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Design of a Wireless Scoring System for Fencing Using RFID Technology

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Abstract. This paper focuses on the implementation of a wireless scoring system using RFID technology. It also contains the objectives and significance of carrying out the study. Existing electronic and wireless scoring system are presented to develop comparison with our own scoring system. Discussion on how the prototype functions are also included in this paper. The functionality and performance of the final prototype were shown through results obtained after testing. Conclusions and future directives are stated at the latter part of the paper.

Keywords: active RFID tag, fencing, scoring systems, wireless

1. Introduction

Fencing is a fast and athletic sport which involves two fencers in a battle or combat called assault. Scoring of the game used to rely on judges and referees in order to determine valid hits between fencers. At present, semi-automated electronic scoring systems use wires to interconnect each part of the fencer's clothing and the scoring machine. However, certain problems have been encountered with the implementation of this electronic scoring machine. Some problems include the registration of glancing hits in foil, "whip-over" in saber, and registration of two simultaneous hits in the scoring box. Incidents where valid touches fail to register in the scoring machine and fencers feeling shocks have also been reported [01].

To address these problems, we developed a wireless scoring system dedicated for foil and saber fencing utilizing RFID components. Although RFID is more popularly associated with applications requiring asset tracking and identification, its security features which include tree-walking algorithm, randomized hash lock method, selective blocking, and data synchronization make it reliable even with the presence of different frequencies [02]. These features make it attractive for application in this sport.

Part of the objectives of this study is to develop a prototype which includes the following:

- Transmitters that will send valid hits and touches
- A reader that will receive the signal sent by the transmitters
- A score box that will keep the score of the fencing match
- Signal lights that will indicate which fencer scored
- Foil and saber sword, lame, mask
- Actuators that will trigger the transmitters to transmit valid hits

The paper is organized as follows. Section 2 discusses the existing scoring systems for fencing including both electronic and wireless systems. Section 3 describes the system architecture of the wireless scoring systems. It includes the system block diagrams with appropriate descriptions of each block. The prototype operation is included in Section 4 with discussion on how valid hits are made in both foil and saber fencing. The different tests that were carried out to determine the functionality of the design project is discussed in Section 5. Summary and future directives are included in Section 6 of this paper. Sections 7 and 8 are reserved for acknowledgement and references, respectively.

2. Existing Scoring Systems for Fencing

In fencing, there are considerations to count a hit as a score. First consideration involves the proper

attack which is either a cutting or thrusting attack. And second, the sword must land on the valid target area. The type of attack and valid target area for fencing varies with the type of sword used. For foil sword, points are scored with the tip of the blade and must land within the torso of the body. For epee, touches are scored only with the point of the blade, with the entire body as the valid target area. On the other hand, the saber sword is used as both cutting and thrusting weapon. The target area is from the bend of the hips (both front and back), to the top of the head, simulating the cavalry rider on a horse [03].

There are existing scoring systems that facilitates in a fencing match. The most common and widely used is the electronic scoring system. There are also wireless scoring systems that are now being utilized in international competitions.

2.1. Electronic scoring system [04]

The conventional electronic scoring system is a single large circuit whose main component is the scoring machine which runs through a series of reels, piste cables, body wires and weapons.

The scoring machine employs solid-state technology which makes them smaller and less vulnerable to damage. The actual voltage by the machine is only 12 V but it is made in such a way that it can use the ordinarily available voltage (240 V). The machine has a scoring display compose of lamps that aids the referees in scoring. Older scoring machines are equipped with a ground circuit protecting the fencers from electrical shocks. However, modern machines are already designed with double-insulation and other internal protections to avoid any incident of electrical shocks.

2.2. Wireless scoring system

Previous attempts were made to develop a wireless scoring system for fencing. One wireless scoring system was developed by a group of engineering students at Simon Fraser University in British Columbia [05]. The scoring system was designed for epee matches. The wireless system still uses the traditional wire that runs from the sword to the fencer's clothing but the pulley system was removed. The system uses radio type circuits as opposed to the conventional reels and piste cables. When a hit is made, a button on the end of an epee sword is depressed, completing a circuit. Full circuit sends a signal to a small transmitter at the back of the scoring competitor. The judge's box receives this signal causing a light and a buzzer to turn on confirming the hit.

Another design uses simple "buzz boxes" having compact battery-powered devices that signal touches with a light or a buzzer. But these devices, which are available from various sources, have limited functionality. They cannot distinguish between targets, or distinguish the timing of hits, and do not work with saber at all [06].

Another wireless scoring system for fencing that we have encountered involves the use of touch detector unit that is worn by each fencer. The touch detector operates by providing signal indications of fencing touches or hits which uniquely identify each fencer and which signify valid and invalid hits. The hits can be wirelessly transmitted to receiving apparatus coupled to the scoreboard or other scoring equipment [07].

3. System Architecture

Figure 4.1 The modules are attached in a belt using Velcro straps. The wires from the modules run to the body of the fencer to his sword and vest.

The system architecture of our wireless scoring system is primarily made up of the transceiver and

voltage-controlled oscillator (VCO) modules and the host computer. Each fencer is assigned with transceiver and receiver modules. Figure 4.1 illustrates how the prototype is worn by the fencer. The system block diagrams for foil fencing and for saber are shown in Figures 4.2 and 4.3, respectively.

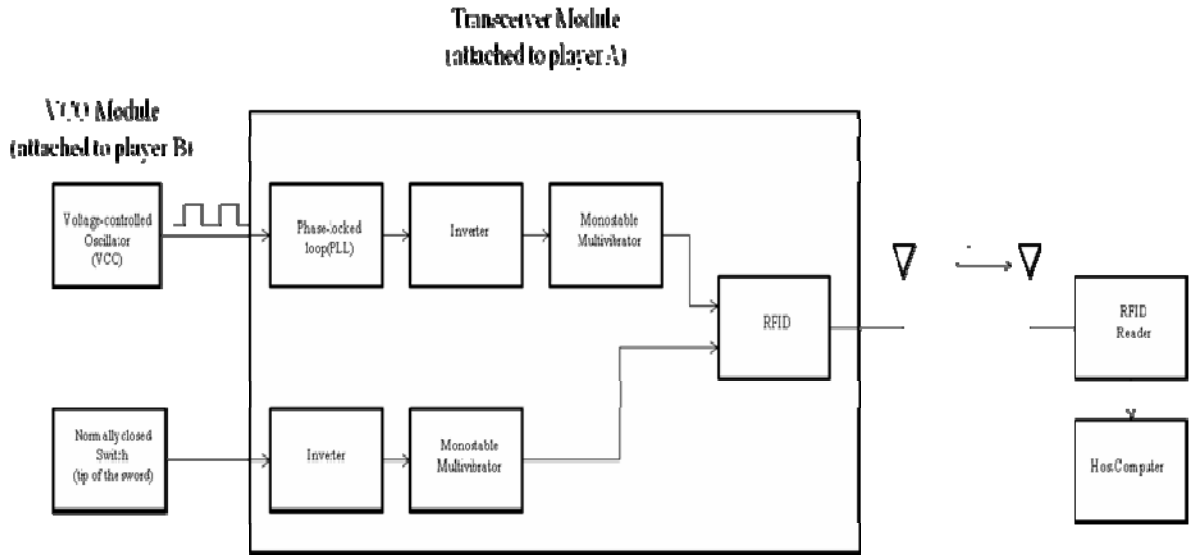

Figure 4.2 Functional Block Diagram for the Wireless Scoring System for Foil Fencing

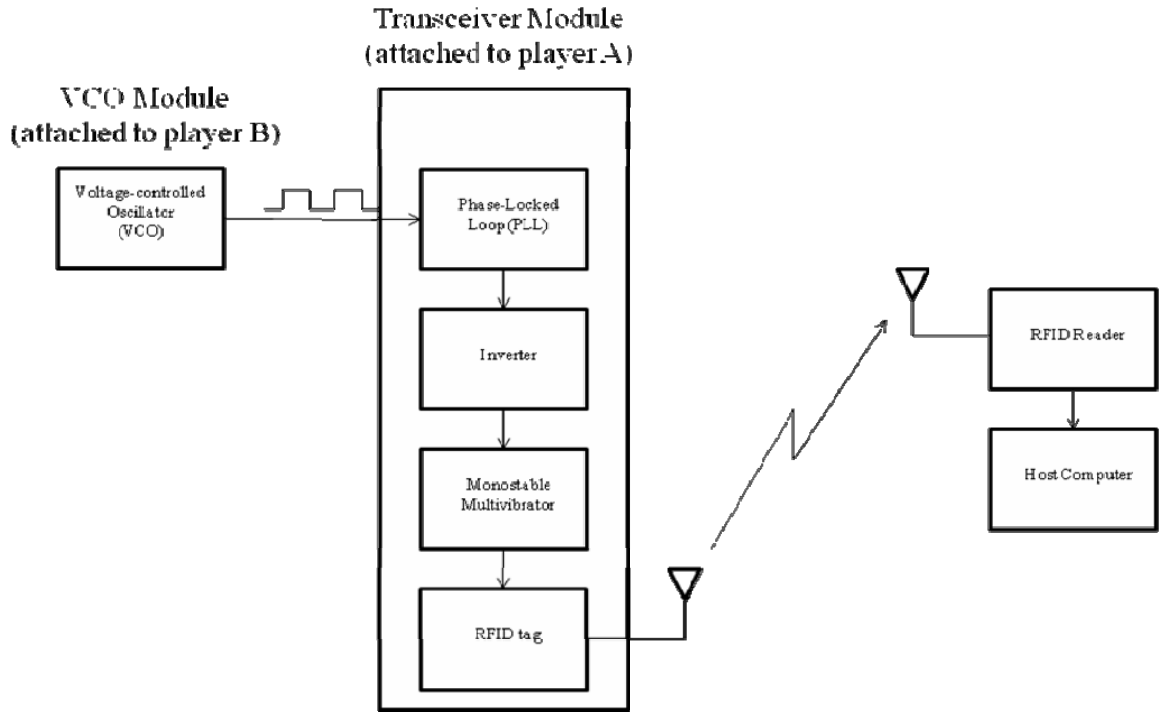

Figure 4.3 Functional Block Diagram for the Wireless Scoring System for Saber Fencing

3.1. Transceiver module

The transceiver module is composed of various electronic circuits namely the phase-locked loop (PLL), inverter IC, and the monostable multivibrator. An active RFID tag was added to send the signals wirelessly to the RFID reader. In addition, a buzzer that will signal that a hit is made was added in the final prototype.

The phase-locked loop (PLL) is the receiver of the transceiver module. Its main function is to capture the VCO output frequency when the sword touched the opponent's vest. The PLL was made from CD4046 IC.

The inverter reverses the output of the PLL from logic "1" to logic "0" to trigger the monostable circuit. We used 74LS04 IC to construct the inverter circuit. Next to the inverter is the monostable multivibrator stage which lengthens the single pulse it receives from the inverter IC. Once triggered, it actuates the active

RFID tag for transmission. At the same time, the output of the monostable multivibrator causes a buzzer to sound, alerting the fencers that a hit is made.

For foil fencing, additional inverter and monostable multivibrator circuits were connected to the normally closed switch at the tip of the foil sword. The final prototype of the transmitter module is shown in Figure 4.4.

Figure 4.4 Transmitter module

3.2. VCO module

The voltage-controlled oscillator (VCO) module provides an output frequency that can only be captured by a designated phase-locked loop (PLL) receiver. The PLL normally detects the VCO output frequency, when the sword made contact with the vest. The circuit for VCO uses CD4046 IC as well. Figure 4.5 shows the final prototype for the VCO module.

Figure 4.5 VCO modules produced for the wireless scoring system

3.3. Host computer

The host computer serves as the score box during a fencing match. It houses the program developed by the researchers for this design project. The program was developed using the Microsoft Visual Studio platform. Signals from the active RFID tags are registered to the program via the RFID reader connected to the host computer via the Universal Serial Bus (USB) port.

4. Prototype operation

We placed an active RFID tag at the back of each fencer. These served as the transmitters of signal whenever a hit is made. Aside from the normally closed switch on the tip of the foil sword, two circuits, namely, voltage-controlled oscillator (VCO) and phase-locked loop (PLL) were added in designing the wireless scoring system. This circuit transmits a frequency that can be received by the phase-locked loop connected to the sword of the fencer. The capture range of the phase-locked loop is tuned such that it can only receive the specific frequency transmitted by the VCO.

For the purpose of this design, we created two VCOs, each assigned with its own frequency. There were also two PLLs, the capture range of each was tuned to one of the VCO frequencies. The same VCOs and PLLs were utilized for saber fencing.

We also utilized an RFID tag reader to act as a receiver of the signals sent out by the active RFID tags. It

is connected to a personal computer via the Universal Serial Bus (USB) port. The personal computer serves as the score box for this scoring system. We designed a program that will keep the score for a fencing match. Signal lights and sound alarms to alerts referees, judges, fencers and spectators that a hit was made.

4.1. Making a valid hit in foil

To declare that a hit is valid, two signals must be received by the RFID reader. As shown in Figure 4.2, the first signal results when a contact is established between the foil sword of the fencer and the vest of his opponent. When the contact is made, the output frequency of the VCO will be detected by the PLL. Upon detection, the PLL outputs a particular voltage that enters an inverter IC. In turn, the inverter IC triggers a monostable multivibrator circuit which is responsible in actuating the RFID tag.

The second signal results when the switch at the tip of the foil sword is pressed. Once pressed, this switch provides a single pulse to the inverter IC. The inverter IC triggers the monostable multivibrator circuit. The monostable multivibrator, which is connected to one of the input pins of the RFID tag, lengthens this single pulse to facilitate the RFID tag in detecting this signal. This circuit also triggers the sound alarm to halt the match.

A program designed for this scoring system, will perform an "AND" operation of these signals to consider that the hit is valid. Absence of one of these signals will make the signal invalid.

4.2. Making a valid hit in saber

For saber, only the VCO and PLL circuits are used to validate a hit. The process is the same as in the foil fencing but instead of attaching a piece of metal on the sword, the whole saber sword is used as the antenna for the PLL circuit. As shown in Figure 4.3, once a contact between a fencer's sword and his opponent's vest (either by thrust or point attack) is made, the output frequency of the VCO serves as the input signal for the PLL. When the PLL detects this frequency, it produces a certain voltage which enters an inverter IC. Then the inverter IC triggers a monostable multivibrator circuit, which in turn, sounds the buzzer to stop the fight. It also enables the RFID tag transmit a signal to the tag reader. The program made for the scoring system will then consider this hit as valid and then a score will be awarded to the fencer who made the hit.

5. Testing and Results

After the construction of the prototype, we performed different tests to examine the performance, functionality and response of the whole system including the program, the signal lights and the sound alarms.

Three different tests were carried for the prototype. We performed the first test to determine the capacity of the project to identify valid hits in foil fencing. For this testing, a hit is valid if it satisfies both conditions:

- The tip of the fencer's foil sword touches his opponent's vest. This condition shows that the phase-locked loop detects the voltage-controlled oscillator
- The button at the tip of the foil sword is depressed.
- The second test that we performed tests the capacity of the prototype to identify invalid hits in foil. For this test, an invalid hit in foil fencing follows one of these conditions:
- The metal at the tip of the fencer's foil sword does not touch the vest of the opponent and the switch is depressed on any part of the body except on the target area for foil.
- The metal at the tip of the fencer's foil sword touches the vest of the opponent but the switch is not depressed.

Satisfying one of these conditions will merit an invalid hit because the program created for this thesis needs two signals to consider a valid hit. If only one signal registers in the program, then the program will declare an invalid hit.

The third test that we carried out tests the performance of the project in identifying valid hits in saber. A valid hit in saber occurs when the fencer's sword touches the opponent's vest.

After performing these tests, the results showed that the wireless scoring system was able to identify valid and invalid hits in foil, and valid hits in saber. The buzzer and signal lights were also functional. As shown in Figure 5.1, the graphic-user interface (GUI) registered a score when a valid hit was made. On the other hand, the GUI did not register a score when an invalid hit was made (refer to Figure 5.2).

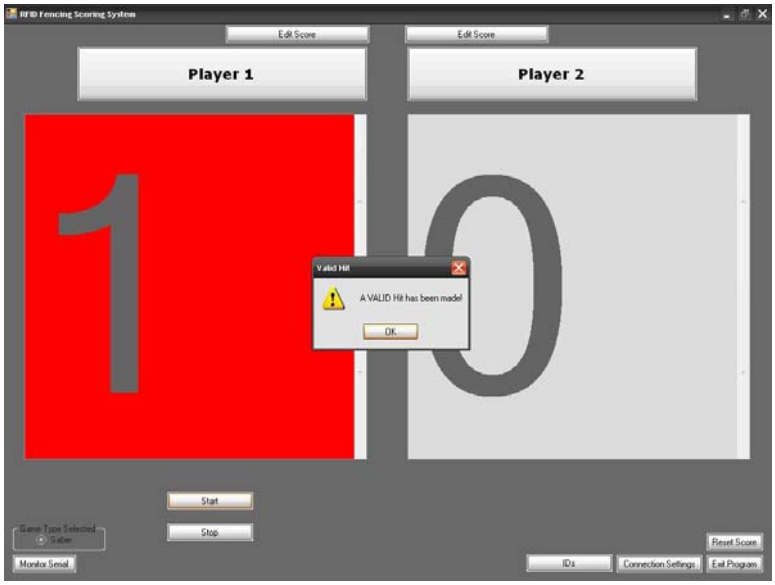

Figure 5.1 The GUI registers a valid hit in saber

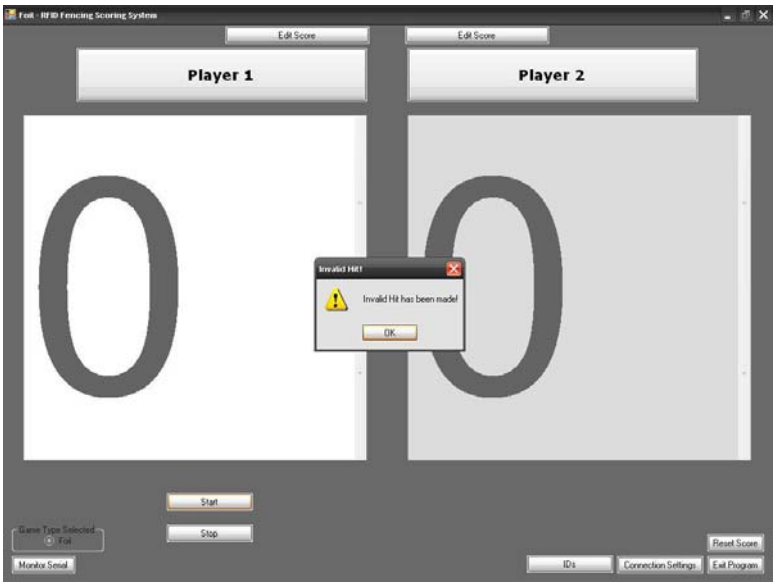

Figure 5.2 The GUI registers an invalid hit in foil

6. Summary

The results obtained after carrying out the tests show that we were able to design and implement a wireless scoring system for saber and foil fencing utilizing Radio Frequency Identification (RFID) technology. Although the results shown are those for one of the frequencies used, these clearly show that development of such wireless scoring system is feasible and functional. In addition, we were also able to produce a final prototype that is wearable and does not obstruct fencers' movements during a fencing match. We were also able to meet the objectives set before the beginning of the design project.

The following are the list of our recommendations for the improvement and development of our design project.

- We recommend the use of other oscillator circuits aside from the voltage-controlled oscillator (VCO) that we used in this project. As the voltage input changes, the output frequency of the VCO changes as well. This disables the phase-locked loop (PLL) from capturing the output frequency of the VCO. The use of other oscillator circuits may also entail the utilization of other receiver circuits aside from the phase-locked loop.
- Aside from oscillator circuits, sensors such as metal detectors can also be considered as actuators of the RFID tags.

- Since the RFID tags introduced a time delay during transmission, we recommend trying out other brands of RFID tags and components that has faster response and lower transmission delay.

7. Acknowledgements

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