Analyzing hockey players shooting technique in real time for player feedback

Alex Apostolescu

Erik Kittelson

Engineering Senior Research

Academy of Engineering and Technology

Table of Contents

Introduction

As hockey players continue to improve upon their technique year after year current training tools and methods continue to become obsolete. In order to properly further player development and to take the next step in technique enhancement, a new tool needs to be developed. This tool will help progress the game and will overall increase the quality of training available not only to hockey players, but also to participants in other swing - sports. In order to segment and analyze the motion of a hockey player's shot, inertial measurement units (IMUs) can be used. Researchers have found that the use of low cost IMUs are an effective way to analyze the swinging motion of a golf player's shot (Ahmadi A et. al 2014). Considering that the motion performed during a golf player's swing is fairly similar to the motion performed during a hockey player's shot, it is reasonable to consider that the use of IMUs for hockey shot analysis is justified.

IMU sensors have also been used to analyze other swing sports. An example of this can be found with a study that used IMU sensors as an alternative to typical motion capture systems. The study concluded that IMU sensors are a valid alternative for the analysis of a tennis player's swing (Delgado Garcia, Gabriel et. al 2021). Within this study, the analysis performed by the IMUs was compared to the analysis performed by a typical motion capture system (high frame stop motion cameras). This can be expanded further in order to allow for a more accurate and comprehensive analysis. When analyzing a golf swing, researchers compared acceleration and gyroscope data from the IMU sensors that were attached to both a professional golf coach and a regular player and used differences in these readings to determine where players were messing up in their swings (Reintrakulchai, N., & Kimpan, W. 2014). This method can be used in conjunction with an optical capture system in order to facilitate empirical testing.

In addition to the applications of the aforementioned training tool for athletic purposes, the tool can also be used in order to help facilitate work in the medical field; the general function of the tool is to breakdown and analyze motions in order to provide precise motion feedback. This can be applied to help monitor patients undergoing extensive physical therapy in order to confirm that they're completing their exercises properly. This could also be applied to help provide surgeons with feedback during surgery preparation. This general concept could be further extrapolated to fit any career that requires precise, technical movements - comparing a motion to a pre-established baseline motion will help to determine how different these motions are which in turn will help the user of the tool improve at their specific task.

In order to properly address the problems associated with current methods of shot tracking a new tool will be developed that utilizes gyroscopic data along with data from an accelerometer in order to simulate the performed motion. This will be done in real time and then compared with data collected from a well established player. By analyzing the similarities and differences between these motions players will be able to collect important information that will significantly improve their in game shooting performance - this will help players fine tune their technique to allow them to improve their shot speed and accuracy.

In order to properly quantify the success of this project, the steps taken to complete the project must first be outlined. In order to properly provide players with feedback regarding their shooting technique multiple data sets will need to be collected. An original data set must be collected, in which a player performs multiple shooting sessions (of 200 shots each) for each of the three shot types of snapshot, wristshot, and slapshot. Each of these shooting sessions will also be recorded by a motion capture system in order to collect the timestamps for when each shot was performed. These timestamps will be compared to those collected from the IMU sensor placed within the player's stick in order to confirm the accuracy of the shot detection model being used. This originally collected data set will be used to build up a shot detection model. The tester will then collect more datasets in a manner identical to the one described above. This will continue until the detection model's accuracy falls above 90 percent.

It can be expected that this project will produce results that confirm the idea that IMU sensors are a suitable replacement for typical shot speed detection systems for hockey. This will be done by comparing shot data from both a well established player and an average player. In addition to this, it can also be expected that the results will confirm the idea that IMU sensors are a suitable method for analyzing a motion and then comparing it to a pre-established baseline for technique improvement. As previously mentioned, these results are extremely applicable to other fields that require precise, technical movements. Guaranteeing the success of this project could potentially establish the framework for the development of a tool that could be used to help save lives and to vastly improve the quality of life of everyday citizens. It can also be expected that the success of this project would make everyday jobs much easier to complete, thus reducing any safety risks/concerns associated with more dangerous jobs.

Purpose

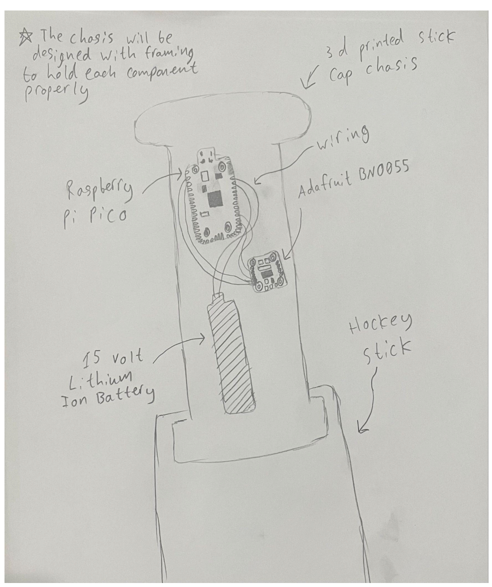
Current methods of ice hockey shot tracking are inaccurate and inefficient, and in the cases that they are satisfactory they do not help to provide players with important feedback about their shots. This is due to the fact that they are inefficient as they require external speed radars (either in the goal or somewhere in the ice rink) which are sensitive to external movements. These external movements can result in inaccurate data readings due to interference from other players. These methods, as previously mentioned, do not provide players with useful feedback about their techniques, which in turn could stall the development of players. The mechanics present in a hockey shot are similar to those found in other sports like field hockey, golf, lacrosse, and even tennis. Therefore, developing a method to accurately track and simulate a movement, like a hockey player's shot, could also be beneficial to other professional sports players.

This general concept is also applicable to other professions; comparing a swing/motion with a baseline could also be further extended to help monitor and improve the care of patients undergoing physical therapy, in order to ensure that they are completing their recovery exercises properly, and to help provide surgeons with feedback while preparing for surgeries (evaluating a surgeon's fine motor skills and comparing this to a baseline established by other well known surgeons will help provide them with crucial feedback that could help save a patients life). In order to properly address the problems associated with current methods of shot tracking a new tool will be developed that utilizes gyroscopic data along with data from an accelerometer in order to simulate the performed motion. This will be done in real time and then compared with data collected from a well established player. By analyzing the similarities and differences between these motions players will be able to collect important information that will significantly improve their in game shooting performance - this will help players fine tune their technique to allow them to improve their shot speed and accuracy.

Methods

For the completion of the project a Raspberry Pi Pico W was required. Initially, two were required for debugging, however, this was modified as it was determined that one was enough to properly debug. An Adafruit BNO055 accelerometer/gyroscope sensor was required in order to collect data from the player's shot. In order to power the system a 15 volt Lithium Ion battery was used. Various wires were also required in order to connect the system together. In order to properly fabricate the stick cap TPU filament was used to print a lightweight and flexible cap. The programming was done on Micropython, a subset of python, and the stick cap was inserted into an ice hockey stick and used to collect data regarding a player's stickhandling, shooting, and general movement.

Figure 1: Prototype Stick Cap Design



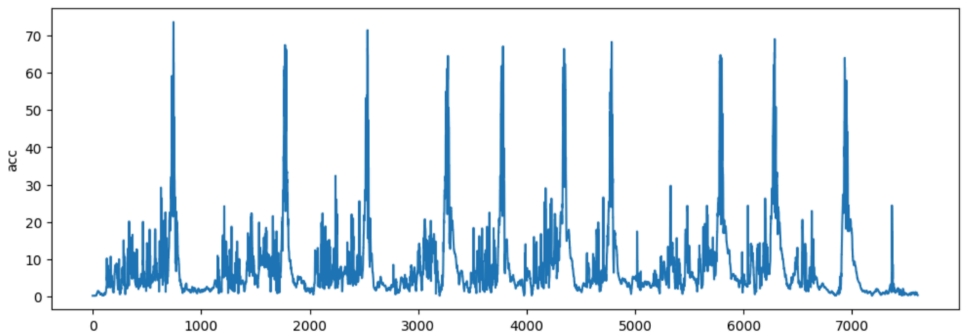
The stick cap used to house the sensors will be 3d printed and will be custom designed in order to support each of the components required. Sections will be delegated within the cap to allow for wiring to pass through the cap to different components to support the system. The casing itself will be modeled after the cap of a hockey stick and made to be the same dimensions except for the length which will be made longer in order to accommodate the sensors. This casing will serve as the cap for a hockey stick and will be inserted into the top of the stick where the cap is usually situated. The replacement cap will still be usable in game as it will not increase the length of the stick.

In order to collect data the sensors will be fitted and wired into the 3d printed stick cap. The cap will be fitted into a hockey stick and used to collect data from a player’s shooting movement. The tester will take part in shooting sessions, with each session being limited to the player only taking one type of shot (snapshot, wristshot and slapshot). Each shooting session will consist of 100 shots of each specified shot type. This dataset, which will serve as the original/first dataset, will then be used to train an LSTM machine learning model for shot classification. This will be repeated until the machine learning model’s accuracy has reached above 90 percent. The misscategorized shots (for both timestamp and classification) will be used to improve the detection model’s accuracy. In addition to this, the datasets collected will also be combined into a larger dataset and then have their values shifted by a set amount in order to produce new artificial datasets that will maintain the overall shape of the dataset while changing the data points themselves. These values will only be shifted by a specified amount in order to ensure that each shot can still be properly classified.

Data

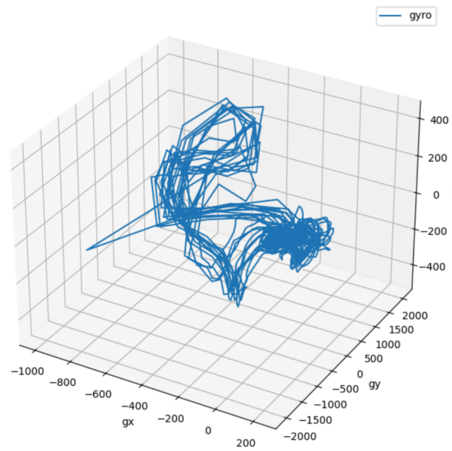
During the data collection process both gyroscopic and acceleration data was collected by the BNO055 sensor. Figure two illustrates a representation of the linear acceleration data during a condensed shooting session. As seen in the figure there are ten noticeable peaks that vary vastly from their surrounding data points. This represents when a shot took place, as the instantaneous linear acceleration value is at its highest as the shot is taking place.

Figure 2: Linear Acceleration vs. Time graph



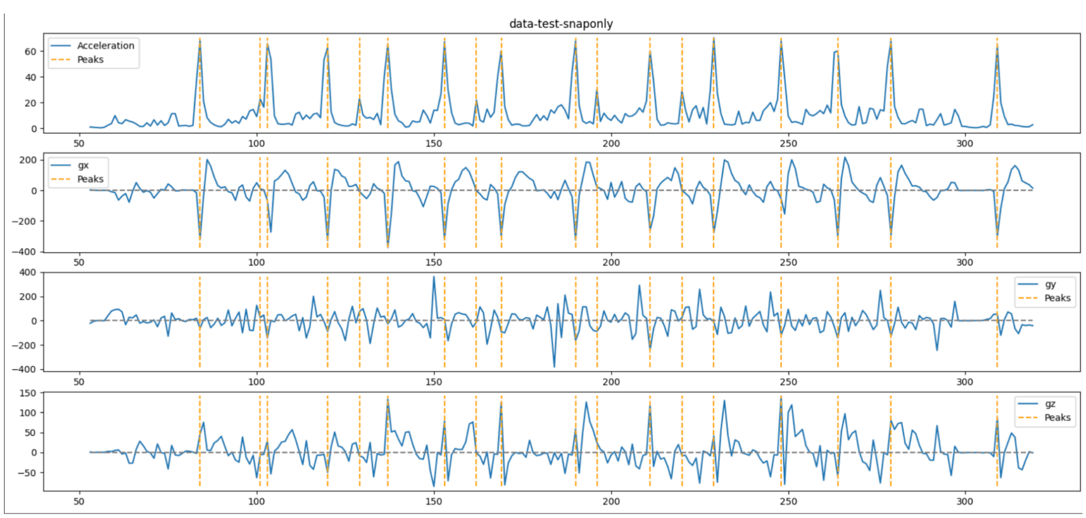
The data collected was also visually represented on a 3d plot. This can be seen within figure 3, which is a representation of the gyroscopic coordinates of the cap throughout the duration of a shooting session. As can be seen within the figure, there is a noticeable pattern in the movement. Thus, it can in fact be justified that there is a way to track the accuracy of a player's technique and then use the gyroscopic coordinates in conjunction with the data from the accelerometer to help provide player's with shot form feedback.

Figure 3: 3d plot of gyroscopic coordinates over time



A peak detection algorithm was also used in order to determine relative peaks within the datasets. This, however, was later substituted out in favor of an LSTM machine learning model. This model was able to determine patterns within datasets which in turn allowed for shot classification to occur. The peak detection can be seen within figure 4, which shows peak detection taking place for the linear acceleration, gx, gy, and gz coordinates of a dataset. As mentioned, the LSTM machine learning model was able to spot peaks within the dataset, and thus, the original method of utilizing a peak detection algorithm was no longer needed in order to provide accurate results.

Figure 4: Peak detection on a dataset



The data collection process itself can also be seen within figure 5. This figure illustrates the method utilized for collecting shot data, with the player demonstrating a shot with the stick cap placed within the stick. This shooting session took place on ground, not at an ice rink, but it still demonstrates a valid use of the apparatus to determine shot characteristics.

Figure 5: Data collection

Results

The process of data collection proved to be a success. The data was properly collected using the methods originally planned for. The collected datasets were successfully filtered utilizing a low pass filter (to reduce noise) which improved the quality of the overall datasets and the clarity of the resulting graphs. Figure 2 demonstrates a small ten shot dataset which was successfully filtered utilizing the low pass filter - thus resulting in no acceleration values below a certain threshold. The larger datasets, once collected, were successfully analyzed utilizing a peak detection algorithm to detect when a shot had taken place, which is demonstrated within Figure 4. The LSTM machine learning model was successfully trained utilizing the collected datasets.

Real time shot detection was achieved by utilizing a sliding window along with this LSTM model to detect when a shot took place.

Conclusion

The initial goal of creating a device to assist hockey players with improving shooting technique was achieved. The movement involved in a hockey player's shot was successfully captured and represented in a variety of measures. The individual components of the movement (gx, gy, gz, ax, ay, and az coordinates) were graphed in 2d and 3d with respect to time.

The peak detection algorithm was also successful in determining when key events took place. This along with the real time speed calculation demonstrates the feasibility of measuring and representing a swinging motion in real time. The LSTM was able to be fully trained, and thus demonstrated that it is possible to classify motions utilizing IMUs. All of these factors demonstrate that it is possible to detect similarities in swing motions to provide technique feedback.

Discussion

The findings of this project have implications for both professional athletes and professionals within other fields. As demonstrated within the project, it is feasible to utilize IMU sensors to collect data for analysis of a swinging motion. The general concept can also be applied to other professions. This could include assisting skill heavy professions such as welding or carpentry as well as within medical professions.

A similar system could be used to assist and monitor patients during physical therapy. It could also be utilized to detect falls, which could potentially help save the lives of the elderly. The concept could also be used to help surgeons while training for surgery. Further research can prove to be extensive. A potential extension to this project could come with testing whether or not IMU sensors and machine learning is applicable to more precise motion analysis - such as preparing surgeons for complex operations.

Works Cited

Ahmadi, A., Destelle, F., Monaghan, D., O'Connor, N. E., Richter, C., & Moran, K. (2014). A framework for comprehensive analysis of a swing in sports using low-cost inertial sensors. *IEEE SENSORS 2014 Proceedings*. https://doi.org/10.1109/icsens.2014.6985479

Anand, A., Sharma, M., Srivastava, R., Kaligounder, L., & Prakash, D. (2017). Wearable Motion Sensor Based Analysis of Swing Sports. *2017 16th IEEE International Conference on Machine Learning and Applications (ICMLA)*. https://doi.org/10.1109/icmla.2017.0-149

Dong, R., & Ikuno, S. (2023). Biomechanical analysis of golf swing motion using Hilbert–Huang Transform. *Sensors*, *23*(15), 6698. https://doi.org/10.3390/s23156698

IEEE. (n.d.). Measurement and analysis of golf swing using 3D acceleration and gyroscopic sensors | IEEE conference publication | IEEE Xplore. https://ieeexplore.ieee.org/document/6060497/

Institution of Mechanical Engineers. (n.d.-b). IMU gyroscopes are a valid alternative to 3D optical motion ... https://journals.sagepub.com/doi/pdf/10.1177/1754337120965444

Reintrakulchai, N., & Kimpan, W. (2014). The design of golf swing pattern analysis from motion sensors. *2014 International Computer Science and Engineering Conference (ICSEC)*, 222–227. https://doi.org/10.1109/icsec.2014.6978198

Tremblay, S. (n.d.). *A deep learning approach to automatically classify ice hockey shooting methods using inertial sensors - ProQuest*.

https://www.proquest.com/openview/2f9462c90b68429cb7f629eb2c01eb2b/1?pq-origsite=gscholar&cbl=18750&diss=y