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To Smart City: Public Safety Network Design for Emergency

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ABSTRACT In smart cities, there are always unpredicted emergencies, which must be handled to maintain the regular order. Then a smart system is needed to detect threats and deal with them. In this paper, we propose a system structure composed of a central agent and three layers: unmanned aerial vehicle (UAV) layer, multi-robot layer and sensor network layer. The UAVs act as moving sensors and conveyors in the air. They provide the overall rough monitoring data from the air and transport robots to the emergency occurring places. The robots on the ground are responsible for obtaining detailed monitoring data and dealing with the emergencies. The sensor networks keep monitoring the environment and assist robots and UAVs in the range to complete their tasks. The central agent can adjust the system according to the specific task requirements. We provide a general system design and review main required technologies, highlighting the challenges and some possible solutions. The future researching directions are presented to guide the system design.

INDEX TERMS UAV, multi-robot system, distributed sensors, smart city, emergency.

I. INTRODUCTION

The rapid development of robotic techniques prompt people's desire to build the smart city. In smart cities, the intelligent system supervises the urban area and maintains its regular order. It should assist to ensure the safety of all the residents by detecting and handling the coming up emergencies. Such intelligent systems improve the efficiency of urban management and enhance living security of residents.

In the present conception, the information and communication technologies are integrated with the internet of things to manage a smart city. The management mainly includes distribution of resources, supervising of potential threatens, event handling and community services. In this article, the issues of intelligent surveillance and event handling in smart cities are considered.

The emergency detecting and handling system has gained much importance as the life of citizens could be threatened by criminal activities. Nowadays, surveillance cameras have been installed in many critical areas such as banks, supermarkets, train stations as well as elevators in buildings, which are thought to be places of crime with high probability. The data from those cameras is recorded or shown to a security personnel constantly monitoring suspicious activities. The work is too stressful, since the security personnel has to monitor several different places simultaneously with high concentration. This mode is inefficient and labor intensive [1]. To enhance the working efficiency, a smart alarming system should be developed, in which the data is collected and analyzed automatically.

However, such a system is not really smart, for data sources can not be changed dynamically and the emergencies can not be handled by the system automatically. In fact, it is just providing information for the city managers and assisting them to make the decision. The data sources are limited, for which the flexibility of the system is reduced. Furthermore, a real smart system for emergency should be able to deal with events automatically, which can reduce the delay. The design of a more aggressive smart system for emergency should be researched [2].

In the future development, the smart system for emergency should be fully automatic. It should not only collect data for analysis but also make its own decision and handle the events. Furthermore, it should be able to accept requests from citizens and help them to deal with the trouble. The role of human should be adjusting and maintaining the system when it has some uncontrollable systematic problems. The

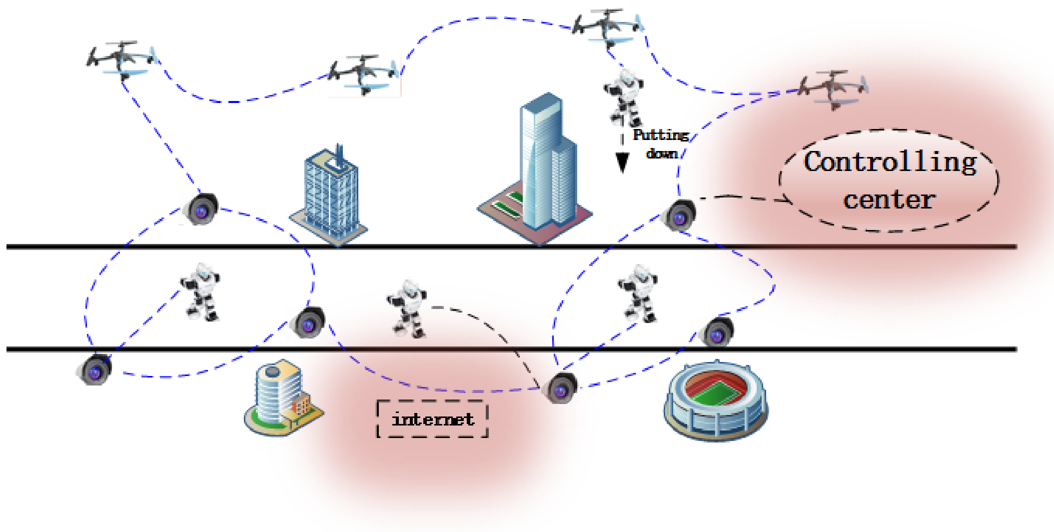

FIGURE 1. The structure of the whole smart system for emergency, in which the layers are connected to cooperate doing surveillance and handling emergencies.

urban environment is very complex for the intelligent system when handling events or collecting data dynamically. However, the increasing development of robotic technology would make it be truth in the near future.

To build such a smart system for emergency, it is necessary to setup a reasonable structure. In [3], [4], structures based on heterogeneous sensors and cloud platform was introduced. A surveillance system using security robots was proposed in [5]. However, by adding the UAVs and building a structure with the cooperation of UAVs, robots and sensor networks, the surveillance can obtain a larger range and higher flexibility. In this paper, we try to touch such a problem and propose a system, which is composed of a controlling center and three working layers based on the resources over three dimensional spatial distribution. In the sky, there is the UAV layer, which collects data in the large area and high angle of view. On the ground, there is the sensor layer composed of distributed sensors around the city. Besides, we have the robot layer composed of moving intelligent robots. These robots collect data from nearby sensors or by themselves. They can be transported and launched by the UAVs. These robots act as detailed data collectors and event handlers. Upon these three layers, there is a center controlled by human. It collects data of the city and makes big data comprehensive analysis to detect problems in a larger range. When there is a systemic problem, people can send commands from the center to adjust the system so that it works normally.

In this paper, functions of different parts in the system are explored and a general structural design of the system is provided. Then the relative technologies and challenges are highlighted and some possible directions of solutions are given. It is expected such a work of us can provide some insights for the research to achieve a real smart system for emergency, which can enhance the security of citizens.

The remainder of the article is organised as follows. We first introduce the whole structure of the smart system by analysing the functions of different parts and interaction between them in Section II. Then in Section III, the UAV layer and its relevant issues are proposed. Afterwards, in Section IV, the role of sensor layer is analyzed. In Section V, we introduce the multi-robot layer. In addition, in Section VI, the role of controlling center is analyzed together with its related challenges. In Section VII, the conclusion is given.

II. SYSTEM OUTLINE

The smart system for emergency need to supervise the city by collecting and analysing the data from urban areas. Based on this, the potential or ongoing emergencies are detected and handled timely to ensure the security.

As shown in Fig. 1, the structure of the system is composed of three working layers and a controlling center. The working layers include the UAV layer, the sensor network layer and the multi-robot layer, in which data is exchanged between and within the layers. Apart from them, there is a controlling center manipulated by human, which synthesizes data from the three layers. Based on this, it sends commands to adjust the whole system working mode. When the system breaks down due to some systematic problems, it can reset the system to ensure its running.

The UAV layer is the most flexible among the three layers, which is composed of unmanned aerial vehicles. Its range of movement and data collection is the largest, which can not be provided by robots and sensor networks. In this way, UAVs can detect threatens in a large area around them and they can move fast to change their supervising areas. Though some details may be sacrificed, they can obtain them from robots on the ground by communication. When handling the events, they inform nearby robots to the scenes or launch some new robots for the work. Then they can send robots commands or information to support the work. In general, the UAVs are flexible supervisors and commanders.

Though the UAV layer is flexible and fast, it can not replace intelligent robots to do specific work on dealing with the security problems. Furthermore, data collected by UAVs lacks details which need to be obtained by robots on the ground. Then the multi-robot layer composed of a large amount of intelligent robots is necessary. The robots are independent intelligent agents with the ability of communication. They move in a relatively small range to collect detailed data of the environment. Some corners beyond the sight of UAVs and sensor networks can be covered by them. Their obtained data can be communicated to UAVs or sensor networks for analysis. In addition, the intelligent robots play the role of trouble handlers. They should be able to complete basic tasks such as tracking or catching criminals.

To supervise some suspicious areas constantly, we need static distributed sensors. The sensors are connected by the network, which enables them to exchange data and obtain more accurate states of the monitored areas. In each area, there should be a local center controlling the sensors nearby. The center can either be a leading sensor or an independent computer, which supervises the environment by analyzing data from sensors or nearby robots. Once it detects problems, it will inform nearby UAVs or robots. In addition, the sensor networks can also assist UAVs and robots to work by providing essential data.

III. THE UAV LAYER

In general, the UAVs can supervise objects in a wider range, for it is high in the sky. In addition, their fast moving speed enables them to do the surveillance flexibly and react to emergencies much faster. Furthermore, the target typically moves fast for which robots may not catch up with it easily. The UAVs can track it in the sky and command robots on the ground to, cooperate handling the event. In addition, UAVs can carry robots on board, moving fast to the scene and launching them for work. This can save much time for emergency handling.

Considering a local region of a city, robots and UAVs are positioned in a local supply station as reinforcement for handling a detected emergency. When an emergency happens, as shown in Fig.3, UAVs can carry robots and fly straight to the scene, while robots on the ground have to find the way and move slowly. As a result, UAVs can react much faster than robots, which is shown in Fig.4. Therefore, it is essential to add the UAV layer to enhance working efficiency of the system.

In this section, a general design of the UAV layer for detecting and handling the emergencies by cooperating with sensor networks and robots is proposed. Then some related problems and possible solutions are discussed to guide the future research to achieve this UAV layer for emergency.

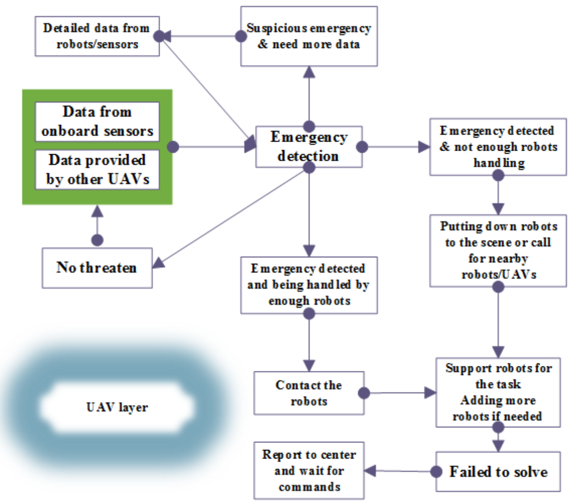

FIGURE 2. The general design of the UAV layer, which shows its procedure of detecting and handling emergencies with the help of other two layers.

A. DESIGN INTRODUCTION

As shown in Fig.2, the proposed system design for the UAV layer mainly includes emergency detection and event handling. In the normal state, the UAVs fly above the city collecting data of the urban areas with onboard sensors. In this procession, the UAVs may also exchange data with the surrounding companions. With the collected data, they analyze it by emergency detecting algorithms. However, as they fly in the sky, the data collected is rough, lacking details of some places. Then the analyzing procession sends its request for data and the UAVs will contact the sensor networks or robots for details.

After the analysis, there are several different conclusions and the system reacts accordingly. In the first case, if an emergency is detected and there are not enough robots involved, the UAV will assist the task by informing nearby robots of the emergency or launching some new robots to the scene for work. Afterwards, it waits above the scene to support the robots by providing data observed from the sky. For instance, when the target tries to flee, the UAV can track it in the sky and command robots to catch it. When the robots call for help, it can also transport more robots for work. When the problem is solved, it returns to the normal state and continue to do the surveillance. However, if they fail to handle the event, the UAV will report the event to the center and wait for the command. In the second case, if an emergency is detected after the analysis but there have been an amount of robots dealing with it, the UAV will contact with the robots and assist them when they require for help. Finally, if no threaten is detected, the UAV continues to do surveillance as planned and collect data in the sky.

B. RELATED PROBLEMS AND TECHNOLOGIES

1) LOCALIZATION

Localization is the basic problem in the system. Most of the layer's functions should be based on the cognition of

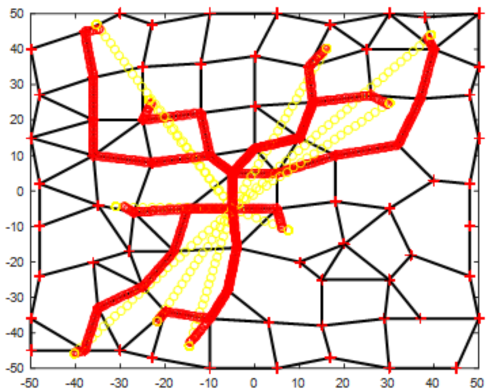

FIGURE 3. The paths of robots and UAVs moving to ten random scenes of events. The yellow lines represent paths of UAVs and the red lines represent paths of robots.

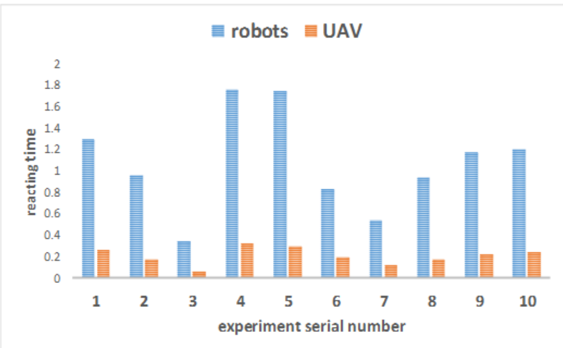

FIGURE 4. The reacting time of UAVs and robots for the ten random emergency scenes.

surrounding environment, which includes its position in the working space and the positions of its target. To accomplish this task, we need a robust localization algorithm with a working scope large enough.

The localization of UAVs is a 3D problem, which is different from the case of robots on the ground. One of the most popular methods for UAV localization is the combination of inertial navigation systems (INS) and global positioning systems (GPS). While INS provides UAV position, velocity and attitude, it has bias errors which accumulate as time increasing. Then GPS can estimate the bias errors and give improved UAV localization [6]. A possible approach for improvement in Urban area is to find some landmarks such as a tower or a sculpture. By referring to them, the UAVs can reduce the localization errors. Another important way is the cooperative localization. By measuring the relative positions of nearby UAVs and communicating the measurements between them, the UAVs can fuse the measurements to obtain an accurate result.

The localization of targets with the onboard sensors is another important problem. With the development of image processing techniques, visual localization has become the most popular method in surveillance applications [7]. In the first step, the target should be found in a visual picture. Then the system should calculate its real position according to its position in the picture. The most challengeable problem in this procession is to develop a robust target detection algorithm. We should let the machine learn the mode of suspicious activities, which needs to be deeply investigated.

2) PATTERN RECOGNITION

To complete the surveillance and event handling task, the UAVs must derive information of interest from the collected data. Pattern recognition is a critical technology for the UAVs to understand the events covered by the video. The UAVs should recognize the potential threatens or ongoing emergencies. Beyond detecting the events, they should also know the progress of them, since the system should handle the emergencies rather than just detect them. For instance, they should know if the events are being handled by robots and if the robots need help. If the events have been handled successfully, the UAVs should perceive it and return to the normal surveillance task. To achieve this, the UAV should recognize robots in the scenarios of the event and contact with them.

Many technologies have been proposed to solve the pattern recognition problem. The classical methods include support vector machines and principal components analysis (PCA). However, the most popular technology for pattern recognition is the neutral network. It enhances the recognition accuracy greatly and replaces the former technologies to become the governor in this area. To solve different pattern recognitions, different neutral network structures are designed. By training on sufficient data sets, the recognition rate can reach a high level.

In this system, the UAVs need to recognize typical emergencies such as abnormal human activities [8], car crashing [9] and fire disaster [10]. Then they should recognize robots below so as to contact with them for information. There are several challenges, including fusion of different recognition, promotion of recognition accuracy and the robustness in bad wether. In the present, neutral network may be a good selection as the basic tool. To do so, it needs to set up proper training set, carefully designed network structure and carefully chosen features. Besides, the fusion of different recognitions into a single system is necessary.

3) SAFETY CONCERN

The UAVs working in urban area have risks of crashing into buildings, which should be considered for safety. In the proposed system, the UAVs fly depending on rotors rather than wings. In this way, they can remain above an area collecting data with promoted stability. In the practical application, precautions have to be taken in case UAVs break down. For instance, there should be emergency power supply. Besides, a safety supervising system should be designed to detect potential problems of UAVs and take actions to help the center to recycle the broken UAVs safely. Before application, the system should be tested sufficiently for dealing with possible dangers.

A critical relative technology is the detection and avoidance of obstacles. For UAVs, the obstacles mainly include high buildings and flying items such as birds or other UAVs. In the system for emergency, UAVs have to fly in a low altitude so as to observe the ground, which enhances their possibility to meet obstacles. This problems can be solved in two aspects. The first one is the optimization of path planning. The planned path should avoid the known possible obstacles, which is effective for static obstacles such as towers. The second one is the dynamic detection of coming up obstacles. The present typical methods include computer vision [11], millimeter wave radar [12], the Global Position System (GPS) [13] and the potential field [14]. No matter what method taken, the goal is to ensure the robustness while reducing the calculation cost.

4) REMAINING CHALLENGES

Apart from the former mentioned problems, some remaining challenges of the UAV system is proposed and discussed in this section.

Communication is a critical part of this system. By exchanging information, UAVs can obtain more detailed data and acquire more accurate detection result. Most of the analysis are based on visual data exchanged between them, in which mobile communication shall be applied. In this process, the delay must be constrained in a reasonable range so that the real-time requirement can be satisfied.

Power supply is a basic problem for nearly all systems. Solar energy, electricity in batteries or fuel oil are all choices for UAVs working in urban areas. While fuel oil can produce sufficient power, the electricity power from batteries or solar energy should replace it for the consideration of environment protection. To ensure a quick supplement of power resources, power stations should be set around the city. In the future development, the combination of solar energy and rechargeable batteries may be a good solution.

Finally, task distribution algorithms should also be proposed. In the procession, UAVs may command a group of robots to work, in which they must convert a task into small ones and distribute them to robots. There are two modes for task assignment. In the first case, the UAV can assign robots with tasks directly. As an alternative, it can broadcast the tasks and wait for suitable robots to accept them.

IV. THE SENSOR LAYER

This layer is mainly used for supervising local areas and assisting nearby robots and UAVs to complete their tasks by providing them with essential information. Based on such functions, there are distributed sensors and a local center for each critical area. The local center can either be a computer or a leading sensor, which detects and tracks emergencies automatically, providing help for robots and UAVs. In this section, the system design are introduced and related problems are discussed.

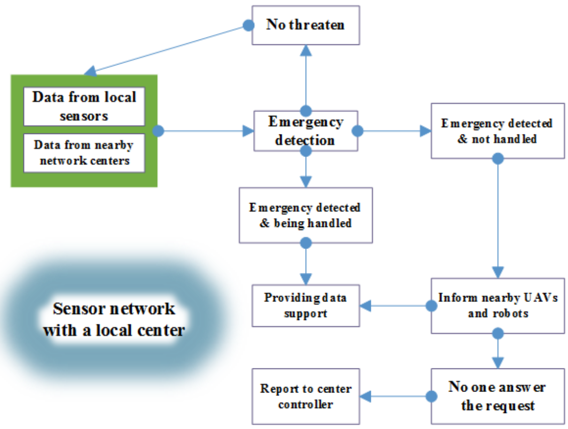

FIGURE 5. The general design of the senor network layer composed of sensors and a local analysis center. The design shows the working mode of the local analysis center based on locally collected data.

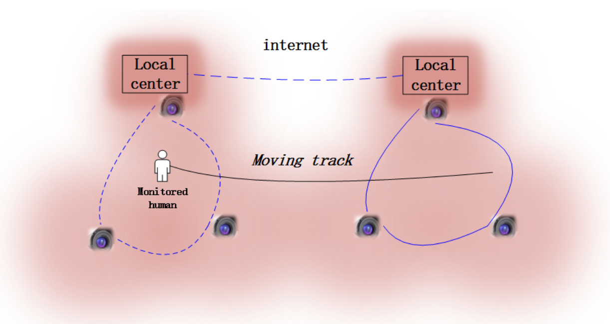

FIGURE 6. The structure of a sensor network supervising and tracking a criminal.

A. DESIGN INTRODUCTION

The working mode of sensor networks is shown in Fig.5. In the normal mode, data of the area is collected by distributed sensors and sent to the local center. Besides, the center can also contact other local centers for data in nearby areas if needed. Based on the real-time updated data, it can detect potential or ongoing emergencies by visual algorithms. If an emergency is detected and it is not being handled, the center will contact nearby UAVs or robots to inform them of the event. Then, it will provide them with data support or guide them. If an emergency is being handled by robots, the local center will contact with them and wait for their request for data. When the target moves fast, the sensor networks can also track it and inform the robots as shown in Fig.6. However, in some remote areas, there may not be robots or UAVs answering the request of the sensor network. In this case, the local center reports the event to the central agent.

B. RELATED PROBLEMS AND TECHNOLOGIES

1) SENSOR DISTRIBUTION

To ensure the efficient supervising of the local areas as well as lower the cost on sensors, strategies of distributing sensors need to be developed, which is an optimization problem. There are different supervising tasks such as criminal activities, water quality [15], pipes and cables. Based on different supervising tasks in different environments, sensors are different and the distribution strategies are not the same. In addition to the specific distribution strategies, the basic theories related to this problem are also worth researching [16].

2) TARGET DETECTING AND TRACKING

In urban areas, the potential emergencies need to be detected by local sensor networks. Then they can inform nearby robots or UAVs to deal with them. Therefore the data analyzing algorithms need to be investigated to detect events with reasonable calculation efficiency. Pattern recognition is the critical technology to solve this problem, which has been discussed in Section III. However, pattern recognition for sensor networks are not the same as for UAVs. Apart from cameras, other sensors are also included in this network such as thermometer. As for visual data, the angle of view is also different, for which the algorithms should be adjusted. Besides, as the data is collected from distributed sensors, the information should be fused and analyzed synthetically [17].

The target such as criminals are always moving across different areas, for which the sensor networks need cooperate to track the target. The tracking is also based on pattern recognition. The network can analyze data to find all cameras with the target occurring and produce the track. For some unsupervised areas, the algorithm to estimate the track and connect the different supervised areas is also a relative researching problem [18].

3) ERROR HANDLING

As sensors are distributed around the city, unreliability is a problem that can not be avoided. When some sensors are broken and provide wrong data, the local center should be able to detect the problem. Then outlier detection is an important part for the analysis of the center. As for the cameras, faults can be detected by analyzing the quality of the video from them. When it comes to other sensors, the data outlier detection algorithms can be applied [19]. Besides, when mixed with possible unreliable data, the algorithms should still be able to detect emergencies. The fault-tolerant data analysis needs to be considered.

V. MULTI-ROBOT LAYER

This layer consists of intelligent robots which handle emergencies and collect detailed data on the ground. Compared with sensor networks, they are more flexible for their mobility. Compared with UAVs, they can practically handle events and collect data with details, for they can be nearer to the target. Besides, the robots can compensate for other two layers by answering their requests. In this section, the working mode design of robots are proposed and related issues of this framework is discussed.

A. DESIGN INTRODUCTION

As shown in fig.8, the main task of robots is to detect emergencies and take actions to handle them. In the procession, they may do surveillance to discover problems or accept requests from UAVs or sensor networks to collect data.

In the first step, based on data from onboard sensors, nearby robots, UAVs and sensor networks, robots make analysis to detect possible threats. If no emergency is discovered, they will move a short distance and continue the former procession. If an emergency is detected and it is being handled by other robots, the robot will judge if they need its help. If the help is not necessary, the robot will move and continue the normal surveillance. If the robot judge the involvement to be necessary, it will start the procession to handle the event. This judging process ensures a reasonable input of robot forces. Apart from the former process, robots can also be informed by UAVs or sensor networks to handle the events.

After get involved in the emergency, the robot should first analyze the event so as to take actions accordingly. The basement is still the data from onboard sensors, nearby robots, UAVs and sensor networks. The robots should recognize the event and their own roles in the cooperative work. Then they should produce the strategies and follow them to solve the problem. However, when the robots can not find the solution or fail to handle the event after taking the actions, they will report it to the center and involved UAVs. Then they wait for further commands to work.

B. RELATED ISSUES

1) COOPERATION ESTABLISH

Once the robots discover the event and get involved, they should set up a cooperation for further actions. The natural mode is choosing a leader to arrange the cooperation. The first robot coming to the scene or the UAV informing the robots can be chosen as the leader. The precondition of this cooperation is building a communication network between robots, which can be accomplished by the leader. It can contact new robots coming up to the scene. Then robots already in the network help to communicate with other robots. In this way, the cooperation system can be built up quickly. Then the leader should analyze the event and assign tasks to robots. Each robots can produce further strategies based on the task and take actions. The assignment should be adjusted dynamically when new robots join.

2) COOPERATIVE FORMATION CONTROL

When robots cooperate to complete tasks, they tend to work in a desired formation for a particular task. For instance, when robots cooperate to transport a large item, they may move in a desired formation to support the item. In addition, when robots cooperate to catch a criminal as shown in Fig.7, they may also move in a formation to drive the criminal to a corner. There are two main problems in this issue. The first one is to abstract some desired formations from different tasks in urban areas. Then for a given the formation, controlling methods

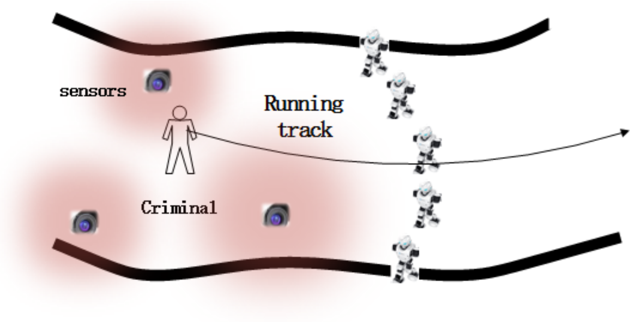

FIGURE 7. A group of robot cooperatively catch a criminal in a formation assisted by sensors on the road.

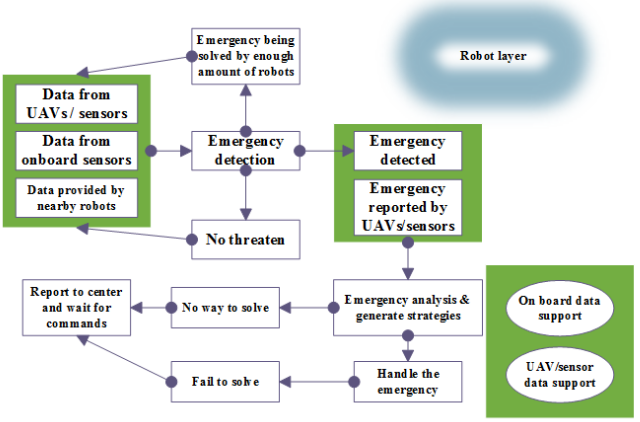

FIGURE 8. The design of the robot layer structure, which shows its procession of detecting emergency and handling the event with the assistance of UAVs and sensors.

to reach the formation should be developed. In this process, the time and resource cost should be reduced and bias error of the final reached formation compared with the desired one should be constrained in a reasonable range [20].

3) MACHINE DECISION-MAKING

To handle the event, robots must have the intelligence to understand the condition and make decisions accordingly. To accomplish it, robots need recognize the environment around them, which is based on target object recognition, texture feature analysis, gesture analysis and sign recognition. After obtaining surrounding environment information, the robot needs a knowledge base system that would determine the appropriate action according to the given task [21]. As the process have to be done in real time, the calculation efficiency of the algorithms should be constrained in a reasonable range.

4) OBSTACLE AVOIDANCE AND NAVIGATION

Robots on the ground moves on roads, where they may frequently encounter obstacles. Simultaneous localization and mapping (SLAM) is the most popular algorithm for robot navigation, which enables robots to build a map of surroundings and locate themselves based on onboard sensors. Given a map and essential location information, the path planning algorithm should calculate an optimal path for robots to follow. However, when encountering obstacles, robots need to deviate from the original path and return as the obstacle has been passed. When there is no road ahead, robots should detect the condition and replan the path. Therefore, algorithms are needed to control this process. The goal is to minimize the deviation while avoiding the obstacles. The process includes obstacle detection, moving strategies for avoiding and mode selection for returning to the path.

For large robots in high speed, there should be hard constraints for them to avoid moving obstacles [22]. Obstacles in dynamic urban areas may be very complex to detect. To solve the problem, one may fuse the data of different sensors to guide the robots with high accuracy [23]. In practical environment, the system is always full of noise and errors. Therefore the robot navigation system must overcome these uncertainties. Specially designed neutral network may help to solve the problem.

5) ROBOT-HUMAN INTERACTION

As mentioned before, robots need to handle emergencies to maintain the normal order of urban areas. In the process, robots may interact with human. Human is typically the target of their tasks or the cooperator of them. Therefore, robot-human interaction mode is a critical challenge, which includes the following aspects. Robots should first understand human by recognizing their speaking, gesture [24], face and identity. Then the reaction strategies for different situations should guide the action of robots. By synthesizing the strategies, there should be a library storing different modes for robots to react to different situations. Furthermore, information model for human to understand the robots should be built [25].

Nowadays, the research on human-robot interaction mainly concentrates on simple actions such as hand shaking. In the future, more complex actions should be completed. Furthermore, the stability of this system need also be improved with less error, which can enhance the working efficiency and protect human workers.

VI. CENTRAL AGENT

To ensure the normal operation of this system, there need to be a center to adjust the whole system, which is controlled by human. The system for emergency works automatically in normal time. When systematic problems occur, people can control the system through the center. In addition, data collected from the urban areas is analyzed here. Then the result guides people to adjust working mode of the system, such as the distribution of patrolling robots around the city. Furthermore, when unsolved troubles are reported to the center, human can make a plan and give commands to the robots and UAVs or send some people to help. Besides, human can also assign tasks to the system from the center.

In this section, a general design of the central agent is proposed and some related issues are discussed (See in Fig. 9).

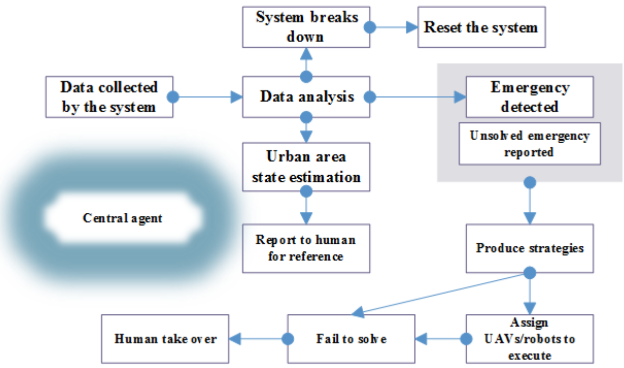

FIGURE 9. The design of the central agent structure, which shows its procession of detecting emergency and handling the event.

A. DESIGN INTRODUCTION

Data of UAVs, sensors and robots is gathered by the central agent through network. Based on the data, the central agent can supervise the working condition of the whole system. If serious errors occur and the system is not working properly, the center can reset the system. In addition, based on big data analysis, the central agent can estimate the state of urban area. This can be provided for human as reference to adjust the system working mode.

If emergencies are detected or some unsolved emergencies are reported, the center will start to make decisions to handle them. In this case, the center tends to detect serious emergencies occurring in a large range, for its data range is far wider than a single UAV, robot or local sensor network. Then if the system proposes a solution, it would send commands to UAVs and robots to execute the plan. If the problems are not solved, human will take over the work. Besides, human will also set in the work directly when the system do not propose a workable plan.

B. RELATED ISSUES

1) BIG DATA

Data analysis of urban area requires algorithms to deal with a huge amount of data. We need to find information of interest and guide the system to work. Given information of interest, the huge data should be dealt with to find the relative results with acceptable cost on calculation, which includes several critical problems. Algorithms need first organize the huge amount of data. The organization should save the memory while ensure convenience of data analysis. Then there should be data mining theories guiding the process of finding results of great importance [26], [27]. In general, given problems of interest, the big data algorithms should quickly pick out the relevant data and find the relative results by data mining theories.

2) CLOUD ROBOTICS FRAMEWORK

In the smart system for emergency, the central agent should support a cloud robotics system. In this system, robots and automation systems may rely on data or code from a network to support their operation, where not all sensing, computation and memory are integrated into a stand-alone system [28].

To build such a cloud robotics system, several problems need to be solved. To enhance the working quality, the cloud should provide robots with large data sources that is not possible to maintain in the memory of robots. Then cloud computing is also an important service provided by the center. It should provide access to powerful remote processors for short time computing tasks. Furthermore, the system should provide a framework for robots to collectively learn. When human want to perform a remote operation, the center should also provide such a mode.

3) SYSTEM SECURITY

Security is the most important problem for this smart system. In the practical world, a hacker may attack the system to perform damage work. The robots, UAVs and sensors are connected in a network. If the network is controlled by the hackers, the residents may be in a dangerous status. In the first case, hackers may send commands to robots or UAVs, informing them to do damaging work. To prevent this, the system should encrypt the commands so that hackers can not send commands recognized by robots. In the second case, hackers may also pose damaging data flow in the network to scramble the system. Then outlier detection should be applied to dig out the damages. Finally, if the system is captured, people should be able to shut it down for emergency.

VII. CONCLUSION

In this paper, we proposed a structure of the smart city system for emergency. The structure is composed of three cooperative working layers and a controlling center. Compared with the former proposed structures, we added the UAV layer, which is more flexible with a wider range of movement and data collection. Furthermore, we introduced the coordination between different layers for detecting and handling emergencies. For each part of the system, a layer working mode design was proposed and related problems were discussed. Challenges were given and some possible proposals are provided. The smart system structure for emergency can provide a reference for the future research to construct such a system.

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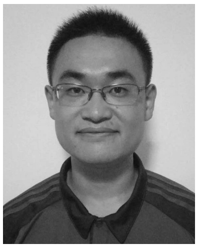

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