Self Awareness and Adaptive Traffic Signal Control System for Smart World

Lawrence Y. Deng[1] and Dong-liang Lee[2]

[1] Dept. of Computer Science and Information Engineering, St. John's University, 499, Sec. 4, Tam King Road Tamsui, Taipei, Taiwan
[2] Dept. of Information Management, St. John's University, 499, Sec. 4, Tam King Road Tamsui, Taipei, Taiwan
{[1]lawrence, [2]lianglee}@mail.sju.edu.tw

Abstract. The most city dwellers are concerned with the urban traffic issues very much. To provide a self awareness and adaptive facilities in traffic signal control system is become more and more urgent. In this paper, we improved the video surveillance and self-adaptive urban traffic signal control system to achieve the development trend in intelligent transportation system (ITS). A self awareness and adaptive urban traffic signal control (TSC) system that could provide both the video surveillance and the traffic surveillance as smart hyper-space. We investigated the vision-based surveillance and to keep sight of the unpredictable and hardly measurable disturbances may perturb the traffic flow. We integrated and performed the vision-based methodologies that include the object segmentation, classify and tracking methodologies to know well the real time measurements in urban road. According to the real time traffic measurement, we derived a grid Agent Communication and the Adaptive Traffic Signal Control strategy to adapt the traffic signal time automatically. By comparing the experimental result obtained by traditional traffic signal control system which improved the traffic queuing situation, we confirmed the efficiency of our vision based smart TSC approach.

1 Introduction

A smart world is created on both cyberspaces and real spaces. As Jianhua Ma [1][2] discussed that the computing devices are becoming smaller and smaller, and can be embedded or blended to many things in the daily life. Therefore, the computing/communicating, connecting and/or being connected to each other, and behaving and acting rationally with some smartness or intelligence are occurring spontaneously. Current and potential applications of intelligent networks may include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring, and building and structures monitoring. The smart objects in these applications may be small or large, and the networks may be wired or wireless. However, ubiquitous wireless networks of various sensors probably offer the most potential in changing the world of sensing [3, 4].

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In this paper, we improved the grid Agent Communication Network (or ACN) and video surveillance for urban traffic surveillance. ACN is dynamic [5]. It involves as agent communication proceeds. Agents communicate with each other since they can help each other. For instance, agents share the traffic information and should be able to pass traffic signal control messages to each other so that the redundant manual processes can be avoided. A grid Agent Communication Network (ACN) then serves this purpose. Each node in an ACN (as shown in figure 1) represents a client agent on a computer network node and the grid server agent is served/ integrated as a Business Process Grids. The scope of Business Process Grids covers business process provisioning, outsourcing, integration, collaboration, monitoring, and management infrastructure [6]. The business process grid is an emerging area, and it's clear that significant research and development will be necessary to make it a reality. When the research results mature, the proposed grid Agent Communication Network for Smart TCS System may primarily cover business process integration and how to bridge the gap between business goals and IT implementations. For this grid, it is necessary to develop a flow technology capable of adapting to the dynamic grid environment and the changing requirements of grid applications.

Since client agent of the same goal wants to pass and to receive local traffic information to the adjacent agents and the grid server agent. Each client agent maintains the local and adjacent traffic information by a client agent active record. The client agent active record comprises four fields: CAID, adjacent agents, number of cars, and signal time messages. 'CAID' is the client agent ID that signifies the critical traffic zone number, direction, road number, and section number. The 'adjacent agents' field takes down the CAIDs these related with adjacent agents by a road junction (i.e. both to serve the possible cars coming and going). The 'number of cars' filed minutes the section's number of cars by a vision-based surveillance technology dynamically (i.e. current number of cars/maximums capacity of cars). Signal time field records the Signal time field records the go-straight, turn-right, and turn-left signal times.

As a result of the growing rapidly of urbanization, the traffic congestion occurs when too many vehicles attempt to use a common urban road with limited capacity. The efficient, safe, and less polluting transportation of persons and goods calls for an optimal utilization of the available infrastructure via suitable application of a variety of traffic control measures and Mech. Traffic control directly depends on the efficiency and relevance of the employed control methodologies [6]. Recently, more and more researcher investigated the real time vision based transportation surveillance system [7] [8] [9]. They deliberate to analysis and detect the objects first then measuring the number of cars after that they could extrapolate the transportation information of the main urban road. There are three essential methodologies to detect the vehicles: the Temporal Differencing [10][11][12], the Optical flow[13], and the Background subtraction [14] [15]. The Temporal Differencing and the Optical flow methods provide the abilities for processing successive images and detecting the moving objects. But they are not suit for motionless or slow motioning objects. Therefore, these methods don't fit the very busy urban road situation. The method of Background Subtraction could deal with the motionless or slow motion objects by way of comparing the preparative background and the current image. This method could make use of the very busy urban road situation.

SCII-2 [16] proposed a transportation expert system with adaptive traffic control mechanism. It set out and tune up the cycle time, phase and split in every 20 min. situation. [17] figured out the different traffic control strategies for influencing traffic conditions. Adaptive control degraded the conventional “fixed-time Control” queuing phenomena (and corresponding delays) while the infrastructure capacity is fully utilized. The main drawback of fixed-time strategies is that their settings are based on historical rather than real-time data. This may be a crude simplification for the following reasons [6][18][19]. (1) Demands are not constant, even within a time-of-day. (2) Demands may vary at different days, e.g., due to special events. (3) Demands change in the long term leading to “aging” of the optimized settings. (4) Turning movements are also changing in the same ways as demands; in addition, turning movements may change due to the drivers' response to the new optimized signal settings, whereby they try to minimize their individual travel times. (5) Incidents and farther disturbances may perturb traffic conditions in an unpredictable way.

In this paper, we integrated the grid agent technologies and image processing technology to analysis current traffic situation form receiving video, and then send a signal to control traffic light’s scope to improve to the higher class the traffic condition. This integrated technology, more reliable wire/wireless communication, and low-cost manufacturing have resulted in small, inexpensive, and vision-based imager with embedded processing and wireless networking capability. Such smart communication networks can be used in many new applications, ranging from environmental monitoring to industrial sensing, as well as TCS applications.

The background subtraction issues by a client agent, and the object segmentation model is presented in section 2. The preliminary experimental evaluation by self awareness and adaptive traffic signal control system are discussed in section 3 and, finally, the conclusion is given in Section 4.

2 Vision-Based Supervision with Self Awareness

In order to measure the very busy urban road situation and then deal with the motionless or slow motion objects. We compared the preparative background and the current image firstly. With combined average and inpaint method, we built the background for separated foreground object.

Average Method: Computing the average value of pixel value in background bitmap (the pixel value at (x,y) in jth iteration background bitmap) and current image (the pixel value at (x,y) in jth image) at same position.

Inpaint Method: Computing two continuous images and to find each pixel’s lightness difference whether it belongs to background or not. If the difference is lower than the threshold value (set by user), filled it in background bitmap at same position.

Building Background steps: (1) Get two continuous images. (2) Compute the difference of each pixel value. Determine whether the difference is lower than the threshold value or not. (3) Ignoring the lower one, and take it as a background and fill in background bitmap at same position. (4) Repeat the step 1 to step 3 until the complete background bitmap is built.

(a) current image (b) updating background

Fig. 1. Building the background image with combining the Average and the Inpaint methods

Figure 1 shows the successive current image and the updating background images. We used median filter and morphological operations to eliminate noise and then to merge the object's fragment.

(a) After Median filter and segmentation (d) after classify each objects

Fig. 2. The object classification

Rearranging all the pixels value (with gray-level) with a N*N mask in a sequential order and the medium value is the center pixel value. For example, if we got the set {104, 255, 136, 25, 38, 206, 178, 193, 236}, rearranging it to {25, 38, 104, 136, 178, 193, 206, 236, 255}. The medium value: 178 is the center pixel's value. Then compare the background and the difference of lightness in each pixel respectively. If the difference is larger than the threshold, this point will be taken as a part of object.

We removing the isolation point and smoothing the current image by using the Median filter, then adopt the morphological operations closing (Perform the dilation followed by erosion operation) to eliminate the noise spikes, filling in the small anomalies (like holes) and merging the object's fragment. We got more precisely object's number. Figure 2 illustrated the object classification processes. According to the number of cars information, we could decide whether if the traffic signal should be adapted to increase or decreased the period of red/green light.

3 Adaptive Traffic Signal Control and Preliminary Experimental Results

Once traffic lights exist, they may lead to more or less efficient network operations, therefore there must keep an adaptive control strategy leading to minimize the total time spent by all vehicles in the network. Server agents (to serve a critical traffic zone) play the leading role as rendezvous and supervision service center. They receive the traffic information from active client agents with the same zone number.

Grid Server agent verifies the CAID firstly, and then record to the database (as Table 1 shown). CAID is composed by three numbers. For example, CAID = 01.001.02 means: this client agent is located in zone 01, road number is 001 (if the lower two bit is odd that express this road is same with the longitude direction and if the first bit 0 means it only monitors from north to south traffic, 1 means it only monitor from south to north; if the lower two bit is even that express this road is same with the latitude direction and if the first bit 0 means it only monitors from east to west traffic, 1 means it only monitors from west to east traffic). The third number 02 is the section number of road 01. Number of cars field records the current number of cards and the maximum capacity cars of this section. Signal time field records the go-straight, turn-right, and turn-left signal times.

Table 1. ATSC database maintained by grid server agent

CAID	Adjacent Agents	Number of cars	Signal time
…			
01.001.02	01.001.01, 01.102.01, 01.002.02,	80/250, 95/200, 34/200,	90.90.30
	01.001.03, 01.004.01, 01.104.02,	90/250, 41/200, 35/200,	
01.101.02	01.101.03, 01.004.02, 01.104.01,	65/250, 55/250, 47/200,	90.90.30
	01.101.01, 01.102.02, 01.002.01,	58/200, 39/200, 35/200,	
…			

With grid strategy, server agent could compute the traffic load with percentage. Server agent takes the statistical inference and then decrease/increase the signal time with specific sections of roads.

The factors of traffic jam contains: Uniform Arrivals period, Random Arrivals period, and Platoon Arrivals period. The uniform arrivals period was proposed by May [21] :

$$D = \frac{r^2}{2C\left(1 - \frac{q}{s}\right)} \tag{1}$$

Where,
D: average delay(sec/car);
C: cycle(sec);
r: time of red light;
q: arrival rate of adjacet road(%);
s: saturation rate of adjacet road(%)。

Webster [22] and HCM [23] had considered both Random Arrivals period, and Platoon Arrivals period :

$$d_t = 0.9[UD + RD] = 0.9\left[\frac{C\left(1 - g/C\right)^2}{2\left(1 - \left(g/C\right)X\right)} + \frac{X^2}{2q(1-X)}\right] \tag{2}$$

Where,
d_t : average delay (sec/car);
C : cycle(sec);
g : period of green light(sec);
X : saturation(%);
q : flow(car/sec);

So, then get the uniform dely(UD) $d_u = \frac{C[1-(g/C)]^2}{2[1-(g/C)X]}$, (3)

the random dely (RD) : $d_r = \frac{X^2}{2q(1-X)}$, (4)

the adjustment: $d_e = -0.65(C/q^2)^{1/3} X^{2+5(g/C)}$ (5)

is got from the real world measurements (about 5%~15% of the d_t).
The delay estimation by HCM:

$$d = d_1(PF) + d_2 + d_3 \tag{6}$$

where,

$$d_1 = \frac{0.5\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]} \tag{7}$$

$$d_2 = 900T\left[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}\right] \tag{8}$$

Where,

d : average delay (sec/car);

d_1 : uniform delay(sec/car);

d_2 : incremental delay(sec/car);

d_3 : initial queue delay(sec/car);

C : average delay (sec/car);

X : saturation(%);

c : capacity(number of car);

T : duration of analysis period(h);

k : increasing adjustment factor;

l : decreasing adjustment factor;

PF : progression adjustment factor)

$$PF = \frac{(1-P)f_{PA}}{\left(1-\frac{g}{C}\right)} \tag{9}$$

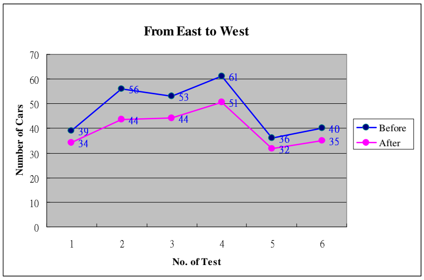
Where,

P : arrivals rate;

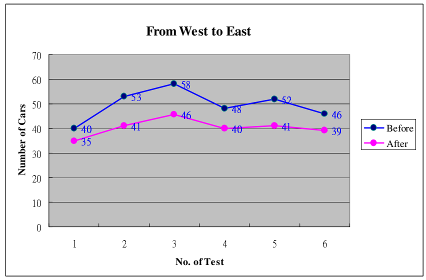
f_{PA} : Platoon Arrivals factor;

In order to prove our approaches, we recorded the video at the very busy crossroad of MinQuan W. Rd. and ChenDer Rd. Taipei in morning business hours. We installed four cameras in each intersection with a bird's-eye view and capture the video simultaneously. By the way of image processing methods as we mentioned above, we measure the traffic condition for individual intersection (such as queuing length, average vehicle speed, and the number of vehicle…etc.).

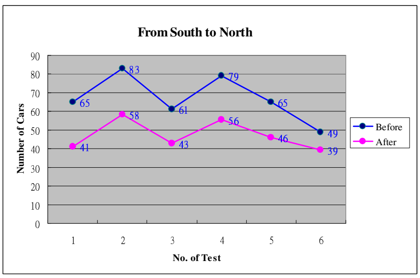
Figure 3 shows the experimental results of queuing vehicles in four directions. After six times random testing, we proved our system can downgrade 20% the queuing situation approximately. If we make a conversion the queuing vehicles into time cost with estimating speed 10 km/hr, by any means , we may save about 15~20 second a car. As you know, the traffic congestion results in excess delays, reduced safety, and increased environmental pollution. So, we will investigate the more efficient and practicable adaptive TSC system as our future-proof.



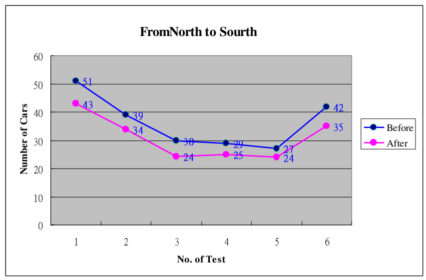
(a) Queuing vehicles form east to west



(b) Queuing vehicles form west to east



(c) Queuing vehicles form south to north



(d) Queuing vehicles form north to south

Fig. 3. An experimental result of Agent monitoring the queuing vehicles in four directions

4 Conclusion

In this paper, a vision-based adaptive traffic signal control system with grid Agent Technology for smart world has been presented. We performed the real-time traffic surveillance and to solve the unpredictable and hardly measurable disturbances (such as incidents, illegal parking, pedestrian crossings, intersection blocking, etc.) may perturb the traffic flow. We investigated the self awareness and adaptive Agent technologies, vision-based object classification (as well as segmentation and tracking) methodologies to know well the real time measurements in urban road. According to the real time traffic information, we derived the adaptive traffic signal control with grid server agent centralized stratagem to settle the red–green switching time of traffic lights. In our experiment results, they diminished approximately 20% the degradation of infrastructure capacities. In fact, the applications are only limited by our imagination. The ubiquitous intelligence indeed can make our living more convenient and comfortable but also take us to some potential dangerous environments with the possibility of sacrificing privacy and the risk of out of control. Therefore, the potential applications of underlying ubiquitous intelligence would at first go to those environments where the privacy may not be a serious or sensitive issue to users or can be well under control. Benefiting from the intelligence evolution, human life and working style are evolving towards more convenient, comfortable, and efficient.

References

1. Jianhua Ma, Laurence T. Yang, Bernady O. Apduhan, Runhe Huang, Leonard Barolli and Makoto Takizawa: Towards a Smart World and Ubiquitous Intelligence: A Walkthrough from Smart Things to Smart Hyperspaces and UbicKids, in Journal of Pervasive Computing and Communication vol. 1, (2005) 53–68
2. Jianhua Ma: Ubiquitous Intelligence - The Intelligence Revolution, ID People Magazine, (2005)
3. CHEE-YEE CHONG, AND SRIKANTA P. KUMAR: Sensor Networks: Evolution, Opportunities, and Challenges, PROCEEDINGS OF THE IEEE, VOL 91, NO 8, (2003) 1248–1256
4. 10 emerging technologies that will change the world, Technol. Rev., vol. 106, no. 1,(2003) 33–49
5. Lawrence Y. Deng, Timothy K. Shih, Teh-Sheng Huang, Chun-Hung Huang, Ruei-Xi Chen and Yang-Long Chang: Universal Access for Roaming User via Mobile Agent Technology, in the International Journal of Tamkang Journal of Science and Engineering, Vol. 5, No. 3, (2002) 175–186
6. Liang-Jie Zhang; Haifei Li; Lam, H.: Toward a business process grid for utility computing, IT Professional Volume 6, Issue 5, (2004) 62–64
7. Markos Papageoggius, Christina Diakaki, Vaya Dinopoulou, Apoatolos Kotsialos, and Yibing Wang: Review of Road Traffic Control Strategies, PROCEEDINGS OF THE IEEE, VOL. 91, NO. 12 (2003).
8. Giusto, D.D., Massidda, F., Perra, C.: A fast algorithm for video segmentation and object tracking, Digital Signal Processing, 2002. DSP 2002. 2002 14th International Conference on , Volume: 2 , (2002) 697–700.
9. Haritaoglu, I., Harwood, D., Davis, L.S.: W4: real-time surveillance of people and their activities, Pattern Analysis and Machine Intelligence, IEEE Transactions on , Volume: 22 , Issue: 8 , (2000) 809–830.
10. Hsu, W.L.; Liao, H.Y.M.; Jeng, B.S.; Fan: Real-time vehicle tracking on highway, The Proceedings of the 2003 IEEE International Conference on Intelligent Transportation Systems, (2003) 909–914.
11. D. J. Dailey, L. Li: An algorithm to estimate vehicle speed using uncalibrated cameras, Proceedings of IEEE/IEEJ/JSAI International Conference on Intelligent Transportation System, (1999) 441–446.
12. M,-P. Dubuisson, A.K. Jain: Object Contour Extraction Using Color And Motion, Proceedings of IEEE Computer society Conference on Computer Vision and Pattern Recognition, (1993) 471–476.
13. T. Nakamishi, K. Ishii: Automatic vehicle image extraction based on spatio-temporal image analysis, Proceedings of 11th IAPR International Conference on Pattern Recognition. Vo1.1. Conference A: Computer Vision and Applications, (1992) 500–504.
14. Y. Mae, Y. Shirai, J. Miura, Y.Kuno: Object tracking in cluttered baced on optical flow and edges, Proceedings of the 13th International Conference on Pattern Recognition Volume: I, (1996) 196–200.
15. D. Koller, J. Weber, and J. Malik: Robust Multiple Car Tracking with Occlusion Reasoning, Technical Report UCB/CSD-93-780, University of Calibornia at Berkely (1993).
16. Y. Matsushita, S. Kamijo, K. Ikeuchi and M. Sakauchi: Image Processing Based Incident Detection at Intersections, Proceedings of the Fourth Asian Conference on Computer Vision 2000, (2000) 520–527.

17. May, Adolf D.: Traffic Flow Fundamentals, Premtice Hall, Englewood Cliffs New Jersey (1990).
18. Reports of urban traffic signal control in the Taiwan, the Transportation Institute of the Ministry of Communications (2001).
19. T. Van Vuren: Signal control and traffic assignment, in Concise Encyclopedia of Traffic and Transportation Systems, Papageorgiou, Ed, Oxford, U.K.: Pergamon (1991) 468–473.
20. U.S. Department of Transportation/ FWHA, Traffic Control System Handbook (1985).
21. May, Adolf D.: Traffic Flow Fundamentals, Prentice Hall, Englewood Cliffs New Jersey (1990).
22. Webster, F.V.: Traffic signal settings, Road Research Technical Paper No. 39, Road Research Laboratory, Her Majesty's Stationery Office, London, U.K. (1958).
23. Special Report 209: Highway capacity manual, Transportation Research Board, National Research Council, Washington, D. C. (2000).