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Business Process Modeling for a Smart Street Lights System

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Abstract- Recent advancements in technologies have revolutionized our world. New visions and approaches are being presented for the integration of the physical world with the cyber world. New and smarter systems for daily life utilities are being introduced and existing systems are being transformed towards smarter, efficient and more reliable systems. This paper is based on the same phenomenon. We propose a dynamic and efficient street lights operation strategy in the form of a smart street lighting system. The proposed design is based on collaborative sensing of motion and decision making in terms of the direction of motion and light intensity control. Business process modeling provides the illustration of each process in detail and provides the basis for the smart street light system implementation as part of a larger internet of things project.

Keywords- Sensor network, Street lights, Control, Process, Modeling

1. Introduction

The recent advancements in technologies have made it possible to automate many industries and other systems which were completely manual few decades ago. With the more recent developments in the fields of sensing equipment and communication technologies, intelligence and smartness have become the buzzwords for researchers. The introduction of concepts such as sensor web [1] and internet of things [2] has revolutionized the world and has resulted in rigorous research in the fields of smart systems and service provisioning in the form of smart home [3], smart office [4] and smart grid [5] etc. The major focus of these intelligent and smart features is to increase the efficiency of the systems and reduce the power consumptions. There is still a lot of work needed to perfect these systems but some very basic systems such as public street lighting systems, which still operate on the same old static procedures and consumes too much energy, needs special attention from the research community.

As street lights mostly operate in groups, centralized control seems a logical choice. However, the size of the group or area under the centralized control may affect the usefulness and efficiency of the centralized control scheme. For example, operating all the street lights of a city from a single centralized point may not be a good idea especially when the system lacks dynamic operation.

The proposed smart street lights system introduces the concept of Regional Gateway (RG) for region-wise centralized control of the street lights in a specific area. All street lights in a region are directly connected to the RG in that area and can be controlled collectively by the RG, which provides a remote manual control interface to the operators. Apart from manual control of street lights, a large geographic area such as the city in the example above can be divided into different regions based on weather and geographic conditions and each area could be installed with a separate RG. This distributed setup of RG enables the proposed system to take into account the regional weather conditions for its dynamic operation of street lights. Thus an RG with integrated sensing module to monitor weather conditions in a specific region can automatically operate the street lights in the region even at daytimes when pedestrians or drivers could get benefit from dimmed street lights during severe fog, rainfall or stormy days.

2. Conceptual architecture

This section discusses briefly the major components of the smart street light system. Fig. 1 illustrates the conceptual architecture of the system in terms of the major components and their association with each other. The major components include street light pole and the associated Local Control & Communication Unit (LCCU). The LCCU is capable of detecting movements in the vicinity of the light pole with the help of the integrated motion sensor. Each LCCU is capable of communicating with its adjacent LCCU through a direct connection so that motion detection events could be passed on in advance to provide proper lighting in the direction of the movement. The connection between LCCUs may be wired or wireless.

As street lights mostly operate in groups, centralized control seems a logical choice. However, the size of the group or area under the centralized control may affect the usefulness and efficiency of the centralized control scheme. For example, operating all the street lights of a city from a single centralized point may not be a good idea especially when the system lacks dynamic operation. Weather conditions and natural light intensity at a given time may vary in different regions of a city (coastal, mountainous, etc.) and hence the centralized operation of street lights in such a scenario would be too inefficient from the perspective of energy usage and system management.

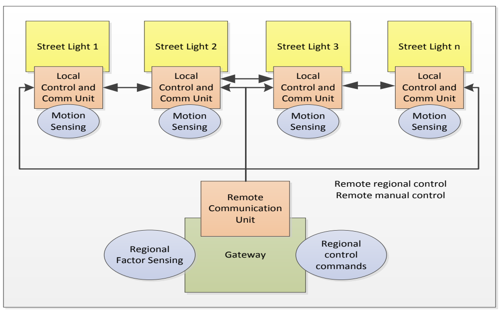

Fig. 1. Conceptual architecture for smart street light system

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3. Operational Scenarios

Fig. 2 shows the scenarios for the smart street light operation in case of moving vehicles and moving pedestrians. Part (a) of the fig. shows a vehicle moving on the road while part (b) shows the scenario for a moving pedestrian. As the first LCCU detects any kind of motion, it alerts the adjacent two LCCUs about the detected movement. At this time the type of the moving entity (vehicle or pedestrian) or the direction of the movement is unknown so all the three street lights are turned on and the adjacent LCCUs wait for the vehicle to arrive towards it. If no movement is detected by the adjacent LCCUs in predefined time interval, the lights would be turned off. Otherwise, the LCCU detecting the motion will decide on whether the moving entity is a vehicle (speedy) or a pedestrian (slow).

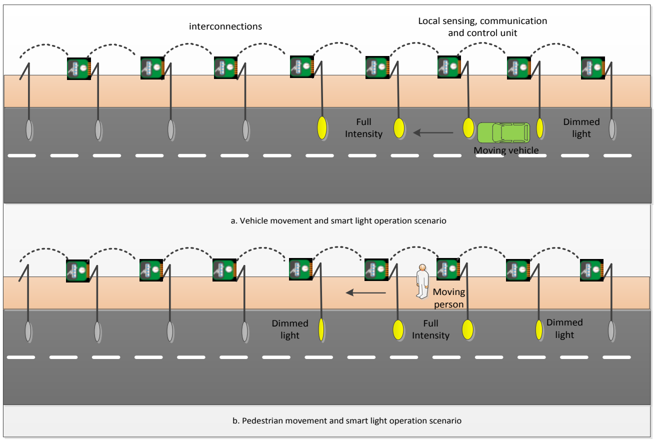

Fig. 2. Motion detection based smart street lighting operation

The figure shows that for a moving vehicle, more lights in the direction of motion are turned on with full intensity and the interval to keep light on at full intensity is short. This way, as a vehicle passes, the intense lights would be dimmed after a short time and finally turned off again if there is no further movement detected. In case of a pedestrian, as the movement is slow, few lights in the direction of motion are turned on with only those lights in full intensity which are directly above the moving pedestrian. The duration for a light to remain at full intensity is longer before the light is turned off after there is no movement detected. This way the area, in which a movement is taking place, is lit dynamically and hence considerable amount of energy can be reserved in the process.

4. Business Process Modeling

Fig. 3 shows the business process model diagram for the motion detection based smart street light control process. As the process involves dynamic lighting of an area based on the detection of movement, the direction of movement and the speed of the moving entity, it is more of collaboration among adjacent smart street lights and their associated sensing and communication components. As mentioned earlier, the LCCU on every smart street light pole can detect a motion in its vicinity. Once a motion is detected by any one of the LCCU's motion sensor, that specific LCCU alerts the immediate next smart street lights via the inter LCCU communication interface. This is done because at that time, there is no information about the speed and direction of the motion. The alerted LCCUs then wait for a motion to happen in their vicinity. If, in a predefined time interval, a motion is detected by the alerted LCCU then the direction and speed of motion is calculated. Otherwise, the alert is ignored and lights on the alerted LCCUs are turned off.

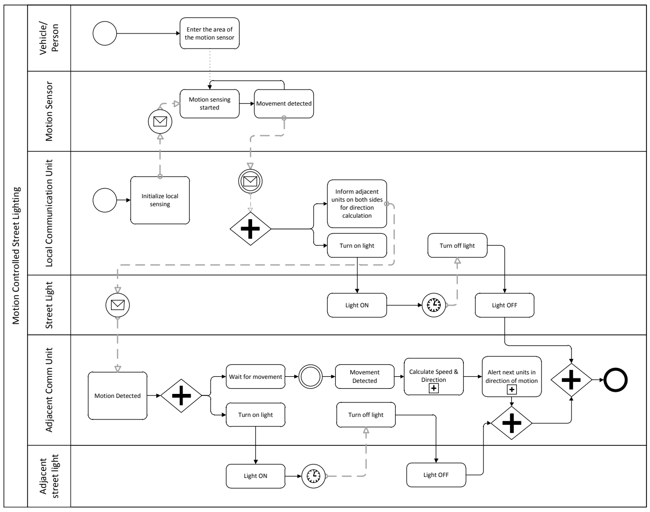

Fig. 3. Process model for the motion detection based smart street light operation

The speed of the moving entity also helps in identifying whether it is a vehicle or a pedestrian. Smart street light system uses this identification to decide the number of lights to turn on in the direction of the motion, the intensity of the turned-on lights and the time interval after which the lights should be turned off or dimmed according to the situation. For example, for a fast moving vehicle, more number of lights should be turned on with full intensity to provide a farther line of sight with a shorter interval to turn lights off or dimmed. For a slow moving vehicle or pedestrian, on the other hand, few lights directly over the moving entity are turned on with medium/full intensity for a longer interval before turning off or dimming the lights.

5. Conclusion

This paper presented the design of a smart street lighting system. The system provides smart operation capabilities based on intercommunication among individual street lights in order to operate based on motion sensing, direction aware lighting for moving vehicles and pedestrians, weather condition based assistance operation and energy conservation apart from the usual functionalities such as optical controlled, scheduled operations and remote manual control operations. The proposed system is capable of reducing energy consumptions to a higher degree and provides smart services in real sense. The business process modeling for the smart street light system can also be utilized in an IoT based implementation of the system, which is the intended future work for this study.

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