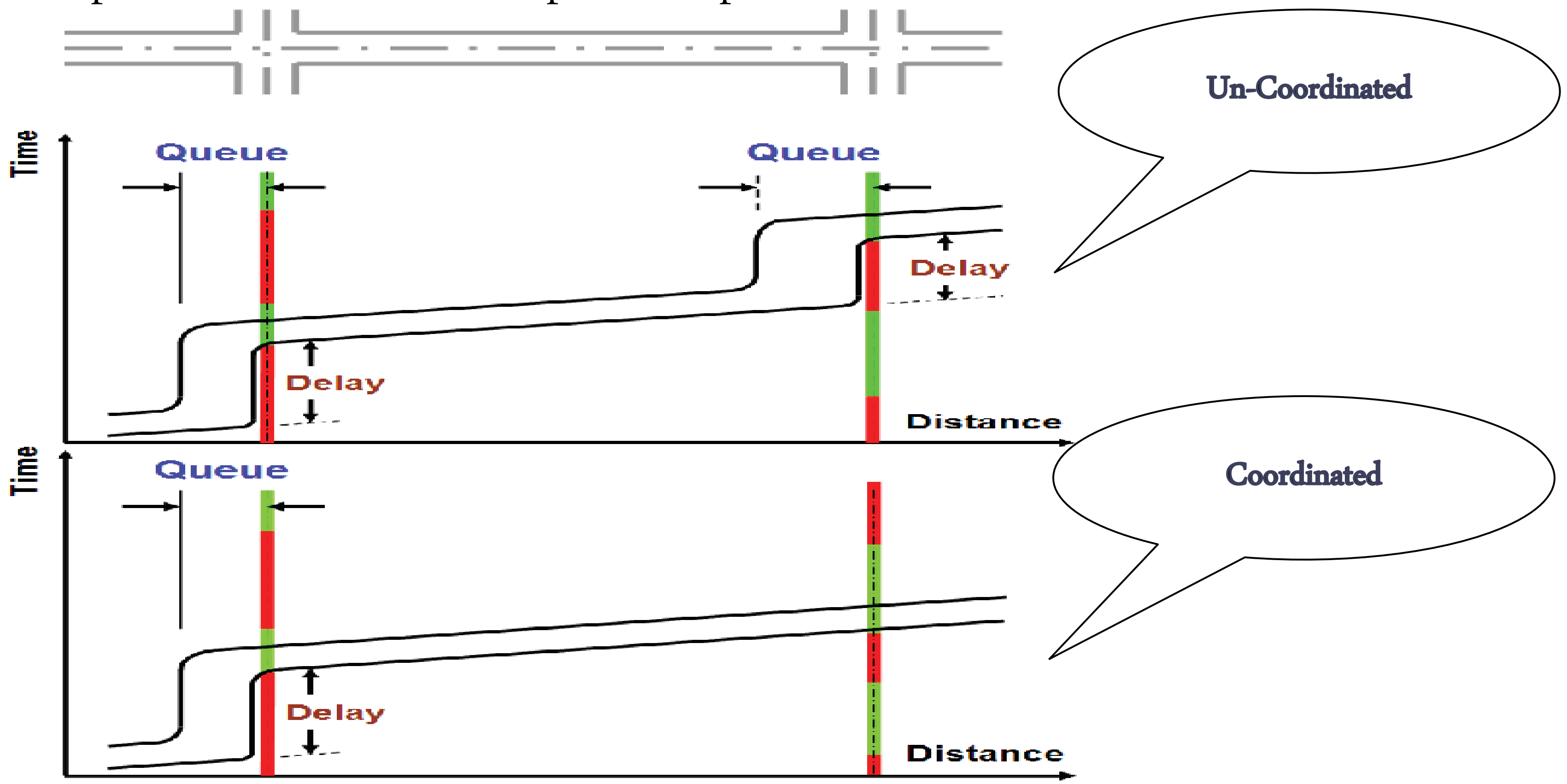
Signals

- Traffic Actuated Signals are further classified into:
  - Semi-Actuated Signal Control System
    - Major movement gets green phase until there is conflicting call on a minor movement phase.
    - Detectors are placed in minor street's approaches only
    - Coordinated System: Major road phase is coordinated with adjacent intersection.
  - Fully Actuated Signal Coordinated System
    - All movements get green phases
    - Detectors are placed in all approaches



Signals

- Coordination
  - Progression: A time relationship between adjacent signals permitting continuous operations of vehicles at a planned speed.



Signals

- Traffic adjusted Signals
  - Combines both the advantages of traffic actuated signals and fixed time signal
  - Based on real time traffic volumes
  - Sensors forward the volume information to master controller
  - Master controller calculates and distributes appropriate signal strategy (signal cycle, phases and interval) to the signal controller in each intersection

Agent Technology

- ACTAM utilizes an agent model that meets certain characteristics
  - Delegation
  - Communication
  - Autonomy
  - Monitoring
  - Actuation
  - Intelligence

Agent Technology

- DAI (Distributed Artificial Intelligence)
  - Multi-agent systems are a subfield of research under DAI
- The ACTAM design focuses on certain topics
  - Agent action
  - Agent interaction
  - Agent relationship with the environment
  - Agent adaptation
  - Coordination, negotiation, and cooperation
- FIPA (Foundation for Intelligent Physical Agents)

Agent Learning in ACTAM

- ACTAM implements a Learning Module. Learning Module attempts to achieve adaptation in agents

- Learning in ACTAM is divided into two categories
  - Short-term Learning: How the recent volumes effect traffic control
  - Long-term Learning: Discovering pattern/trend in historical data and adjusting traffic control strategies

Experiment

- The objective is to compare the total delay in the network due to the presence of ACTAM and fixed time signals.

Performance Metrics	
1.	Total Delay (T) $T = \sum_{i=1}^{n} \sum_{j=1}^{m} W_{ij}$ T= total delay, n=number of intersections, m= number of vehicles W_{ij} = waiting time infront of each traffic signal
2.	Improvement= ((Fix TDT-ACTAM TDT)/(Fix TDT))*100 Where, Fix TDT = Total delay for fixed time traffic control ACTAM TDT = Total delay for ACTAM

Experiment

Environment Parameters	
1	30 intersections (6 X 5),
2	Distance between intersections =500 meters
3	Vehicle speed = 50 kilometer per hour
4	Simulation time = 120 minutes
5	Turning movements: through: 50%, left turning: 25% and right turning: 25%
6	Vehicle entry headway (I)= 10 s (6 vehicles per minute)
7	Vehicle entry headway (II) = 2 s (30 vehicles per minute)

Experiment

Agent Parameters		
For Fixed Time Signal		For ACTAM
1	Cycle length=100s	Cycle length = f (R), where, Ri = Predicted upcoming flow of intersection I / Sum of predicted upcoming flow for every intersection
2	Split=1:1(H:V)	Horizontal Split = Cycle length * D1 / (D1+D2) Vertical Spit = Cycle length * D2 / (D1+D2) Where, D1 =Horizontal traffic volume, D2 = Vertical traffic volumes

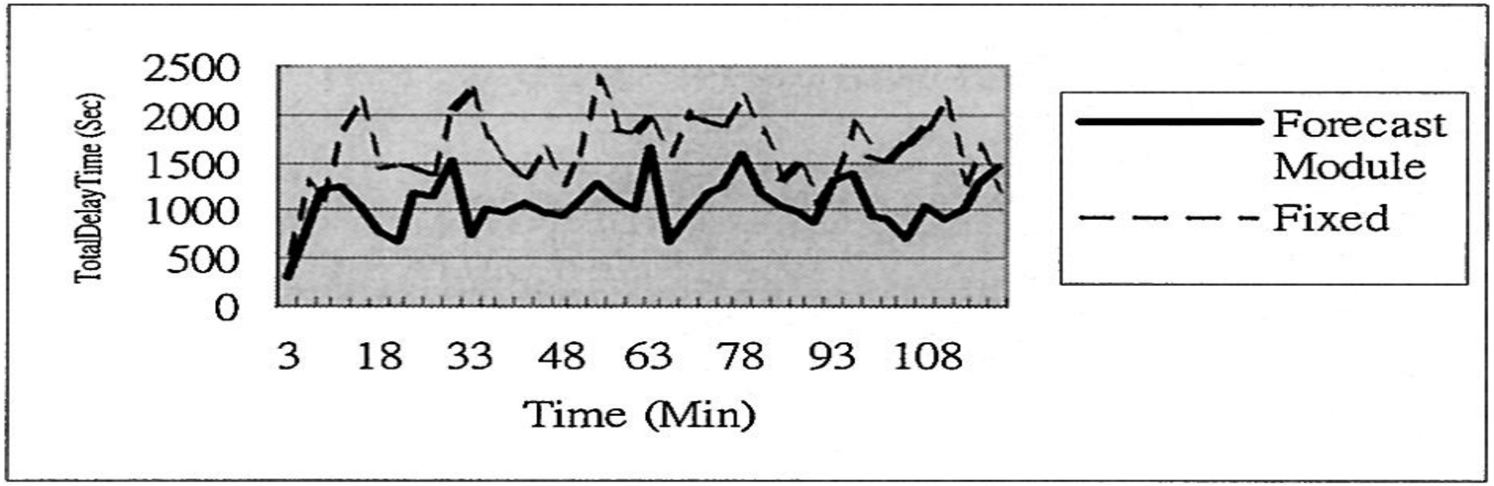
Experiment

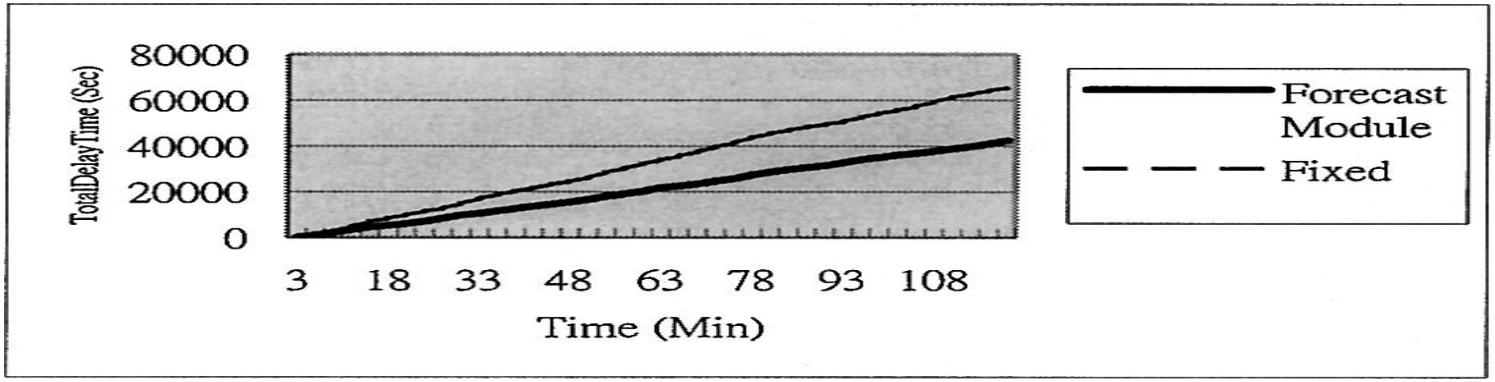
- Table for cycle length corresponding to R values

Type	Traffic Condition	Cycle Time
C1	R < 1/45	40s
C2	1/45 < R >1/40	60s
C3	1/40 < R > 1/35	80s
C4	1/35 < R > 1/25	100s
C5	1/25 < R > 1/20	120s
C6	1/20 < R > 1/15	140s
C7	1/15 < R	160s

Results

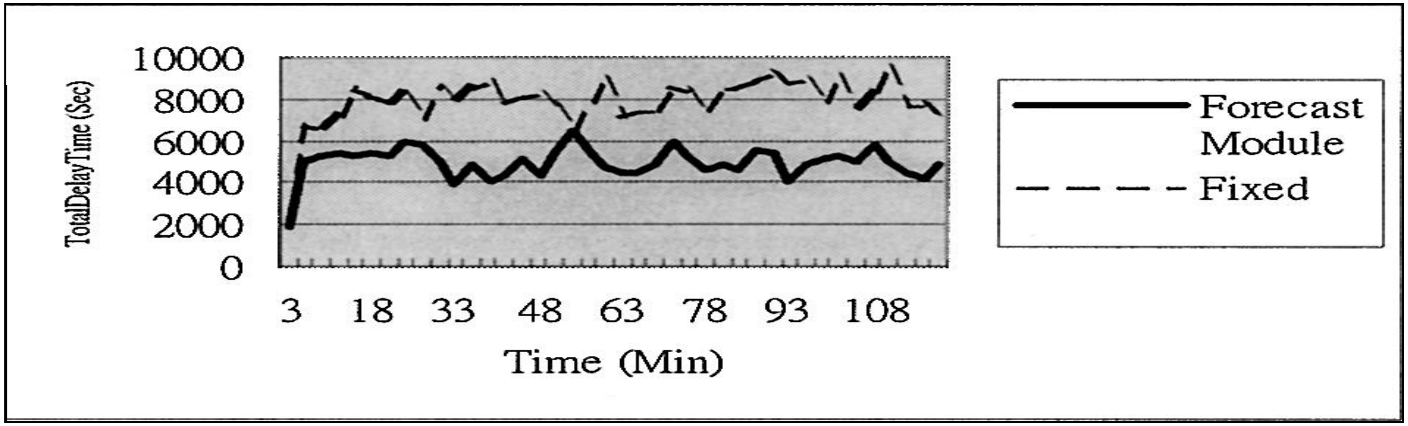
- 10 second vehicle entry headway (delay vs. time plots)

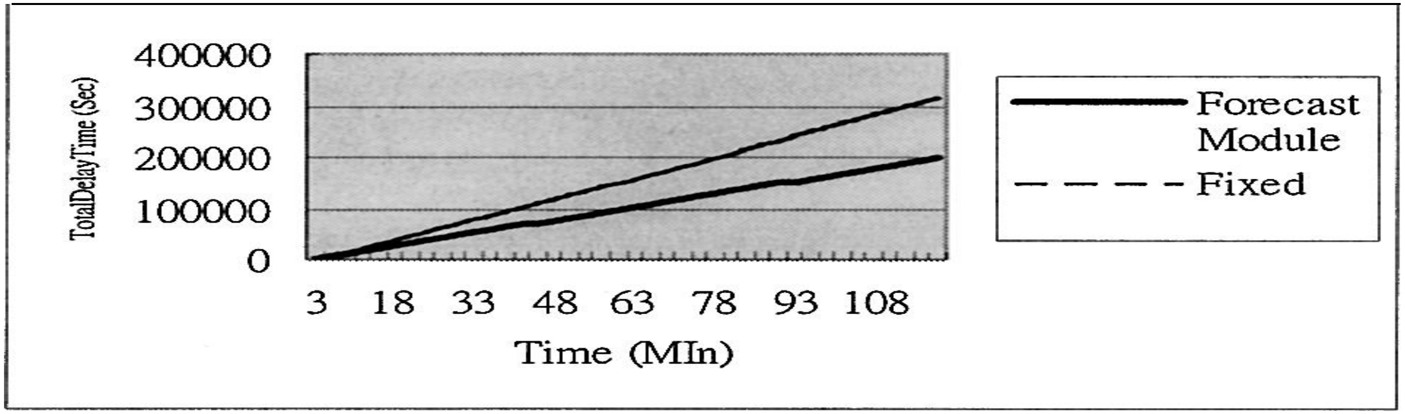




Results

- 2 second vehicle entry headway (delay Vs. time plots)





Results

- For vehicle entry headway 10 s (6 vpm) case, reduction in delay with the use of ACTAM compared to fixed sequence traffic signal= 33.47%.
- For vehicle entry headway 2 s (30 vpm) case, reduction in delay with the use of ACTAM compared to fixed sequence traffic signal= 36.96%.

Conclusion of the Paper

- The use of a multi-agent system in an urban traffic signal network enhanced the capability to cope with congestion by reducing delay in the network as compared to more conventional traffic signal strategy.

- ACTAM exhibited decentralized control strategy by utilizing a multi-agent system which enabled it to operate autonomously and to react to incidents more rapidly and proactively.

- Due to the modular design of ACTAM, individual modules can be improved or replaced as the situation evolves. Hence, it ensures the flexibility and extensibility of ACTAM.

- Use of multi-agent systems in traffic signal networks can increase robustness and scalability.

Our Conclusions

- Praises
  - The experiment strongly addressed the topic of optimization and local decisions vs. global coherence. As concluded by our topic paper, optimizing the flow of traffic at an individual intersection led to higher performance at the global level.
  - The paper also showed that cooperation and communication allow agents to be autonomous and efficient. In our example, IIA of adjacent intersections interact with each other to share information, allowing them to be effective without the need of a master controller.

Our Conclusions

- Praises
  - The results of the experiment make a strong case supporting the decentralized nature of a multi-agent system. Decentralization makes it ideal for solving problems over a geographically large environment, such as an urban city.

Our Conclusions

- Critiques
  - The paper did not explain in details about the learning algorithms used for the Learning Module. Research in other papers has suggested that Reinforcement Learning can be effective in traffic signals, but this paper did not detail how the learning was done, nor did the experiment test the effectiveness of the Learning Module.
  - The effectiveness of the ACTAM was only tested against a fixed-time signal control. It was not compared to a traffic actuated control. So while we can make a comparative judgment against the fixed control, we cannot say whether or not ACTAM is more effective than a traffic actuated control.

References

- Chen, R.S, Ceh, D.K & Lin, S.Y (2005). ACTAM: Cooperative multiagent system architecture for urban traffic signal control. *IEICE Trans. Inf & Syst.*, vol. E 88, 119-125.

- Yunlong, Z. & Xie, Y. (2011). A multi-agent adaptive traffic signal control system using swarm intelligence and neuro-fuzzy reinforcement learning. *IEEE Forum on Integrated Sustainable Transportation Systems*. 233-238.

Thank You

Q/A