Recruiting Crowd Cameras

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***Abstract*—This paper was originally submitted to Xinova as a response to a Request for Invention (RFI) on new event monitoring methods. In this paper, a method to select/recruit attendees who will participate in the surveillance is proposed.**

In more detail, a surveillance camera emits RF signal in direction of its field of view. The other camera determines whether it is in the Line of Sight (LoS) of the surveillance camera or not. Also, the other camera determines its facing direction in relation to the facing direction of the surveillance camera. Based on the determination, cameras which will become new surveillance cameras are decided.

I. Problems

SURVEILLANCE cameras are installed in many locations, but it is not enough to cover whole areas, not only because of lack of the numbers of cameras, but also because of blind spots generated by the occlusion by other objects in the area. In some cases, it may be desired to facilitate event attendees' collaboration. However, how to select collaborators among crowds would be an important issue.

II. Summary of the Invention

The proposed method is about how to select/recruit attendees who will participate in the surveillance.

A surveillance camera emits RF signal in direction of its field of view. The other camera determines whether it is in the Line of Sight (LoS) of the surveillance camera or not. Also, the other camera determines its facing direction in relation to the facing direction of the surveillance camera.

Based on the determination, cameras which will become new surveillance cameras are decided.

III. How is This Invention Made and Used

Figure 1 shows an example that a surveillance camera is installed at a location. In this example, there is no major obstacle so every object in the area can be properly monitored.

However, it is possible that there is an object which makes occlusion so the other objects in the area may not be monitored by the camera. In other words, the blind spot is generated by an object (obstacle). (See Fig. 2.)

The proposed method is about how to select/recruit attendees who will participate in the surveillance.

In the proposed method, the surveillance camera emits RF signals. It is preferred to emit the signal in direction of its field of view, as using any beamforming methods (Fig. 3). Optionally, the RF signal contains its direction information, signal strength, or etc.

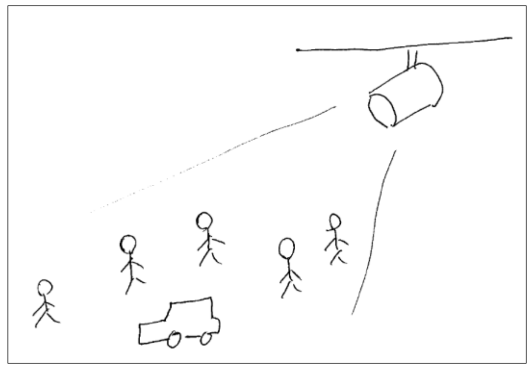

Fig. 1. A surveillance camera with clear vision

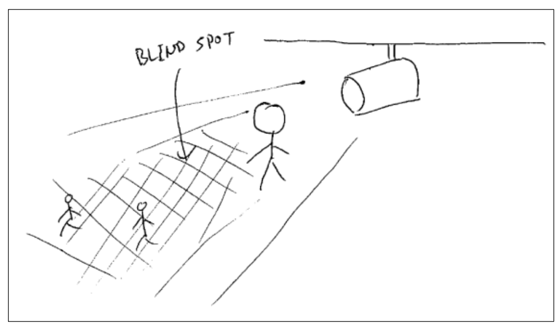

Fig. 2. Blind spot by an obstacle

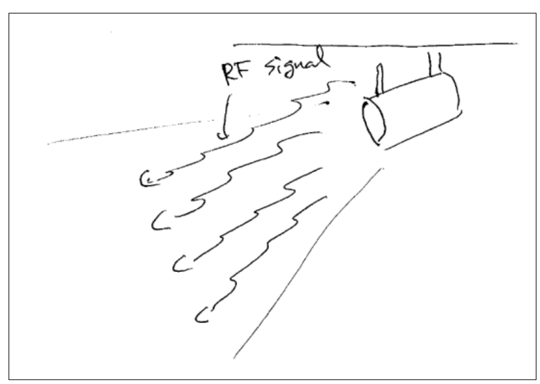

Fig. 3. Camera emits RF signals in direction of its field of view

In this case, we can easily determine whether an object (or a candidate camera to join the surveillance system) is in LoS or not as analysing the received RF signal by the object. In Figure 4, a person (in the left side of the figure) is occluded by the other person (obstacle), so one's mobile device (which has camera) may receive attenuated RF signal because of the obstacle. The attenuation can be easily determined if the

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receiver knows the transmission strength. The transmission strength can be previously decided, or be included in the RF signal, and etc. Or, we can use any kind of LoS detection methods.

Let's call those cameras which are determined as not in LoS, or in NLoS (Non Line of sight), as cameras in blind spot.

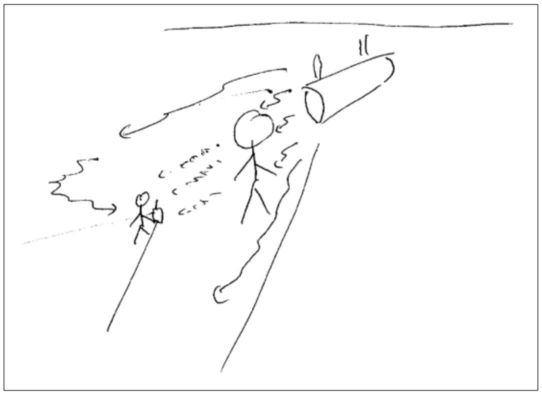


Fig. 4. Object is occluded by the other object / camera faces same direction with existing camera

For the cameras in blind spot, determine the facing direction of those. It can be done simply by analysing the orientation of the devices based on 6-axis sensors, and etc.

Also, the facing direction of the surveillance camera is determined. It can be done by analysing the beam pattern, or alternatively, from the RF signal if it contains the direction information.

Then, compare the direction of the cameras in blind spot with the direction of the surveillance camera. If the directions are aligned (as in Fig. 4), the camera in blind spot is recruited as a new surveillance camera. Then, the surveillance system can have vision which was blind spot before the new surveillance camera is recruited.

Alternatively, rather than selecting cameras which are facing the same direction with the surveillance camera, it is possible to select a camera, among the cameras in blind spot, and instruct the owner of the selected camera to set the direction of the camera as same with the direction of the surveillance camera.

In above, we describe the proposed method to overcome the blind spot generated by the obstructive objects. However, we may need to recruit cameras even though there is no blind spot generated. Let's take an example as depicted in Fig. 5. In the figure, a person (in the left side of the figure) is in LoS. However, the person's device is facing a different direction with the direction of the surveillance camera. In this case, recruiting that device can provide a new field of view to the surveillance system.

However, it is possible that there are more than two existing cameras, and even though the user's device is not aligned with the one of the existing camera, it could be aligned with the other existing camera, and then the necessity of the user device may be degraded. (See Fig. 6.)

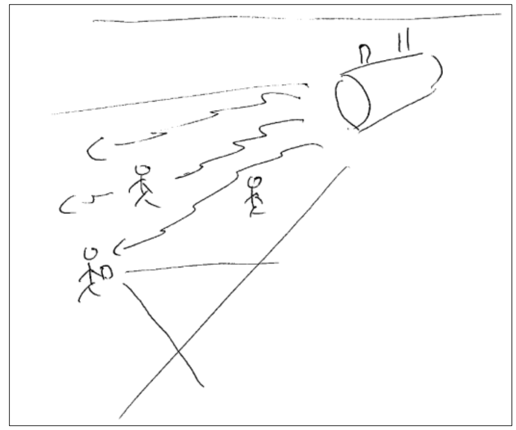


Fig. 5. Camera faces different direction with existing camera

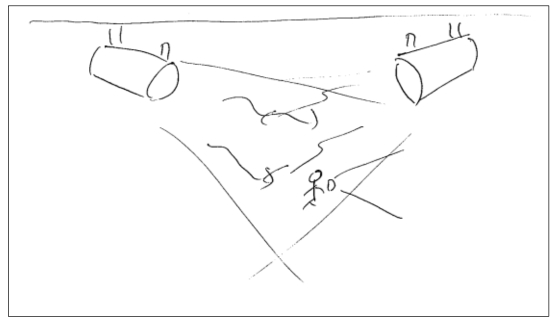


Fig. 6. Camera faces different direction with existing camera

IV. More Detailed Explanation

A. Entities/Elements of the Proposed Method

The proposed method is consisting of:

- Main Cameras
- Surveillance System (or System)
- End-users' devices (including cameras)

B. Main Cameras - Surveillance Cameras in Operation

In above, we described that "a surveillance camera is installed at a location". However, the proposed method is not limited for the case where there exist(s) (a) pre-installed surveillance camera(s).

For example, the security managing entity may fly a number of drones with cameras to monitor a region. In such case, there would be a blind spot when there is/are (an) object(s) between the drone camera and the region to be monitored. The proposed method can be applied in such cases also.

To easier explanation, let's call the surveillance cameras installed or temporally operated by the security managing entity as "main cameras".

C. Location information of Main Cameras

As described above, main cameras would be: 1) pre-installed cameras, or 2) temporally deployed cameras. Also, the temporally deployed cameras may move when they monitor/record a region. (Of course, if a camera is pre-installed on a rail, it may move during it operates.)

In any cases, we can assume that the main cameras and surveillance system easily know main cameras' positions/ locations.

The end-users' devices may know the locations of the pre-installed main cameras, as the locations are stored in DB of the System, and the devices pre-download the locations from the System. However, the devices may not know the locations of the temporally deployed main cameras in some cases.

D. How It Works

1) User's Opt-in the Service

As the proposed method requires end-users' voluntary participation to provide the video images, the end-user needs to opts in the service. The user may receive benefits in return.

Also, a government may set a rule to use/wiretap the end-user's device in case of national disaster.

2) User device pre-loads the location information

As described earlier, the locations of main cameras may be known beforehand. In this case, the user device may pre-load the information. It is possible that the device may download the info on the specific region when the device approaches/enters that region, to manage its storage more efficiently.

However, the user device may not have entire information of the main cameras' locations beforehand. (e.g., moving temporal main cameras)

3) Main camera emits RF signal

A main camera emits RF signal in direction of its field of view while it records/monitors a region.

The RF signal may contain information which would be helpful for an end-user's device to detect whether it is in LoS of the main camera or not.

For example, the information may contain: location of the main camera, facing direction of the main camera, field of view of the main camera, strength of the RF signal, and etc.

If location info of the main camera is included in the RF signal, the user device can know the main camera's location in real-time even though the main camera is moving one.

4) User device determines LoS

User device receives the RF signal from the main camera, and determine whether it is in LoS or not based on the received RF signal.

To determine LoS, the information contained in the RF signal may be used.

It may report its LoS/NLoS to the System.

When reporting, it may further report its (or user's) ID, its device info (camera type, resolution, etc.), its location (including height/elevation), its (or user's) context information, remaining battery, communication capacity and etc.

Here, context information may include: what the user is doing with the device, how long the user may be in the region, which direction the user is from/is moving to and etc.

5) How to select the device / input video

Let's call a device which is selected / recruited and used as a surveillance camera as "Sub Camera".

Different operation modes are possible:

a) Every device which is in NLoS becomes sub cameras.

b) User (or device) in NLoS devices determine whether to become sub cameras or not.

c) System determines which devices in NLoS become sub cameras based on the reports from the devices, and giving instructions to the devices to become sub cameras.

In a) and b) cases, the System may discard some input from some sub cameras, and may release them, or instruct them to operate in different way (e.g., change direction, etc.), based on the image/video inputs from the sub cameras.

In b), user device may consider its ability/capacity/context for the determination. E.g., if its dynamic range control in night is very poor, it may not become a sub camera. Also, if the user needs to leave the place, it may not become. If its communication capacity is poor (e.g., the user uses AT&T, and the cellular capacity of AT&T in that region is far below than the other operators), it may not become. If its position is far from the obstacle, and may not provide a large FOV, it may not become.

Also, in b), user device may communicate nearby devices which previously opted-in via device-to-device, machine-to-machine, near field communication protocols, and determines which ones become sub cameras. For example, if three devices are in proximity of each other, we may need only one device to become a sub camera. In this case, three devices may communicate with each other to exchange the information, and then decide who will be the sub camera. The information to be exchanged may be similar the information to be reported to the system as in c).

In c), the system may consider the devices' ability/capacity/context and also the track records of the user/device to select sub cameras. For example, the system may perform user profiling, so may know which user provides better image/video in terms of reducing blind spot. For example, User A and User B are in blind spot together, and assume all the other conditions (location, ability, capacity, context, etc.) are very similar. User A's profile says that image/video quality is highest, but often strays from the required spot, and User B's profile says that image/video quality is just ok, but always points out the required spot. In this case, the System may select User B, rather than User A.

There would be many aspects on user profiling, including concentration level on blind spot, responsive to control instruction, consistency and etc.

6) *How to work as a sub camera*

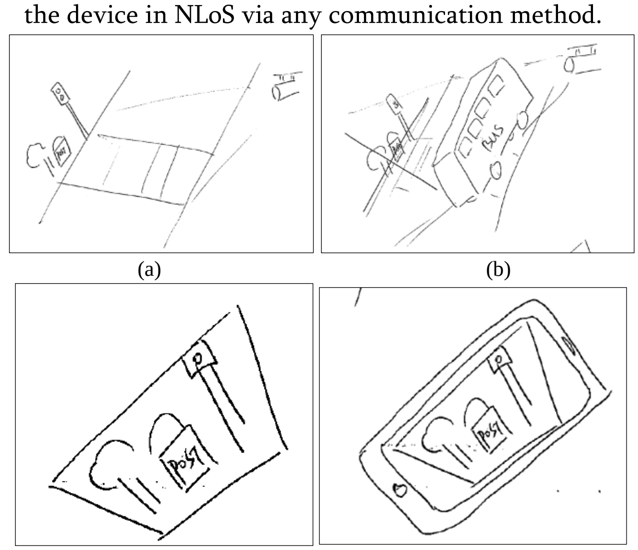
Once a device starts to work as a sub camera, it should contain the scene which is not available to the main camera.

In one embodiment, the device may already know where the main cameras are, and can determine which direction it should face, based on the location of the main cameras and location of itself.

Also, the RF signal from the main camera may contain the location information/direction information of the main camera, and the device can determine which direction it should face.

Once the device knows in which direction it should face, it may give instruction to the user, as beeping or vibrating the device. For example, it may sound "to left" "higher", or when the facing direction is changing, beeping or vibrating to give alarms to the user.

Also, once the main camera has a blind spot, it or the system may find out where is the blind spot, they may generate the desired image of the blind spot. One way of generation is to crop where the blind spot is from the previous image, in which the blind spot doesn't exist. For example, Figure 7 (a) shows a case there is no blind spot, and 7 (b) shows a Bus generates a blind spot to a tree, a post box and a signal light. In such case, the system generates an image as Figure 7 (c), and provides the image to the device. Then the device may overlay the image on the camera input so the user can easily face the spot. In one embodiment, the RF signal may contain this image, or the main camera or the system may transmit to the device in NLoS via any communication method.



(a) (b) (c) (d)

Fig. 7. Generate a guide image

7) When to release the sub camera

There are basically four cases when the sub camera is released.

a) The System doesn't need it.

b) The user needs to leave the place

c) Change the sub camera

d) Obstacle is removed

We already partially described the case a). If the system doesn't need the input from a certain sub camera – it may be due to poor image quality of the sub camera, or there are enough inputs so the sub camera is not required.

Also, if the user needs to leave the place, it may be known beforehand based on the user's context information – schedule, etc., so the system may prepare the other sub camera. Or, the user suddenly moves to a direction and then becomes in LoS. In this case, the user device reports it is now in LoS, and then the system releases the device.

The other case is that, for example, the device provides image/video for 10 minutes as a sub camera, and then, a new device, which is also capable of becoming a sub camera, enters the region. Then, to evenly occupy the resource of each user / device, the system may change to use the new one as sub camera, and release the one which has worked for 10 minutes. For this purpose, not only a new comer, but an existing one in the region may be selected.

Lastly, as the obstacle may be a temporal one, it can disappear. In such case, devices which were in NLoS become in LoS, and then report to the system that their status changes. Then they are released. However, in some cases, the even though the obstacles are temporal ones, they may continuously appear. Considering the bus stop case, buses come and go, so remain semi-permanent obstacles during bus operation hours. As described, devices may report when they are in NLoS, so the system may know when/which areas have semi-permanent obstacles. For this case, the system may not release sub cameras even though the obstacle disappears, as the system knows that the other similar obstacles will be there pretty soon.

8) Additional aspects

The single image/video from a single device may not be enough sometimes, so the system may collect more than one image/video from more than one devices for a given time slot, and then merge the images/videos to overcome the blind spot.

There will be "always on" devices, which would be: head-mounted camera (including smart glasses), body-worn camera, and etc. This kind of property could be used when selecting devices. As they are always on devices, they may have higher chances to be selected.

Also, one required aspects would be, not to intrude the user's way of using the device. For example, one may not be inconvenience to run the mobile phone as the sub camera when s/he reads an article from web browsing. However, one may have hard time to type something during one's phone is used as the sub camera. So, user's way of using the device would be also considered (as user context) when the system selects the devices. E.g., the devices which are doing web browsing may have higher chance than the devices which are used to write an e-mail, and the devices which are in pockets or in bags.

When there are multiple main cameras, it is possible that a device is in NLoS of more than one main camera. In this case, when the system needs to determine which one would become a sub camera, it may apply additional criteria, as the number of sub cameras in each main camera, or the completeness of overcome blind spot of each main camera, as using the other criteria described above. For example, based on the characteristic of the device (including its location) and also the user profiling, it may predict how much blind spot of each main camera is covered by the device.

V. CONCLUSION

As summarization, the proposed method is about how to select/recruit cameras of event attendees to overcome the blind spot generated by an obstacle ("artificial blind spot"), and also to overcome the blind spot which is out of field of view of the surveillance camera ("natural blind spot").

In the proposed method, the surveillance camera emits RF signal (or perform other LoS detection method). A device, which receives the RF signal, determines whether it is in LoS or not, and also determines the direction of the surveillance camera. Based on the determination, it becomes a new surveillance camera (and optionally gives instructions to the owner of the device).

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