Outdoor Long Range Low Latency Ubiquitous Projectiles Tracking System Using LoRa and Computer Vision

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***Abstract*—There has been a growing body of research that explores low-latency target tracking and detection. Shotmarker, a previous study, proved that predicting a shooting point is possible. However, there were limitations in using various types of tools and it was costly. The aim of this research is to propose a model that tracks a shot point with high accuracy and low latency when shooting at a long range without constraints by applying LoRa, Computer Vision and sound detection. This system starts with a default photo taken by the camera next to the target. Whenever the acoustic sensor beside the camera detects a projectile, the camera takes a new visualization and the Raspberry Pi next to the target operates to calculate the coordinate by comparing it with the previous image. This research is cost-effective in terms of time and convenience. In addition, the proposed research is adequate for the military intelligence training system.**

***Index Terms*—LoRa, Computer Vision, Sound detection**

I. Introduction

Shooting is a developing sport all over the world. Given in a 2017 report by the Small Arms Survey, a Geneva-based organization, there were approximately 120.5 firearms per 100 residents. This concludes that there are more firearms owned than the number of residents [1]. National Rifle Association elaborates "The NRA sanctions over 11,000 shooting tournaments and sponsors over 50 national championships each year." This organization provides various shooting-related activities for all ages, including firearm target training. As much as shooting targets became a popular sport, it is extremely important in the Armed Forces of the United States. The United States military takes range training seriously, however checking the targets is still inconvenient. The method of verifying their target is walking down range leaving a mark on the first target round, to see the difference in the second target round. It is especially notable that the proposed research assists to overcome this shortage.

Shotmarker is a program designed for the F-class shooting competition, which is conducted from 300 to 1,000 yards only using the prone position [2]. This system has several complications, first, it depends on environmental factors such as wind and rain. The average error in an ideal state is within 2-3mm, but an error rate can be higher when the weather is not at its best for shooting. Secondly, this system is dedicated to a specific type of gun, a gun that uses a supersonic bullet. Namely, if the gun does not use a supersonic bullet, Shotmarker is dysfunctional.

This paper presents a new approach to the projectile mark-detecting system. The proposed system shows high accuracy without any environmental constraints by using LoRa, Computer Vision and sound detection. Similar to Shotmarker, this system uses LoRa networks to facilitate long-range attacks. However, transmitting large data using LoRa takes a while due to low power. The proposed research captures an image at the beginning once to have a set image, then in the continuous stage, the coordinates are transmitted and displayed into the set image.

The sound detection system that is used in the proposed module can be utilized in everyday life. ShotSpotter is used to detect gunshots in cities such as New York and Chicago, however, it has a low accuracy issue [3]. In effect, around 50,000 alerts for probable gunshots have been notified with only 9.1% resulting in evidence of a gun-related offense. Unlike ShotSpotter, the proposed system starts only when a gunshot sound is detected. Therefore, the gunshot detection module that derives high accuracy is developed by this research. LoRa is the fastest-growing technology that researchers are interested in these days, the benefits of LoRa are long battery life, long-distance communication, and low cost of the application [4]. However, LoRa is not the best outdoors because there are chances of having packet loss utilizing LoRa due to various environmental factors. Then, this research goes deep into the Multi-Packet LoRa(MPLR) algorithm to ensure that transferring data is successful. With these strengths, the proposed system has the potential to be utilized in military intelligence training systems.

II. Relative Work and Motivation

The proposed research is composed of three main technologies: LoRa, Computer Vision and Sound detection.

Andreea developed an electronic archery scoring system using the calculation of the difference between a previous and current image with two cameras [5]. Zin et al. have performed not only background subtraction but also applied the frame difference between the current frame and the two immediate frames so that they can discriminate between the present and previous arrows [6]. Compared to [5], the factor of importance to consider is the choice of thresholds for image segmentation. They applied dynamic thresholding after the binarization of the images. These thresholds are obtained by using the Otsu method for image segmentation. There are a total of two threshold values used, thus, the combination of color-based background modeling, gray-level frame differences and dynamic thresholding lead to accurate targets and arrow detection.

Park et al. were incapable of handling the image accurately in an outdoor test because of environmental factors such as shadow [7]. The proposed paper utilizes Water-Filling Algorithm to overcome this problem [8]. Compared to [7] the difference is that the proposed research is conducted outdoors, however, it can be applied considering the background of the image captured by the Raspberry Pi camera is removed. This algorithm has a time complexity that is proportional to image size, hence it is hard to apply to real-time applications. As a consequence, the proposed paper utilizes the Water-Filling Algorithm after image compression.

[7] focuses on the target using YOLO V5; the gunshot is determined when a change in the target is detected. Although the camera continuously focuses on the target, there is a difficulty of detecting the gunshot with various backgrounds. In contrast to [7], the proposed system alerts when the shooting sound is detected, then searches for the new projectile.

As shown in [9], there is a case of sound classification using the Convolutional Neural Networks (CNN) method by converting sound data into spectrograms. Similar to this study, the CNN model that the proposed research handles is not too deep, for that reason, it requires less training. The previous study derives about 86.7% accuracy when 10 categories of classification tests are conducted with the Urbansound8K dataset. This test uses 3 fully connected layers that affect the number of parameters and complexity of calculation. On the other hand, the proposed research reduces the complexity of calculation by decreasing the number of fully connected layers. On top of that, the proposed research conducts binary classification, unlike the previous research conducting various classifications.

Chen et al. presented a Multi-Packet LoRa(MPLR) that provides effective recovery when packet loss occurs during image transmission using LoRa [10]. The image transmission time of LoRa is determined by the following: spreading factor(SF), bandwidth(BW), coding rate(CR) and image size. The transmission process speeds up when the SF is low, BW is high, CR is resulting in 1, and lastly when the image is small. For example, when an image is transmitted by using MPLR with these specific conditions: SF 7, BF 500, CR 4/5 and 9KB image size; the transmission time resulted in 4.92 seconds without any packet loss. Along with the same condition, when 2% packet loss occurs MPLR provides a fast recovery of 0.17 seconds totaling in 5.09 seconds to recover the packet loss as well.

The proposed paper overcomes limitations and argues for a new system that includes three main novelties: (1) cost-effective, (2) long-range outdoor, and (3) unlimited types of projectiles. This system emancipates inconvenient settings. Additionally, in terms of power, it starts only when the shooting sound is detected, so it is said to (1). LoRa has advantages in long-range communications, and this system controls the shadow for accurate image analysis, namely, it has the advantage of (2). Lastly, (3) is superior to previous research because this research works without any limitation of types of projectiles such as bullets and arrows.

III. Proposed system

IV. Implementation

V. Conclusion

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