Night Ultimate Frisbee

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***Abstract*— Ultimate Frisbee is a sport that is ubiquitous on college campuses and is starting to gain traction as a semi-professional sport as well. This proposal demonstrates the necessity for a system comprised of an illuminated disc and a set of illuminated wristbands which can communicate with each other through the use of radio frequency identification (RFID) to enable the game of Ultimate Frisbee to be played at night. This proposal details the different aspects of the system as well as the steps required to complete the design, execution and fabrication of the Night Ultimate Frisbee system.**

I. Introduction

Ultimate Frisbee is a sport of a relatively simple design, with many aspects akin to other sports such as football, soccer and rugby. Ultimate Frisbee utilizes a disc as the single required component. While Ultimate Frisbee, a sport played outdoors, is almost always played during the day, Ultimate Frisbee at night is also becoming increasingly popular.

To be able to play at night, multiple requirements exist for both the players and the disc. The players must have an illumination system that identifies them as a member of one of the two teams on the field. The disc must also be illuminated so that players can identify the location of the disc to catch or block it.

In Ultimate Frisbee, it is easy to identify the team who has control of the game disc during the day by identifying the predominant direction that the disc is traveling and identifying the player who is either throwing the disc or the last person to throw the disc when it is in the air. At night it can be extremely difficult to identify the person who has control of the disc or who last threw it, as the illumination system, often a wristband glow stick, can be difficult to see, especially if a member of the defensive team is actively guarding the offensive player with the disc. A disc which can change color to identify the team currently in possession is therefore necessary.

Currently, the discs used for Night Ultimate Frisbee have a series of light emitting elements which often produce a constantly changing pattern of colors or produce multiple colors concurrently as shown in Fig. 1. These discs are not designed for Ultimate Frisbee but instead are designed for casual Frisbee at night when the color pattern is not as distracting as it is during a game. The disc used for Night Ultimate Frisbee must then display a solid color and only change that color when prompted.

Thus a complete Night Ultimate Frisbee system is necessary to make the game as enjoyable, competitive, and playable at night as it is during the day. To accomplish this, the disc needs to be able to identify each of the players so as to be able to identify the team which currently has possession of the disc and emit that team's colored light. This can be done through the use of Radio Frequency Identification (RFID).

The use of this system would be limited to recreational games, as in official games players are not permitted to have any jewelry or clothing that could interfere with play or other players. The wristbands would be considered as articles of clothing that could interfere. The disc to be created for the Night Ultimate Frisbee system would also not match regulations as it will most likely be over the regulation limit of 175 grams and the excess material that would enable the system will change the shape of the disc from regulation as well. This system is meant for use in competitive games at night.

II. Background

Background on the principle aspects used in the development of a Night Ultimate Frisbee system

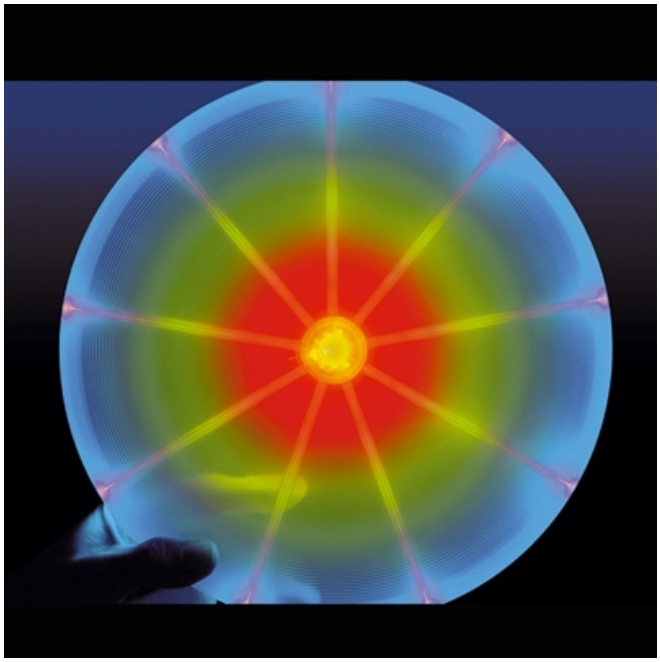

Fig. 1: A multi-colored light-up Frisbee disc for use at night [1].

including the Frisbee, 3-dimensional (3D) printing, RFID, and Arduino.

A. *Frisbee Disc*

The origin of the Frisbee disc lies in pie tins. The Frisbie Pie Company sold pies and cookies. Students at Yale University took the pie tins and cookie tins and threw them back and forth, putting spin on the tins to enable them to stay balanced and remain airborne for a time. A man named Walter Morrison took this idea and created the Pluto Platter, a disc design that was later bought by the company Wham-O. Wham-O redesigned the disc and, after an executive heard students at Harvard call out "Frisbie" when they caught the disc, named the new disc "Frisbee", as he did not know the proper spelling. All discs used in Ultimate Frisbee are either Frisbee discs or discs based off of the original Frisbee design [2].

In competitive Ultimate Frisbee, a 175 gram disc is used. While a football or soccer field is usually used as the field for Ultimate Frisbee, a regulation field is 70 yards long by 40 yards wide with 25 yard end zones as shown in Fig. 2. There are two teams comprised of seven members apiece. The two teams start out at their respective end zones and one team pulls the disc to the other.

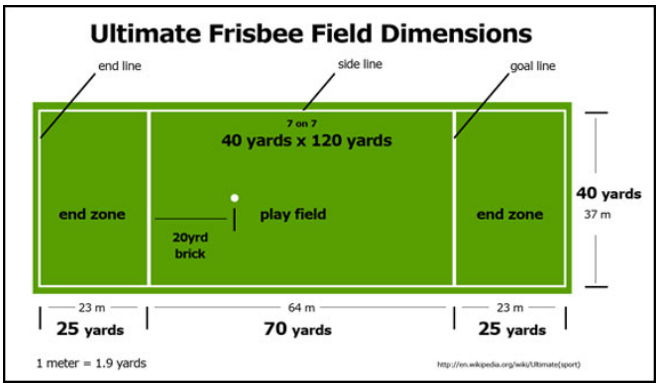

Fig. 2: The setup of a regulation Ultimate Frisbee field. The field of play is 70 yards long and 40 yards wide, with end zones of 25 yards [5].

The team which received the disc then attempts to pass the disc among the players on the team while moving the disc toward the other team's end zone with the goal of catching the disc in the end zone. The other team, which is on defense, tries to disrupt the passes and either knock the disc to the ground or catch it themselves. If the defensive team successfully disrupts the disc before a member of the offensive team catches the disc in the end zone, then there is a turn over. In this case the defensive team becomes the offensive team and tries to catch the disc in the other end zone [3].

B. *RFID*

Radio Frequency Identification (RFID) allows for basic identification of devices. An RFID tag will carry data and will send that data out when applicable. An RFID reader will access the data which the RFID provides. The basic RFID communication scheme is shown in Fig. 3. There are multiple different types of RFID tags. Below are the five main types of tags [4]:

1) Low Frequency tags
2) High Frequency tags
3) Ultra-High Frequency tags
4) Battery Assisted tags
5) Active tags

Low frequency, high frequency and ultra-high frequency tags are all passive tags. This means that they do not supply their own power. Instead they use the electro-magnetic field supplied by the reader. This requires the reader to be in close proximity to the tags in order to access the data

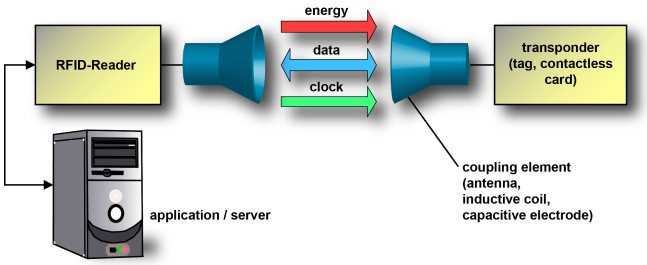

Fig. 3: The basic communcation scheme of RFID. An RFID reader provides power for a passive RFID so that communication between the two is possible. The tag transmits its identification, as well as sometimes other data, which the reader passes along to the application [6].

stored in the RFID tag. Low frequency tags operate at low frequencies, as the name suggests, and are the cheapest type of RFID tag. This requires that the reader be in extremely close proximity to the tag. High frequency tags can be read from a greater distance, but are more susceptible to interference by packaging and objects between the reader and tag. Ultra-high frequency can be read at the greatest distance of the three, but are even more susceptible to interference and have the highest cost of the passive tags [4].

Battery assisted RFID tags utilize a power source other than the reader as their primary power source. The power that the reader provides is used to turn on the battery from which the tag can then take power and use the battery's power to communicate the information which the tag holds. These tags can be read at a greater distance and with a lesser chance of interference than any of the passive RFID tags. However, due to the battery that is used to provide the tag power, the cost is higher than any of the passive tags and life-span of the device is lower than passive tags due to the life-span of the battery [4].

Like the battery assisted RFID tags, active RFID tags use a battery to power the tags. Unlike the battery assisted tags, the battery is not activated by a reader. The battery continually remains engaged to provide power for the active tag to transmit its information, regardless of the presence of a reader. Active RFID tags have the greatest range of any RFID tag, but also have the greatest cost [4].

C. Arduino

An Arduino board is an inexpensive microcontroller that enables users to build elaborate devices to do a myriad of different operations. The hardware itself is entirely open-source with free public licenses which allows users to create boards themselves. The microcontroller can be connected to many different peripheral devices and circuits to facilitate their operation. There are many different types of Arduino boards, such as the Arduino Nano shown in Fig. 4. Many other similar boards use the open source nature of the system to create clones of Arduino boards [7].

D. 3D Printing

3D Printing is an additive form of rapid prototyping that has become increasingly available at a very reasonable cost. Computer generated 3D models are input into the 3D printer which then creates a physical plastic part that almost exactly matches the model. Recently, 3D printers have been created in desktop sizes that are fully capable of producing functional plastic parts for mechanical prototypes. Most desktop 3D printers are able to make parts that fit inside of an 8" cube bounding box which enables a broad range of functional prototype sizes. Desktop 3D printers use filament that is typically purchased in 1kg rolls and comes in a variety of plastics. Some of the most common plastics used are polyactic acid (PLA) and acrylonitrile butadiene styrene (ABS). Exotic materials such as nylon, polycarbonate, wood, wax, carbon fiber infused ABS, and even flexible plastics are available. Desktop 3D printers are generally able to create parts with .020 inch accuracy and with fine tuning and calibration can sometimes achieve accuracies down to less than .005 inch. With this kind of precision and size capability on such a small scale, 3D printing has become not just recommended but almost required for mechanical inventing and prototyping.

III. Implementaion

A. Wristband

The wristband which each player will wear will have LEDs capable of emitting different colors of light to identify players as being members of

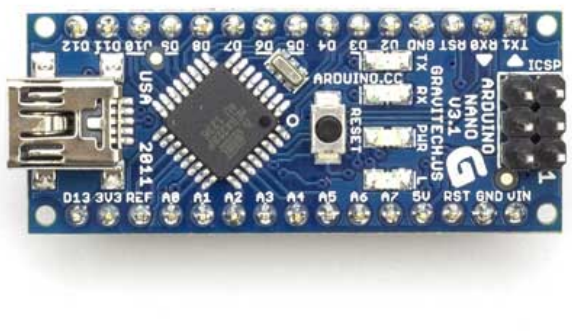

Fig. 4: The Arduino Nano. Contains an ATmega328 microcontroller and is only 45mm by 18mm [8].

a specific team. Each wristband will also contain an RFID tag to communicate team/player identification. A battery to support LEDs and, if necessary, the RFID tag will also be housed within the wristband. In order to ensure the safety of all participants, each wristband will have a breakaway clasp to ensure that the wristband will come apart safely if it gets caught on any object. Finally, an enclosure to house all electronics will be utilized.

B. Disc

The disc will contain LEDs capable of emitting different colors of light to identify the team currently in control of the disc. Light piping elements will enable the light from the LEDs to be more visible from a distance. An RFID reader will be utilized to identify the team in control of the disc according to the tag in the wristband of the player possessing the disc. An accelerometer and a gyroscope will determine when the disc is on the ground and not in the possession of either team. Buttons will turn the disc on and off, tally the score for each team, select teams, and reset the disc. Multiple 7-segment LEDs will show the score for each team. An Arduino Nano will process data from the RFID reader, accelerometer, gyroscope and buttons. Finally, an enclosure to house all electronics will be utilized.

C. User Experience

Initially, the disc will be turned on by pushing a button housed on the disc. Each wristband will be brought into proximity of the reader to allow for identification of the player who will be wearing the wristband. Each player will be assigned to one of the two teams. Once all players have been assigned to a team, the game is begun. The disc will be pulled by one team to the other to start the game. When a player on the receiving team catches or picks up the disc, the disc will change color to match that player's team, according to the player's wristband. The disc will remain the same color until the disc is dropped or is caught by a member of the opposing team. If the disc is dropped and is on the ground, the disc will change to a color not matching either team to indicate a turnover. When a player on the other team either picks the disc up after a drop or intercepts the disc, the disc will change to the color of that team. This process will continue until a point is scored. At that time, the player who scored the point will press a button to tally a point for the scoring team. The 7-segment LEDs corresponding to the score of that team will then update to show the new score.

IV. Proposed Work

There are many steps required to complete the final goal of creating a disc that can be used at night to play Ultimate Frisbee. Firstly, an RFID communication reader and tag system need to be chosen. This necessitates further research into the different types of RFID readers and tags and their respective pros and cons. After an RFID system is chosen, the individual components must be purchased. This purchase is for the prototype and does not need to have all of the parts for the final system. While it may be most cost effective to purchase all of the tags at the outset, it may be best to purchase only a small number for testing purposes and complete the purchase for all necessary tags after the testing has confirmed that the RFID tag and reader system function as needed.

The reader will then be connected to an Arduino Nano. A program will be written for the Arduino that uses the RFID reader to obtain the information from the tags and indicate when the information is received via either LEDs or serial communication to a connected computer. A basic antenna system will be used at this point to prove

that the reader can connect to the tag and retrieve the tag's identification information. A Frisbee disc will then be modified to hold the antenna system for the reader so as to replicate the environment in which the antenna will be active. A wristband will be created to house the antenna system for the tag as well. At this time the Arduino program will be used for testing communication between the reader and tag and the antenna design will be optimized for the distance and direction required for the final system.

The tag will then be customized to incorporate both the antenna and the battery required for operation. This may be done on either a regular printed circuit board (PCB) or on a flexible PCB depending on the final size of the complete circuit. A customized PCB will then be created to incorporate the reader, antenna, battery, and Arduino components necessary, as well as additional peripherals, including accelerometers and a gyroscope. These customized PCBs will be purchased and all of the electronic components will be soldered to the boards.

The original wristband design which was made to hold the antenna for testing will be reworked to hold the tag, antenna and battery. At this point light piped LED elements will be introduced to the wristband to enable it to identify team members at night. The disc will also be redesigned with the enclosure to hold the customized PCB with the reader, antenna, battery, Arduino components, and peripherals. Light piped LED elements will also be designed and integrated into the disc as shown in Fig. 5.

The program which will operate on the Arduino Nano will need to be created. This program has many aspects which it will need to fulfill. The program will be used to identify individuals based on their tags and identify the teams based on the individuals recognized. It will determine which individual/team has control of the disc at any one time and set the LEDs which light up the disc to match the color of the team in control. Based off of the accelerometers and gyroscope, the program will determine whether the disc is on the ground and will indicate that there has been a turnover of the disc. The program will also keep track of the score and any other pertinent data which is necessary to retain. The program will set or clear individual LEDs to indicate the score to users.

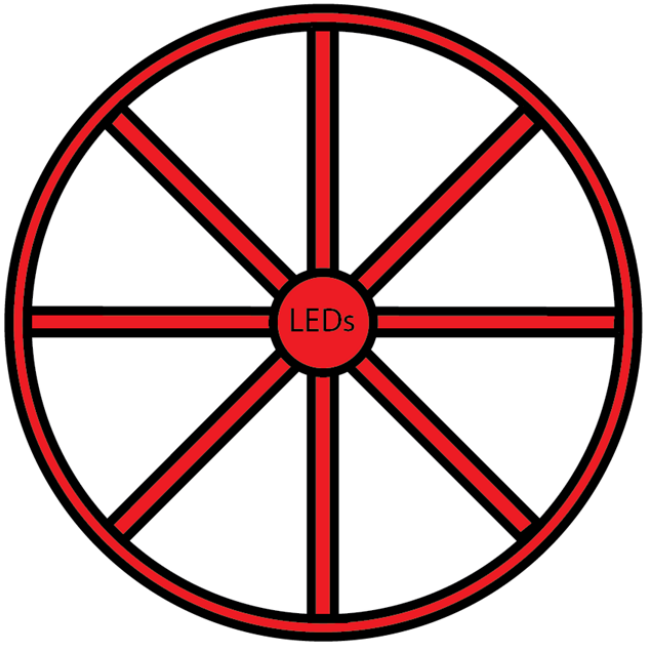

Fig. 5: Proposed light piping setup for the disc, with primary LEDs in the center of the disc with the rest of the circuitry and the light piping elements bringing the light out to the edge of the disc.

At this point the disc and wristband should be able to communicate over the proper distance and hold all of their respective components and be illuminated. The entire system must then be tested and modified based on analysis from testing.

A. Risk Assessment

There are many risks associated with the different aspects of the proposed work. The first risk is that the RFID reader/tag does not arrive as fast as the manufacturer claims or does not arrive at all. As all components will be bought from respected entities, this is unlikely, but possible. To avoid this problem, the components will be bought early to ensure that there is enough time for them to arrive and to order replacement parts if necessary.

Another risk is that the reader/tag communication distance is too short for the purposes of the proposed project. This is an unlikely scenario, as research into the components will confirm their minimum operating distance. However, if this

problem does occur, a higher frequency tag and reader will need to be purchased.

The reader may not be able to connect with the Arduino Nano. There can be issues where connections can be made with certain devices, such as Arduino Unos, but cannot work with others. While this is unlikely as the components should work as long the required power is provided for them, it is possible. In this case if the connection cannot be successfully made through debugging another reader/tag will need to be purchased.

The customized tag or customized reader circuit may not work. This is very likely, especially early on in development. A sizeable amount of time will be given towards the development of these circuits and their testing. If the customized circuit still does not work, the original set of devices which were connected directly will be used. The result will be a more bulky system, but should still achieve the final objective.

Another risk is the possibility that the LEDs on either the disc or the wristband are not bright enough to be effective for use in Ultimate Frisbee at night. In this case more power may be necessary, requiring larger, more expensive batteries and larger enclosures. Another possibility is to use different LEDs that can provide more light at the same power requirement. The light piping elements may also be at fault, so it is possible that more effective light piping elements can be designed which would allow for better distribution of the light.

As the wristband will be worn on the throwing wrist of the player, it is possible that the wristband may be too cumbersome. In this case the circuit contained in the wristband must be optimized or flexible PCB may be used.

The disc may be off balance, especially at the beginning of testing. This is very likely as it may be difficult to balance all of the components so that the disc can fly like a regular Frisbee disc. This issue can be solved through testing, analysis and modification to the circuit enclosure and light piping design.

A major risk is that the components break during regular game use. The game of Ultimate Frisbee naturally causes the disc to make repeated, heavy impacts with many different objects, from hands to bodies to the ground. Through testing, the risk of damage to the components will be made apparent. To reduce the risk, stronger plastics and better, more resilient parts can be utilized. Multiple designs will have to be analyzed to determine what is best for gameplay.

A final risk is that the program could fail. This could be caused by multiple issues, with one being a lack of memory. The program will have to be extensively tested and optimized so that all resources are being used to the best ability.

V. Schedule

April 2015)
- Research RFID readers/tags
  - All team members

May 2015)
- Purchase readers/tags
  - All team members

September 2015)
- Connect with Arduino Nano
  - Computer Engineer
- Antenna design and implementation
  - Electrical Engineer
- Initial Disc and Wristband design
  - Mechanical Engineers

October 2015)
- Integrate Antennas into disc and wristband
  - All team members
- Optimize read distance
  - All team members

November 2015)
- Design Wristband
  - Mechanical Engineers
- Design Disc
  - Mechanical Engineers
- Begin Programming
  - Computer and Electrical Engineers

December 2015)
- Combine disc and electronics to form basic prototype
  - All team members
- Begin testing and analysis for next iteration

All team members

Spring 2016)

Test, Debug, Optimize, Develop more stable, sturdy, powerful, working system, attempt to reach 175 gram disc

All team members

VI. Required Resources

A. Currently Obtained

- 175 gram Ultra-Star Disc
- Arduino Nano
- 3D Printer
- 3D Printer Filament

B. Necessary to Obtain

- RFID reader/tag
- Accelerometers
- Gyroscopes
- Flexible 3D Printer Filament

VII. Conclusion

As the sport of Ultimate Frisbee gains popularity, different versions and modifications are made as participants try to make the game as enjoyable as possible. One of these versions is the sport being played at night. There are many issues with this newest modification, with the primary problem being that most discs are not made to be seen in the dark. While there are some that have been made with LEDs set within the plastic, most of these light-up discs do not remain a consistent color to allow for the disc to be properly used to play ultimate Frisbee. A Night Ultimate Frisbee system thus needs to be created.

This system will make use of wristbands for each player which will use LEDs and light piping elements to indicate the team of which the player is a part. The wristbands will also use RFID tags to communicate with a disc that the system also employs. The disc will have an RFID reader that will communicate with the tags on the wristbands to determine the team in current possession of the disc. There are many different types of RFID tags and readers that can be utilized for the task. In order to determine the best version for the system, both ultra-high frequency and active tags will be tested. Peripheral electronic devices such as accelerometers and gyroscopes will also be used to help determine possession. Possession will be indicated through the uses of LEDs and light piping elements on the disc. The disc will also have buttons and 7-segment LEDs to indicate the score.

The use of the Night Ultimate Frisbee system will allow for Ultimate Frisbee played at night be even more enjoyable than Ultimate Frisbee played during the day.

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