Testing Environment for Developing a Wireless Networking System based on Image-assisted Routing for Sports Applications

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Abstract: To improve the effectiveness of exercise a novel vital sensing system is under development. For real-time sensing of vital signs by a wireless network during exercise, image-assisted routing that enables dynamic routing of a multi-hop network according to sensor locations estimated by visual information. To develop the novel networking system, testing environment that enables runtime verification of dynamic routing based on image processing. Experimental results actual sensor nodes with AR markers showed that locations of sensor nodes obtained using a USB camera could be appropriately given to the control software of base station to manage routing information.

1 INTRODUCTION

To improve the effectiveness of exercise and prevent sudden illness, a novel vital sensing system is currently under development(Hara et al., 2017). Figure 1 illustrates the collection of vital signs via a multihop wireless network. For the real-time sensing of human vitals by a wireless network during exercise, the most significant challenge is the localization of sensor nodes. This is owing to the inadequate operations of conventional routing schemes based on the received signal-strength indicator (RSSI) or global positioning system (GPS). To address this challenge, image-assisted routing (IAR), which localizes sensor nodes using visual information, was proposed(Miyamoto and Oki, 2016). In IAR, vision-based human detection and tracking processes are applied to obtain the location of humans wearing sensor nodes.

The vision-based localization of humans wearing sensor nodes for vital monitoring comprises human detection and tracking. For the detection process, an exhaustive search based on sliding windows

Figure 1: Collecting vital signs via a multi-hop wireless network.

is adopted. Because accurate detection can be executed(Oki et al., 2019b), its processing speed can be improved, provided parallel processing is adopted, using specialized hardware and a graphics processing unit (Oki and Miyamoto, 2017). Once accurate detection results are obtained by a detector, a simple tracking scheme (Yokokawa et al., 2017) that correlates detection results over several frames of input images can

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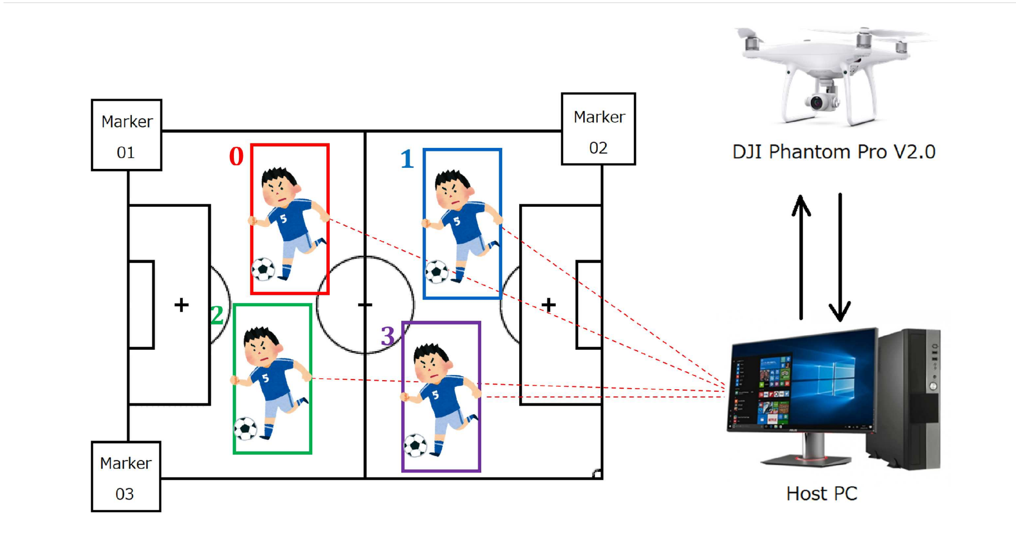


Figure 2: System overview.

be optimally adopted in this application. Fundamental technologies for wireless networking have also been developed to actualize the real-time vital sensing of humans during exercise(Hara et al., 2020; Hamagami et al., 2020).

As described above, elementary technologies that are indispensable for IAR have been successfully developed. However, to develop the definitive system for IAR that combines image-based localization and wireless multi-hop networking, it is necessary to verify the operational efficiency of dynamic routing based on sensor locations estimated using visual information. Accordingly, this study proposes a novel testing environment that enables the verification of dynamic routing for multi-hop networking using locations of sensor nodes estimated by visual information.

The System organization of this definitive system is presented in Figure 2, where the video sequence obtained from a drone flying in a sports field is utilized to localize humans wearing sensor nodes based on computer vision technologies. However, it is impractical to use a flying drone for the integration test, where the algorithm and implementation of dynamic routing based on image-based localization should be verified.

To actualize an efficient system that supports the development of a novel sensor networking system, a testing environment that includes the vision-based localization of sensor nodes without drones is required, as well as a wireless networking system identical to the definitive system. In the testing environment, an AR marker is attached to a sensor node, and its location is determined using a USB camera. Estimated locations are provided to the control software of the base station that handles the routing information of the sensor nodes. Via this approach, it is possible to develop an algorithm and a system for novel wireless networking systems.

2 RELATED WORK

This section explains the concept of IAR, as well as the indispensable computer vision technologies required for IAR actualization: visual human detection and tracking.

2.1 Concept of Image-assisted Routing

In image-assisted routing (IAR), dynamic routing in multi-hop networking is performed using the locations of sensor nodes estimated by computer vision technologies, using a video sequence obtained by a flying drone; however, conventional wireless multi-hop systems control multi-hop networking using RSSI and/or GPS. In addition, although the sensor node presented in Figure 3 can sense RSSI and estimate location using the GPS, IAR is implemented to improve the robustness of multi-hop networking under several conditions that may occur in sports scenes.

2.2 Visual Human Detection

The primary purpose of IAR is to actualize real-time vital sensing of humans during exercise, where the locations of sensor nodes are estimated as the locations of the humans wearing them. Here, a sensor

Figure 3: Sensor nodes for real-time vital sensing during exercises.

Figure 4: Attaching a sensor node to a human doing exercise.

node is attached, as illustrated in Figure 4. The challenge of localizing target humans in an image can be addressed by adopting visual object detectors widely used in several computer vision applications. The YOLO series (Redmon and Farhadi, 2017; Redmon and Farhadi, 2018), RetinaNet (Lin et al., 2017), and EfficientDet (Tan et al., 2020) are advanced schemes based on deep neural networks, with excellent performance in detecting target objects from an image.

In addition, a traditional detection scheme comprising handcrafted features and boosting also exhibits adequate accuracy for human detection in sports scenes (Oki et al., 2019b; Oki et al., 2019a) because humans should be easier detected from background images than generic cases.

We adopt informed-filters, which are one of the most accurate schemes for human detection among the schemes with handcrafted features. This scheme achieves both accurate detection and fast processing by feature design, according to the average edge map obtained from training samples, as illustrated in Figures 5 and 6. The processing speed of this scheme can

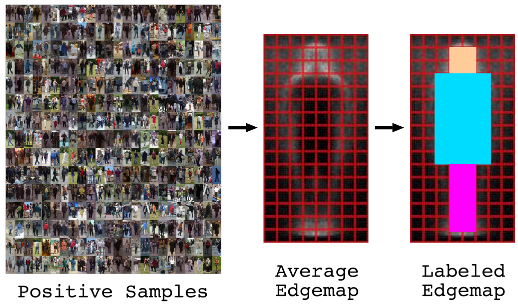


Figure 5: Edgemap generation.

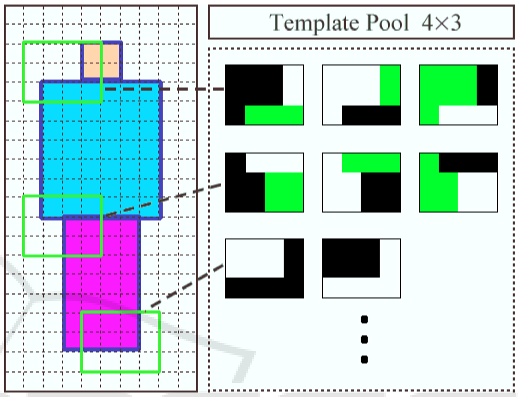


Figure 6: Template generation.

be improved with the parallel application of a GPU and an FPGA. The aforementioned advantages of this scheme are suitable for the real-time processing of IAR in sports scenes.

2.3 Visual Human Tracking to Estimate a Target's ID

Accurate human detection from sports scenes can be realized by utilizing a detector constructed with informed-filters. However, IAR requires human identification when several humans need to be monitored by the proposed vital sensing system. Although several approaches can be applied to the identification of target humans, tracking over several frames of input images is applied for this purpose in the proposed scheme. This task is called visual target tracking or visual object tracking in the field of computer vision, where the family of Kalman and particle filters play a significant role. KCF(Henriques et al., 2015), which does not utilizes time-series filters, instead of image correspondence over frames, has recently garnered remarkable attention.

Several approaches have been proposed for this task; however, we have selected a simpler approach because relatively accurate detection results can be

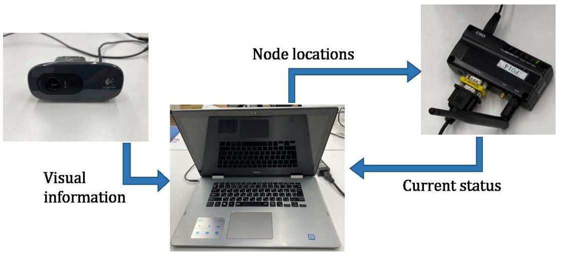


Figure 7: Overview of the proposed testing environment.

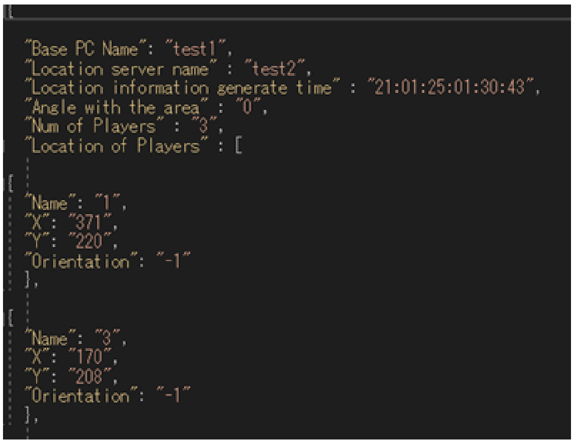
obtained by a detector in the sports scenes that we tested (Oki et al., 2019a). This simple approach solely associates detection results in the current frame with those of previous frames. Remarkably, this approach exhibited optimal accuracy, and became effective in some test scenes with the application of error correction based on color information (Aoki et al., 2020). Tracking-based identification is beneficial when all IDs obtained via the detection and tracking processes are assigned to the IDs of the sensor nodes used in wireless networking. The correct assignment of IDs can be obtained when the target humans line up according to the IDs of the sensor nodes attached to them before starting vital sensing during exercises.

3 TESTING ENVIRONMENT FOR DEVELOPING A WIRELESS-NETWORKING SYSTEM BASED ON IMAGE-ASSITED ROUTING FOR SPORTS APPLICATIONS

This section proposes a testing environment for multihop wireless networking based on IAR, where the location of sensor nodes is estimated via visual information.

3.1 Overview of the Testing Environment

Figure 7 presents an overview of the proposed testing environment. In this testing system, the locations of sensor nodes with AR markers are determined in real time using a video sequence captured from a USB camera, and they are sent to the control software of a base station at runtime. This real-time localization mechanism of sensor nodes using input images enables the development and verification of a dynamic routing system based on IAR.



"Base PC Name": "test1",
"Location server name" : "test2",
"Location information generate time" : "21:01:25:01:30:43",
"Angle with the area" : "0",
"Num of Players" : "3",
"Location of Players" : [
{
"Name": "1",
"X": "371",
"Y": "220",
"Orientation": "-1"
},
{
"Name": "3",
"X": "170",
"Y": "208",
"Orientation": "-1"
},

Figure 8: Example of a JSON file that contains locations of sensor nodes estimated by a USB camera.

3.2 AR Marker Detection

In an actual system based on IAR, the locations of sensor nodes are estimated via human detection and tracking using a video sequence obtained by a camera mounted on a drone. However, it is expensive to verify the networking system based on IAR using a video sequence captured by a drone, because several target humans in the sports field where a drone can fly become indispensable. Therefore, a more compact system is required to verify the basic functions of IAR, especially in terms of the dynamic update of routing information according to the results of the localization based on image processing. Accordingly, we decided to attach an AR maker to a sensor node and provide locations of sensor nodes to control the software of a base station that manages the dynamic routing of sensor nodes.

To verify the basic functions of the wireless networking based on IAR, AR markers are attached to sensor nodes, which can be accurately obtained using image sequences provided by a USB camera. To generate and detect AR markers, the ArUco marker (J.Romero-Ramirez et al., 2018; Garrido-Jurado et al., 2016) used in the OpenCV library was adopted. This library can drastically reduce the implementation cost of AR marker detectors.

3.3 System Implementation

JSON file is adopted as the interface to control the software of the base station. The locations of the sensor nodes are written to a JSON file, and the control software of the base station reads the node locations from the file. Figure 8 presents an example of a JSON file that contains node locations obtained via image processing. The dynamic update of routing information becomes feasible when the control software of the base station reads the current locations of the sensor nodes after their updates. In actual cases, the current locations of sensor nodes are determined by human detection and tracking using a video sequence obtained from a camera mounted on a drone.

To verify the combined application of the image-based localization and dynamic update of routing information using the control software, a software interface for localizing sensor nodes using AR markers to the control software is designed to be identical to the actual one. This implementation does not require any modification to the control software; instead, it solely requires the implementation of the localization based on AR markers with an identical interface. Via the organization of this testing environment, the effective development of the novel sensor networking algorithm and system becomes feasible.

4 EVALUATION

This section evaluates the proposed testing environment according to the following procedures:

1. Identical ID assignment of sensor nodes in the control software and image-based localization,
2. Manual movement of sensor nodes, and
3. Update of sensor locations in the control software, according to the movement.

To assign an identical ID to a sensor node in the control software of the base station and the localization software using AR markers, the ID assignment procedure of the control software that assigns a new ID to a sensor node when it is switched on, as well as the sensor nodes, are switched on according to the ID of the AR markers attached to them. Accordingly, the same ID in the control software and image processing were assigned to a sensor node.

After activating all the sensor nodes, a sensor node was moved, as illustrated in Figures 9,10, and 11. In these images, the AR markers corresponding to all the sensor nodes were accurately detected. Accordingly, appropriate locations and IDs were obtained. The update rate of the base station's control software was significantly less than the frame rate of the USB camera. Hence, the control software updated the locations of the sensor nodes after a while, because the actual movement of the sensor node had finished. Figure 12 illustrates how the locations of the sensor nodes were updated according to the movement of the sensor node. These results indicate that the locations of sensor nodes determined by a USB camera can be appropriately assigned to the control software

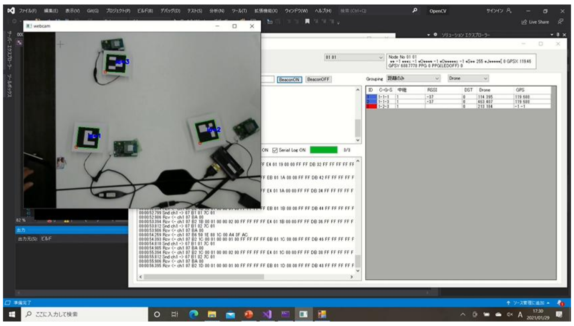


Figure 9: Before moving.

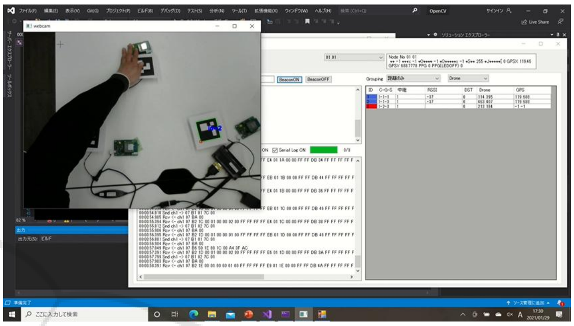


Figure 10: While moving.

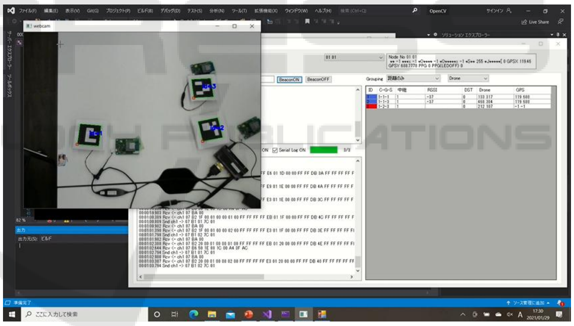


Figure 11: After moving.

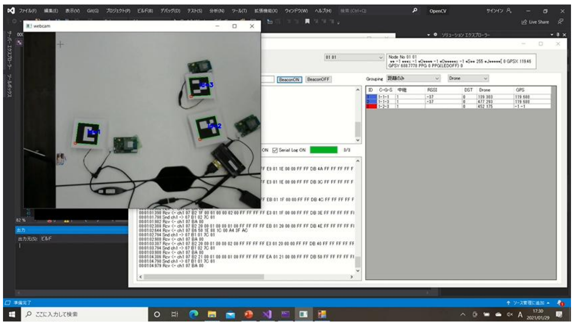


Figure 12: After update of locations.

of the base station to manage the routing information of the sensor nodes. It is evident that the proposed testing environment enables the algorithm design and system development of dynamic routing based on the sensor locations determined by visual information at runtime.

5 CONCLUSION

This study proposes a novel testing environment for developing a novel vital sensing system based on the IAR of humans during exercises in an outdoor sports field. The key technology for the vital sensing system is the dynamic routing of wireless networking among sensor nodes based on their locations estimated by computer vision technologies. However, it is difficult to verify the functions of the networking system using actual video sequences of several people performing exercises on the outdoor sports field captured by a camera mounted on a flying drone at runtime; In addition, the development of this approach is too expensive. To address this challenge, a compact but effective system was developed to verify the combined application of a control and localization software based on image processing. The proposed system adopts AR markers to determine the locations and IDs of sensor nodes and provide locations of sensor nodes to the control software in real time. The experimental results of actual sensor nodes with AR markers indicate that the locations of sensor nodes obtained using a USB camera could be appropriately assigned to the control software of the base station to manage routing information.

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REFERENCES

Aoki, R., Oki, T., and Miyamoto, R. (2020). Accuracy improvement of human tracking in aerial images using error correction based on color information. In *Proceedings of the 9th International Conference on Software and Computer Applications, ICSCA 2020, Langkawi, Malaysia, February 18-21, 2020*, pages 124–128. ACM.

Garrido-Jurado, S., Salinas, R. M., Madrid-Cuevas, F., and Medina-Carnicer, R. (2016). Generation of fiducial marker dictionaries using mixed integer linear programming. *Pattern Recognition*, 51:481–491.

Hamagami, T., Hara, S., Kawamoto, Y., Yomo, H., Miyamoto, R., and Okuhata, H. (2020). Summary of experimental results on accurate wireless sensing system for a group of exercisers spread in an outdoor ground. In *14th International Symposium on Medical Information Communication Technology, ISMICT 2020, Nara, Japan, May 20-22, 2020*, pages 1–4. IEEE.

Hara, S., Hamagami, T., Kawamoto, Y., Yomo, H., Miyamoto, R., and Okuhata, H. (2020). An adaptive superframe change in a wireless vital sensor network for a group of outdoor exercisers. In *92nd IEEE Vehicular Technology Conference, VTC Fall 2020, Victoria, BC, Canada, November 18 - December 16, 2020*, pages 1–6. IEEE.

Hara, S., Yomo, H., Miyamoto, R., Kawamoto, Y., Okuhata, H., Kawabata, T., and Nakamura, H. (2017). Challenges in Real-Time Vital Signs Monitoring for Persons during Exercises. *International Journal of Wireless Information Networks*, 24:91–108.

Henriques, J. F., Caseiro, R., Martins, P., and Batista, J. (2015). High-speed tracking with kernelized correlation filters. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 37:583–596.

J.Romero-Ramirez, F., Muñoz-Salinas, R., and Medina-Carnicer, R. (2018). Speeded up detection of squared fiducial markers. *Image and Vision Computing*, 76:38–47.

Lin, T.-Y., Goyal, P., Girshick, R., He, K., and Dollár, P. (2017). Focal loss for dense object detection. In *Proc. IEEE Int. Conf. Comput. Vis.*, pages 2980–2988.

Miyamoto, R. and Oki, T. (2016). Soccer Player Detection with Only Color Features Selected Using Informed Haar-like Features. In *Advanced Concepts for Intelligent Vision Systems*, volume 10016 of *Lecture Notes in Computer Science*, pages 238–249.

Oki, T., Aoki, R., Kobayashi, S., Miyamoto, R., Yomo, H., and Hara, S. (2019a). Vision-based detection of humans on the ground from actual aerial images by informed filters using only color features. In *Proc. International Conference on Sport Sciences Research and Technology Support*, pages 84–89. ScitePress.

Oki, T. and Miyamoto, R. (2017). Efficient GPU implementation of informed-filters for fast computation. In *Image and Video Technology*, pages 302–313.

Oki, T., Miyamoto, R., Yomo, H., and Hara, S. (2019b). Detection accuracy of soccer players in aerial images captured from several viewpoints. *Journal of Functional Morphology and Kinesiology*, 4(1).

Redmon, J. and Farhadi, A. (2017). YOLO9000: better, faster, stronger. In *Proc. IEEE Conf. Comput. Vis. Pattern Recognit.*, pages 6517–6525.

Redmon, J. and Farhadi, A. (2018). Yolov3: An incremental improvement. *CoRR*, abs/1804.02767.

Tan, M., Pang, R., and Le, Q. V. (2020). Efficientdet: Scalable and efficient object detection. In *Proc. IEEE Conf. Comput. Vis. Pattern Recognit.*

Yokokawa, H., Oki, T., and Miyamoto, R. (2017). Feasibility study of a simple tracking scheme for multiple objects based on target motions. In *Proc. International Workshop on Smart Info-Media Systems in Asia*, pages 293–298.