THE VIABILITY OF CREATING COST-EFFECTIVE COACHING VIDEO DELAY DEVICES FOR SPORTS

by

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Authors Declaration

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Abstract

THE VIABILITY OF CREATING COST-EFFECTIVE COACHING VIDEO DELAY DEVICES FOR SPORTS

Master of Digital Media, 2020

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Digital Media

Ryerson University

In the world of sports, video training has become more commonplace for helping coaches and athletes elevate themselves to a higher-performing level. As athletes progress to higher levels in their sports, more and more athletes are turning to video recording as a means to amplify their performance levels. Currently, video recording and playback devices available to the sports world can be cost-prohibitive. This creates a performance-divide, preventing athletes from progressing to their next level of performance and allowing other athletes to progress faster. This research is designed to identify a solution that is low cost and effective as a training aid. The goal of this research is to determine whether it is financially viable to create and produce a low-cost playback device that helps close the performance-divide gap.

Keywords: performance-divide, video playback devices, feedback, recording, diving, springboard diving

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1 - Introduction

Springboard and platform diving is one of the most popular Olympic sports (Sourav, 2020). Diving requires athletes to perform several flips and twists after taking off from a diving board where they land in the water headfirst. While doing these maneuvers in competition athletes are judged on precision, cleanliness of the dive while in the air and upon entry to the water, and distance to the diving board. A panel of judges will score the performance of the dive based on their technical observations during the execution. According to the rules put out by the Fédération Internationale de Natation (FINA) the international governing body of aquatic sports, judges are to judge dives based on their impression of the dive from a score of 0-10. Each score range is defined as the following: 0 is completely failed, 0.5 - 2 is unsatisfactory, 2.5 - 4.5 is decent, 5 - 6.5 is satisfactory, 7 - 8 is good, 8.5 - 9.5 is very good, and 10 is excellent (FINA, 2017).

The criteria for how judges determine the scores they present after a dive are also defined by the FINA rules. Judges are to consider the following points and score the dive on its technique and grace based on starting position and approach, the take-off, the flight, and the entry (FINA, 2017). For each competitive level of diving there are different levels of nuance when judges score dives, but the overall system remains the same.

To achieve this level of precision, athletes must train rigorously both in a dryland setting using a trampoline as well as in the pool. Training is a long, arduous, and demanding process that involves complex communication between athletes and coaches. To properly coach an athlete, high performance diving coaches look to video feedback to show athletes corrections in both training settings. In a dryland setting, a coach will use video feedback as a means to train athletes on smaller skills that need to be refined before taking them to the water. This may include trampoline practice where athletes practice their rhythm of jumps and arm swings, dry board practice where basic jumps are tweaked to find the right cadence throughout an approach, or land somersaults where athletes practice connection speed that helps them snap into dives faster off their takeoff. In the pool, video analysis is used to make adjustments to the dives athletes will perform while in a competitive setting. Video analysis allows both athletes and coaches to look at these skills and have discussions about what works and what does not work, while still in their practice which helps athletes internalize the corrections given.

Due to the COVID-19 pandemic, changes to the project were made to accommodate social distancing guidelines. The purpose remains the same: designing a low-cost system for athletes and coaches to use to further improve performance. Before, the goal of the project was to create a Minimum Viable Product (MVP) of this solution. This MVP would play delayed live video from a camera connected to a Raspberry Pi Single Board Computer (SBC). The video feed would be connected via HDMI to a monitor or TV, allowing users to view the buffered video. Among the features initially planned to be implemented were stop and play live video on a buffer, slow motion capture and replay at 1080p and 60 frames per second and saving clips to an external hard drive. Due to the pandemic, building an MVP for this project became problematic as social distancing guidelines were put into place, resulting in a lack of access with faculty expertise and equipment available at the University. Creating, testing, and implementing the features and the system became an unrealistic expectation. The project will now examine why video recording systems improve performance, review existing solutions in the marketplace, and an analysis of the performance gaps in these systems which will help define the utility of the proposed system. The revised project deliverables assess the viability of using a Raspberry Pi as a device to record and save video, designing the User Experience (UX) for the system and planning out potential scenarios and use cases that users may experience while using the system, and designing the enclosure that would be used to protect the device from outside elements.

2 - Related Work

Currently, the video feedback systems available in the Canadian and US markets are high end solutions making them cost prohibitive to small and medium sized diving clubs. Coaches are forced to use makeshift solutions which inadequately address their needs. By identifying this gap in the video feedback system market and creating a cost-effective system, the proposed system is designed to give diving clubs an accessible tool to help improve diver performance. The price point of current solutions ranges from $10 to over $3000, with a wide variability in the ease of use and playback capabilities. These prices increase significantly if system acquisition and software costs are considered, for the purpose of demonstration it will be assumed one does not have access to the required hardware and the associated device costs will be added accordingly. To properly assess pricing an added cost of $200 for a low-cost TV/monitor will be added to all systems, and an extra cost of $120 will be added to systems that do not come equipped with cameras otherwise the cost of the device will be used. The prices discussed will be for the bill of material cost for the proposed device and app subscription services and do not include regional sales taxes that may be incurred during purchasing.

2.1 - Literature Review

According to Guadagnoli et al., athletes who are given verbal instructions in conjunction with video analysis on how to manipulate their body while performing tasks demonstrate an increased progress in skill acquisition over time, allowing them to progress further (Guadagnoli et al., 2010). Building off this idea of increased skill progression through video analysis, the term “performance-divide” is proposed to describe this phenomenon. Research conducted by Boyer et al. also suggests that athletes who analyzed video of Olympic level athletes allowed younger athletes to see how their skills should be performed, thus helping them perform the skills at a higher level and at an increased pace than if they had practiced the skills without watching Olympians perform the skills (Boyer et al., 2013). Research by Maslovat and Franks determined that sports that revolve around movement skills that are not greatly affected by the environment in which they are performed, such as diving, gymnastics, and golf, are based around successful repetitive performances. These repetitive performances result in success in the sport. Achieving an elite level requires athletes have a deep knowledge and understanding of certain actions in the skill, whether positive or negative. The researchers claim athletes involved in the analysis of the skills with their coach dramatically improve their error detection capabilities which positively impacts their future skill performance (Maslovat & Franks, 2020). Franks noted that video is beneficial for its feedback potential in the skill learning process and that given the right instruction from a coach, it can show positive benefits to the athlete (Franks, 2004).

The performance-divide is prevalent in sport, affecting athletes by not allowing them to progress past a certain skill level due to an inability to visualize body movements and grasp how proper body movements look outside of how they feel while making them. By using video analysis, athletes can separate how movements feel from how they look. This separation is what allows athletes to progress further as they are not relying on how movements feel, rather, they see how movements affect their performed skills either positively or negatively.

2.2 - Off-the-shelf Solutions

The most common video delay device used in diving is a modified Digital Video Recorder box (DVR), commonly referred to as a TiVo. This device only allows for delayed live video in standard definition and has limited capabilities for all users. The user interface (seen in Figure 1), is minimal in its implementation, allowing users to play, pause, fast forward, rewind, snap to a live view of the camera connected, and jump back 2.5 seconds. The “jump back” feature allows users to create a video delay they can use to view dives or motions after they have happened. The device offers nothing in terms of storage for video or export options, once the device has been turned off after a practice, the day's recorded video is wiped from the device. With its standard definition input and output connections and lack of accessibility for later viewing, this solution is extremely outdated. The company who made the device originally has pivoted, making this option obsolete and extremely difficult to source. The pricing averages about $300 per device which brings the total cost to $620 with the added hardware needed to run the setup.

Figure 1

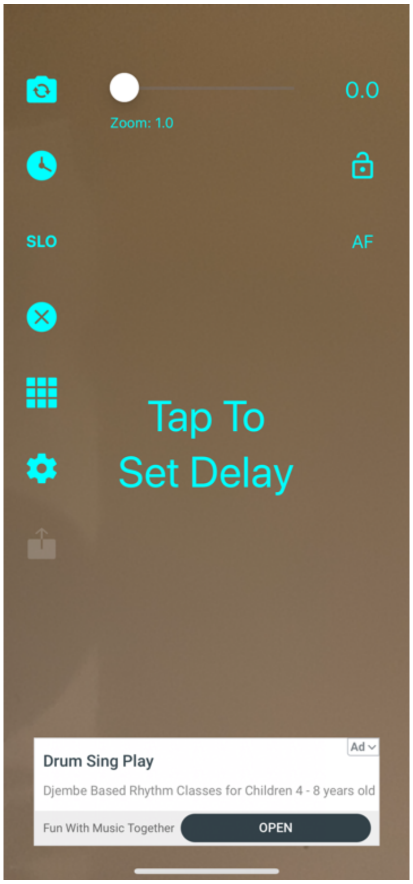
TiVo User Interface

Note. Picture of the user interface of the TiVo system. This figure depicts the minimal UI involved with the system.

The second video delay solution is an application called VideoDelay that is available on mobile and tablet devices. This app allows for video delay through the owned devices back or front facing camera, most of which are high definition cameras, but can quickly become outdated and restrict users to old technology. The UI (seen in Figure 2), allows users to quickly set different parameters for their delay such as setting the delay time, flipping which camera is active, setting a delay buffer, activating slow motion, adding a grid, access to deeper settings, and a clip export option. The UI also displays a zoom slider, the amount of time that has been set for the delay, whether auto focus is on or not, and a screen lock button.

Figure 2

VideoDelay User Interface

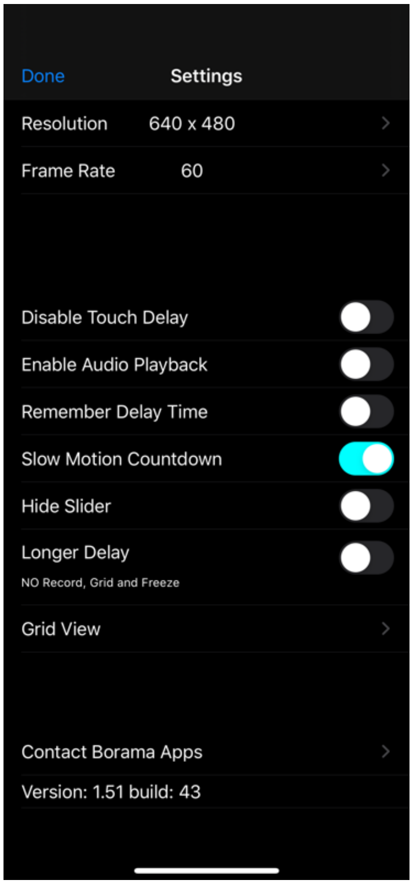


Note. Picture of the user interface of the VideoDelay system. This figure depicts the features displayed to users available in this system.

The deeper settings offered (seen in Figure 3), allow users to set the frame rate from 1 - 60 frames per second and resolution from a minimum 640 x 480 to a maximum 1920 x 1080 on clips they want to save. Users are also able to toggle whether they can set a video delay via tapping the screen, have audio played in their delayed video, whether the app displays a slow motion countdown, whether or not the zoom feature should be displayed, whether users want longer delay options, options for the grid view, and whether the app remembers the previous set delay time. From demoing this app, it seems like it works similarly to how the social media app Snapchat functions. Snapchat uses the device camera to display the camera view, but does not use any of the camera functionality, instead opting to screen capture what the camera sees. In copying this method, this delay apps zoom feature zooms into the bottom left corner of the screen to a certain degree and then stretches the zoomed portion to "increase" the amount of zoom more. None of the main screen options are openly obvious about what action they result in when activated, moreover, the options in the settings menu don't have headings for what actions the user is activating or deactivating making it hard to determine what settings are being changed and for what purpose.

Figure 3

VideoDelay Settings Panel



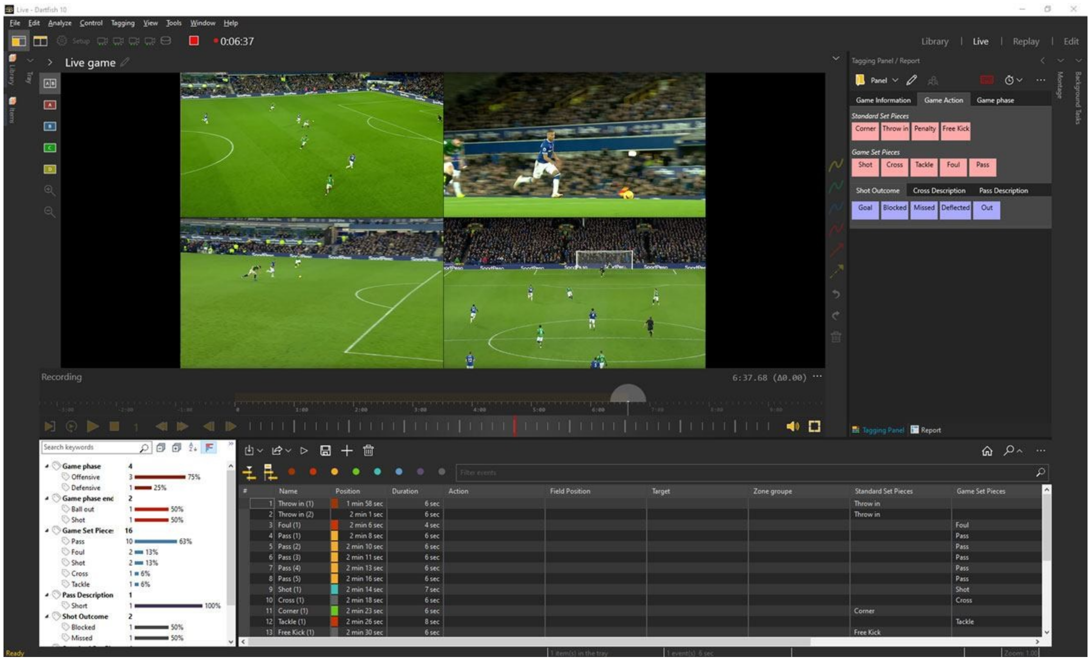
Note. Picture of the user interface of the VideoDelay system. This figure depicts the settings panel available for users to change settings not available in the previous screen.

Pricing for this app is relatively inexpensive. The app is available for free with the caveat that it is filled with footer banner ads while using the app and if you want to view the settings page you have to sit through a longer ad. For a $10 fee, you can purchase an ad free version. Considering that a device is needed to run this app, whether a phone or tablet, a standard 32GB iPad has been chosen as the lowest priced device to operate with this app. The total acquisition cost for this solution comes to $639 with the iPad, TV and ad free version of the app. The device's camera is a major limiting factor in this option as is the device's on-board memory capacity. For this pricing demonstration, the lowest cost iPad has only 32GB of memory which will quickly fill up if clips are saved often.

The next solution is a subscription-based application: Dartfish. This application runs on both mobile devices and computers and allows users to delay live video, mark up existing videos, and save recordings clipped from delayed live video. This solution allows users to record and delay live video off a computer's attached webcam, or any externally connected cameras with a maximum input resolution of 4K. The UI (seen in Figure 4), for this application mirrors what video editing software looks like, displaying a video feed window in the top left, a timeline bar directly underneath, and a library for saved clips at the bottom of the screen. The application has 4 price ranges, starting at $5 monthly for the mobile-only version and goes up to $70 monthly for the highest version with every feature available that runs on both mobile and desktop. The total asset acquisition cost for this solution can land anywhere from $380 - $1160, where $380 gets a phone app that allows users to capture videos and analyse them, and $1160 lets users do everything that the app is capable of. After these initial costs, the solution incurs a $60 - $840 yearly cost to continue use.

Figure 4

Dartfish User Interface



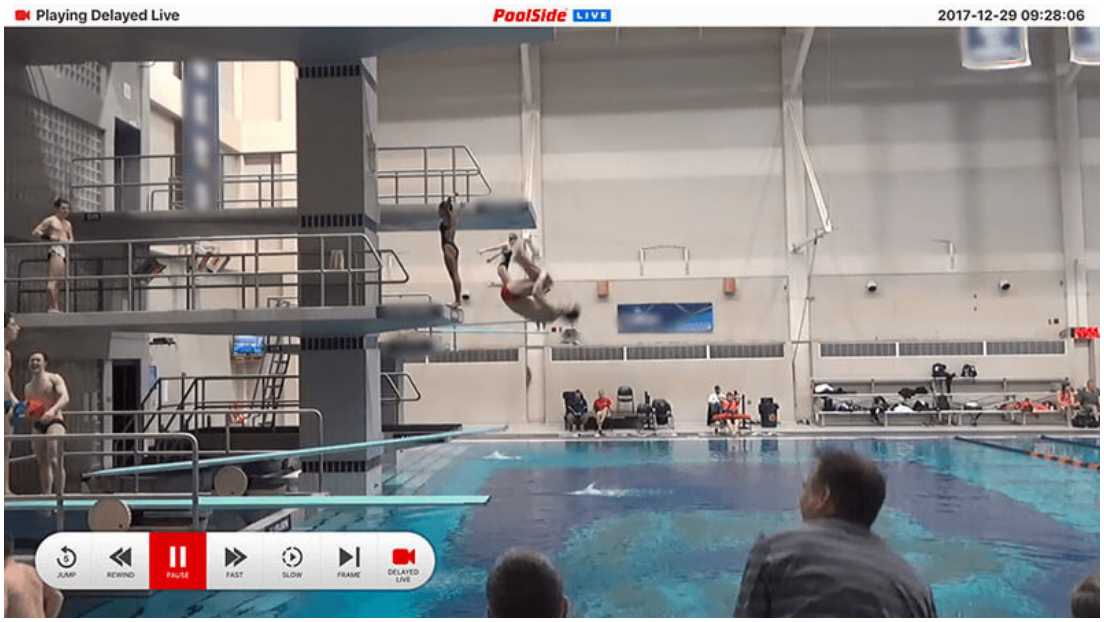
Note. Picture of the user interface of the Dartfish system. This figure depicts the user viewport for the Pro S version of the software. (Dartfish, 2019)

The final solution is a subscription-based application called Sideline Scout. This application runs on various devices such as tablets, Apple TV, computers, and mobile devices. Sideline Scout lets users delay live video, clip and save recordings, and analyze saved videos. The UI (seen in Figure 5), for Sideline Scout follows the same idea as the TiVo UI design in that it keeps minimal elements on the screen to allow for ease of viewing when they are on screen. The system allows users to pause the connected video feed, move the viewed video forward until the video is live or move backwards through recorded video, slow video playback rate for slow motion, jump backwards a certain amount of time, and save video clips. To use Sideline Scout, users are required to “check in” to the servers to verify that licensing fees have been paid, which in a pool setting can be problematic. Public facilities like pools often do not have building wide

WIFI access and when they do, the nature of a pool area being wide open can cause devices to drop connections which can result in missed recordings.

Figure 5

Sideline Scout User Interface



Note. Picture of the user interface of the Sideline Scout system. This figure depicts the UI of the system while it is displaying delayed live footage from a connected camera. (Sideline Scout, 2017)

All the solutions on the market do certain aspects correctly but are lacking certain features necessary in creating a cohesive system. They all seek to include the same features at vastly differing price points while not adding anything new. Some of these devices add in features that, while in theory are beneficial to the user, do not consider key aspects that their users daily experience which negatively impacts the user experience. In creating these solutions, it seems as though only high paying users were considered, and thusly the features were catered towards them, leaving out other users who may not be as fortunate or capable of paying for the latest and greatest equipment. A breakdown of the solutions is seen in Figure 6, which depicts the hardware and the associated costs with each solution.

Figure 6

Solutions Price Breakdown Chart

Solutions	TiVo	Dartfish	Sideline Scout	VideoDelay App
Pricing	$300 (no subscription -device included, camera required ($120), TV/Monitor required ($200)) **Total: $620**	$70/month or $840/year (subscription model - computer required, camera required ($120), TV/Monitor required ($200)) **Total: $1160**	$200-$5000 (subscription model - devices required ($200 Apple TV, higher prices include devices), camera required ($120), TV/ Monitor required ($200)) **Total: $720-$5320**	Free-$10 (phone or tablet required ($429 for 32GB iPad), TV/Monitor recommended ($200)) **Total: $639**
Capabilities	Delay live video	Delay live video, save recordings, markup video	Delay live video, export recordings	Delay live video
Quality	SD Camera Input - System doesn't allow for higher quality camera input	HD Camera Input - System allows for higher quality camera input, up to 4k resolution	HD Camera Input - System allows for HD camera input	Camera Included - System is limited to the camera used on the device
Memory	None	Dependent on computer used	Unspecified	Dependent on device used

Note. Chart depicting the cost breakdown for all solutions.

3 - Proposed Solution

After critiquing the currently available solutions, the proposed solution looks to incorporate the positive aspects and features found in what is available. In doing so, the overall design of the project prioritizes the athlete's perspective and needs in order to properly address the issues that are present in the current solutions. Additionally, the project aims to deliver these aspects at a more affordable price point of $370 to the consumer which will enable access to the performance enhancing benefits of video delay to more athletes which will help bridge the performance-divide. The price of $370 is derived from the prices of the raw components added together at consumer pricing. The system is designed to run off of a Raspberry Pi 4 Model B Single Board Computer which is currently priced at $135, a Raspberry Pi Camera V2 which is priced at $35, and the TV/Monitor priced in with the other solutions at $200, bringing the total bill of materials cost to $370 (seen in Figure 7).

Figure 7

Solutions Price Breakdown Chart with Proposed System

Solutions	TiVo	Dartfish	Sideline Scout	VideoDelay App	MRP Solution
Pricing	$300 (no subscription -device included, camera required ($120), TV/ Monitor required ($200)) **Total: $620**	$70/month or $840/year (subscription model - computer required, camera required ($120), TV/Monitor required ($200)) **Total: $1160**	$200-$5000 (subscription model - devices required ($200 Apple TV, higher prices include devices), camera required ($120), TV/ Monitor required ($200)) **Total: $720-$5320**	Free-$10 (phone or tablet required ($429 for 32GB iPad), TV/Monitor recommended ($200)) **Total: $639**	$135 Raspberry Pi 4 kit, $35 Raspberry Pi Camera, TV/Monitor required ($200) **Total: $370**
Capabilities	Delay live video	Delay live video, save recordings, markup video	Delay live video, export recordings	Delay live video	Delay live video, save recordings, rating system, export recordings
Quality	SD Camera Input - System doesn't allow for higher quality camera input	HD Camera Input - System allows for higher quality camera input, up to 4k resolution	HD Camera Input - System allows for HD camera input	Camera Included - System is limited to the camera used on the device	HD Camera included, can use higher quality cameras if required
Memory	None	Dependent on computer used	Unspecified	Dependent on device used	32GB Micro SD card on board memory or any size external memory

Note. Chart depicting the cost breakdown for all solutions including the proposed solution.

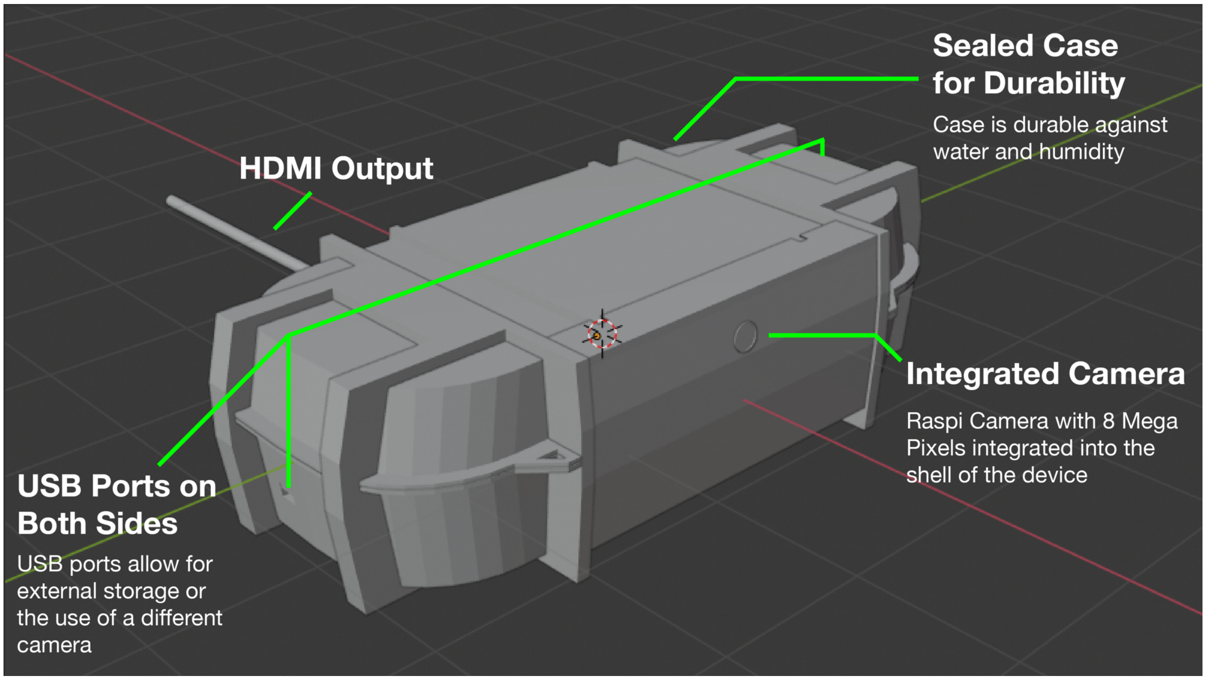
3.1 – Hardware Design

The proposed solution is designed to work on a stock Raspberry Pi 4 Model B computer with an 8-megapixel Raspberry Pi camera. The Raspberry Pi computer and camera work together to make up the bulk of the solution. These two components work together to help cut down on costs, as well as, simplifying user setup requirements allowing for the device to be easily plugged in and used. Additionally, a small USB hub to allow for USB connection would be placed on either side of the Raspberry Pi device. The attached USB hub allows users to easily and quickly connect additional external devices to the system such as higher quality cameras or external storage devices. Along the back, the Raspberry Pi has an HDMI connection that will be accessible as an output to allow users to connect the device to a TV or monitor for viewing. The Raspberry Pi camera will be attached to the front of the device pointing outwards and integrated into the casing, taking away the need to find the optimal position for aiming the camera, instead it will be in a fixed position. If necessary, users can connect external cameras to better position their viewpoint. The device uses small scale components and has a low voltage power draw making it ideal for pairing with a battery system.

To maintain the system, all the components would be encased in a modified Pelican style case allowing the device to remain waterproof. Having a waterproof case for the device is necessary as athletes are constantly impacting the water upon entry creating splashes, whether intentionally or not. Keeping the device dry is of utmost importance as it allows for the device to operate for long periods of time, reducing corrosion on the electronic parts, and driving the acquisition cost of the device down over time. The case for the device will be a modified Pelican case, as mentioned, with modifications being made to ensure that the device is watertight, yet still ensuring the device can keep cool and not overheat. Other modifications would allow for USB and HDMI ports to be accessible from the outside to connect to various devices. These ports will feature watertight connections that allow for the cables to screw in to connect, reducing the possibility of water seeping in through the ports. On the front of the case there will be a hole to allow the camera to protrude from, which will also be made to be waterproof. A diagram of the device housing displaying the above information can be seen in Figure 8.

Figure 8

Device Case 3D Model



Note. 3D designed asset. This figure depicts the designed housing for the system using a Pelican case as a base.

Wireless connectivity for the device has been considered. As a subscription-based service, Sideline Scout requires a connection to their servers to work, thus limiting its potential in public pools which typically do not have public access Wi-Fi. In addition, pool buildings often have poor signal strength for both Wi-Fi and cellular devices making it difficult to request users to connect to either if connectivity is a known problem. While the Raspberry Pi can connect to Wi-Fi, this feature will not be enabled in the first generation of this device for the above reasons.

3.2 – Software Design

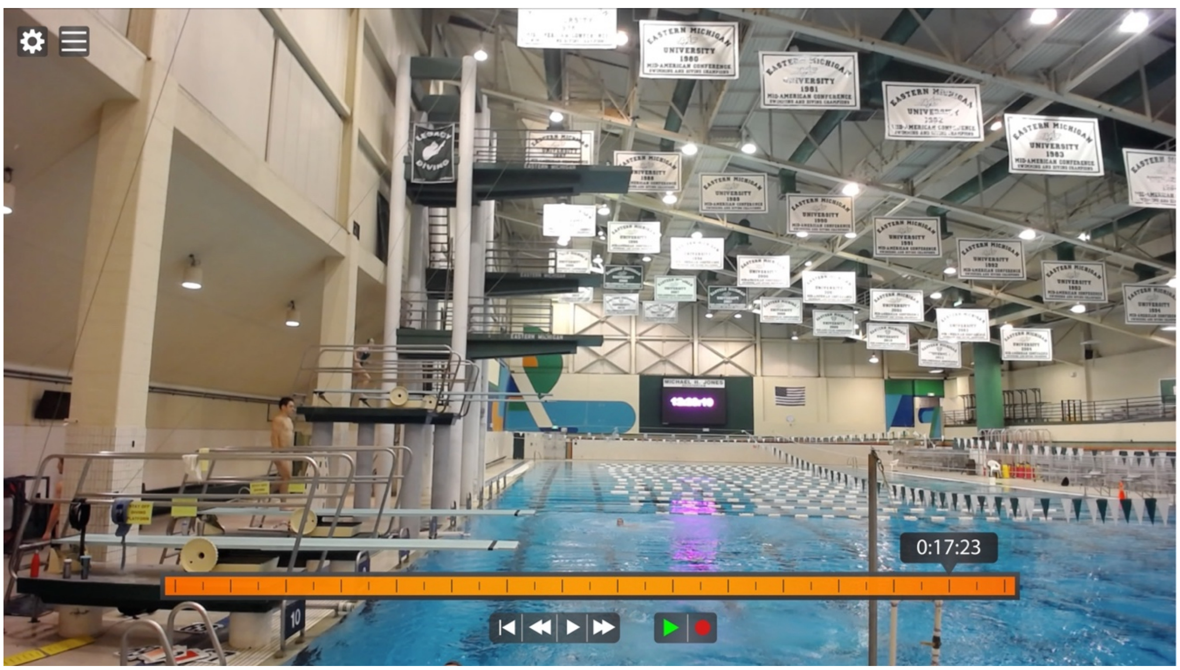
The base system has been mocked up and tested running a community Raspberry Pi project designed to be used as a homemade dashcam which was published in 2019. This dashcam project was selected for its easy implementation and installation from a clean operating system, as well as, its higher frame rate and resolution while recording. The other dashcam projects that were tested were either too complex to install and troubleshoot or they did not result in high quality footage using the Raspberry Pi and Raspberry Pi Camera. The dashcam project selected for testing runs off the Raspbian Lite operating system offered by the Raspberry Pi Foundation. The project uses the Raspberry Pi Camera attachment as a primary camera and allows users to connect additional USB powered cameras to the system and record simultaneously during a user's daily use in a car. The program is run and configured through a Python 3.0 Raspberry Pi Camera software that is highly configurable and can be built upon to allow for external USB cameras to be attached. The dashcam project continuously records video footage through the camera while the Raspberry Pi is powered on for the entirety of the car trip. When the system, and likewise the car is powered off, the dashcam date stamps the footage and saves it to internal storage. This Raspberry Pi project was used to test and validate whether the physical hardware configuration was capable of the intensive requirements that video recording can create on a system. The Raspberry Pi and Raspberry Pi Camera configuration, in conjunction with the dashcam program, worked well enough to warrant continuation on this avenue. The most prevalent issue was the framerate, wherein, the program dropped frames upon review of the saved footage. This issue was determined to be due to the default video codec and was quickly remedied. Although minor issues presented themselves, there were not enough issues to become detrimental to the overall performance for this project.

3.3 - User Interface Design

The User Interface (UI) for the device takes positive aspects from the currently available solutions and packages them together. Taking these aspects allows for a clean look that is easy to navigate, easy to understand, and most importantly, easy to use. The UI (seen in Figure 9), is minimal in appearance while in use, displaying a timeline for available footage that is viewable, as well as, showing basic video buttons such as play, pause, rewind, fast forward, jump to furthest available buffered video, resume feed, and record. Upon first start up, the system will open a dialogue box to allow users to customize the settings available, this dialogue box can be seen in Figure 10. Each setting that is selectable will have a brief description on what action they are responsible for. These settings include clip saving location, delay length, saved clip length, total buffer time, resolution, and frame rate. These settings are the basis for the system and are all editable for the user to change to fit their coaching style.

Figure 9

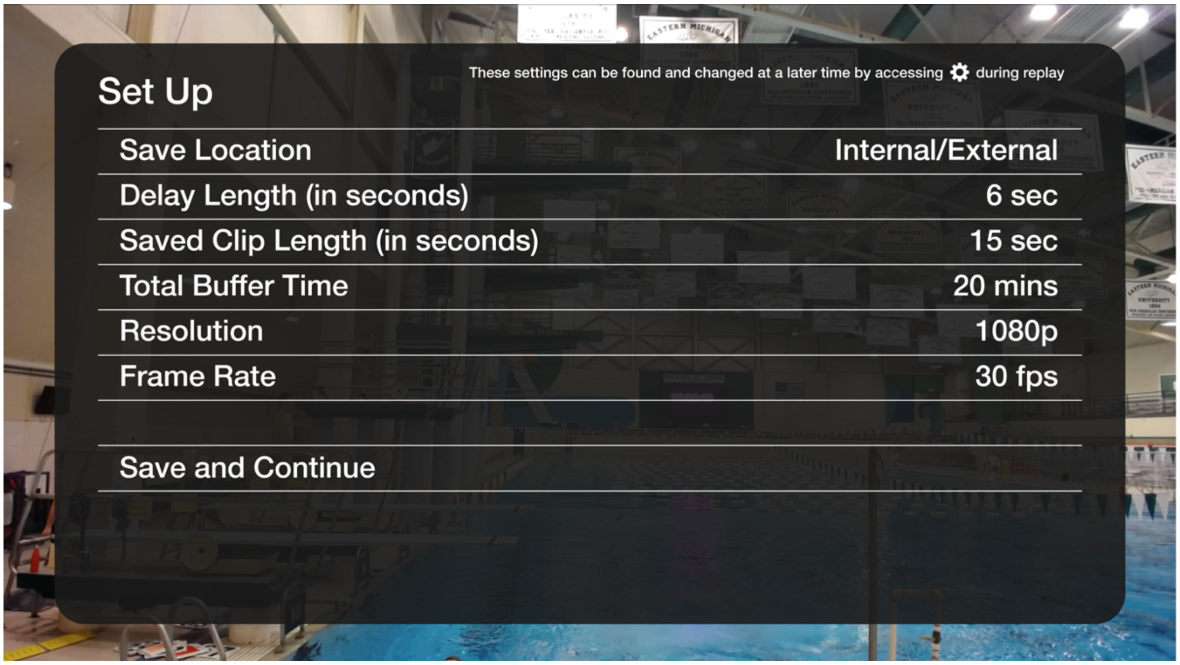
Proposed System User Interface



Note. UI prototype. This figure depicts the design of the user interface when users are viewing delayed live footage.

Figure 10

Proposed System Set Up Panel



Note. UI prototype. This figure depicts the design of the setup screen.

Clip saving location is an option available for users to specify where they want the system to save clips to, providing two options: internal and external. Saving internally will have the system save video clips to the micro SD card that the system runs off and doing so will allow users to access the videos for replay through the clip selector interface. Saving externally requires users to attach an external hard drive or USB stick to the system. Choosing this option makes it easy for users to transfer the clips from the system to their own computer to view at any time independent of the system. Both save options allow for users to view saved clips through the clip selector interface.

Delay length is a setting that adjusts the video to enable a visible delay to the footage. With this setting, the system will automatically create a delay to the live video footage that the system is displaying when showing users live footage. For example, when a user sets a delay length to 6 seconds, the system will automatically delay shown footage by 6 seconds, allowing users to view dives and actions they made 6 seconds prior to when they look at the screen. Use of this feature is delegated to the Resume Feed button, shown as a green play button in Figure 9 will bring users to their set delay length from anywhere in the timeline while users are watching video from a connected camera. This setting is limited to a maximum delay dependent on how long a user has the Total Buffer Time setting set to and can be changed at any time to suit the needs of its users.

Saved clip length refers to the length of saved clips. If a user selects a 15 second saved clip length, the system will cut the recording 15 seconds after the user presses the record button. These clips are saved separately from the buffer time recordings and are only deleted at the request of the user, never by the system itself.

Total buffer time allows users to set how long the system buffers video for. The system will continuously record footage from the moment it is turned on right up until it is powered off. The recorded video footage is saved to a temporary location that allows users to access it through scrubbing. Scrubbing allows users to view any footage that the system has buffered and allows users to record clips the same way they would off the delayed feed. The system also continuously deletes recordings based on the applied setting as time goes on to maintain adequate amounts of storage. The buffer time refers to how much video, in minutes, the system retains that is still viewable to users should they want to go back and view it. This buffered video is depicted on screen to the user as an orange timeline bar. As a practice session goes on and the system is buffering video, the orange bar will slowly fill up the timeline bar. This allows users to see visually how much time, or video, they have available for viewing. This bar is also accompanied by a timestamp that indicates how far removed from live video they are. This timestamp is displayed by minutes and seconds and will never indicate negative time. Once the system is turned off, any buffered video that was viewable during the session is then deleted to make room for buffered video during the next session.

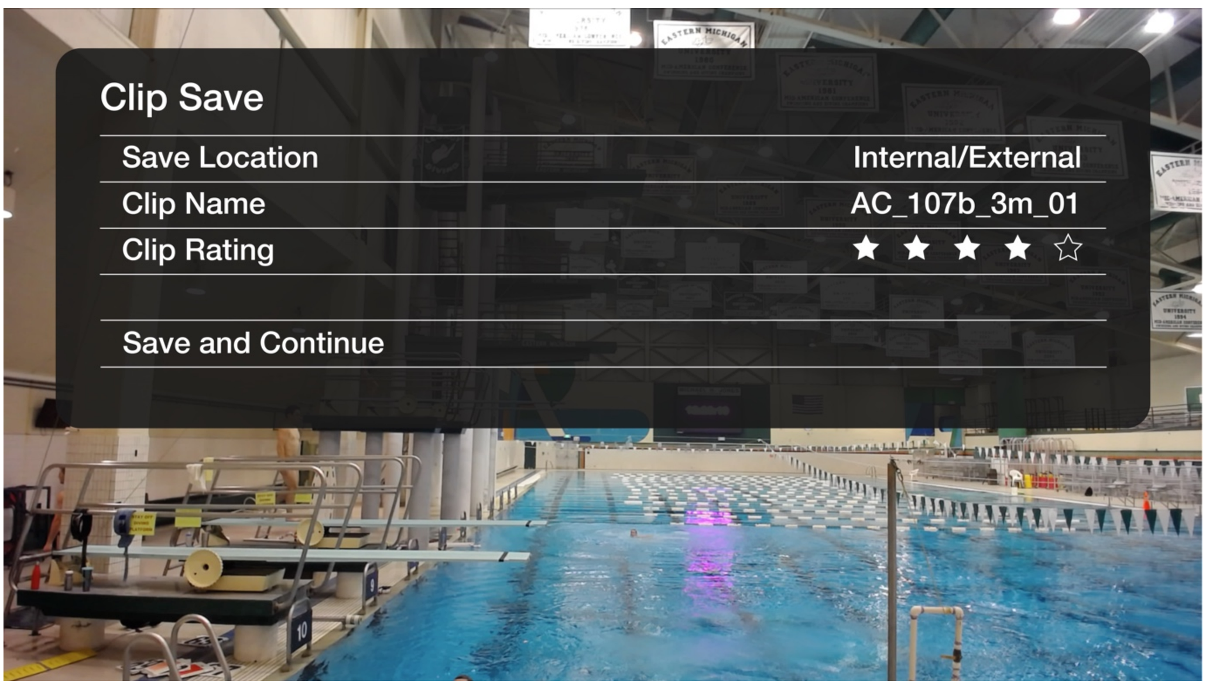
Resolution refers to the size of the video that the system will save clips as, such as 720p or 1080p. The system allows the user to customize image resolution and is not reliant on the camera to define the lower resolution parameter. For example, a high-resolution professional camera can be used with the system to record low resolution images. Conversely the resolution of saved clips will be capped at the highest quality that the camera is capable of recording at. If an externally connected camera can capture at a higher resolution, the system will recognize that, and the option will be available to users.

Frame rate refers to how many frames per second the system saves videos at. Average cameras typically record between 24-30 frames per second to achieve a smooth video at normal speed but lack enough frames to be played at a smooth rate when slowed down for slow motion analysis. As higher frame rates are recorded, dependent on the camera's capabilities, the smoother these clips will play while analyzed in slow motion, but at the cost of a bigger file size.

The system will allow users to save clips based on the saved clip length setting that is applied during the first-time setup. This feature will save clips to either internal memory or external memory, if such a device is connected, which will then prompt users to name and rate the clips for the system to organize into a clip sorting panel, which can be seen in Figure 11. The UI also will allow users to review clips saved onboard, as well as, clips that are saved externally, if the system can read the clips via USB connection. The device will feature a file sorting screen, which can be seen in Figure 12, where users can look through saved clips that are arranged based on name, timestamp, or user given rating. If a clip with a high frame rate is played through the playback feature, an option for playback speed will be introduced for users to access. This will display the speeds at which users are able to watch the clips they are analysing, such as 1x, 0.75x, or 0.5x, depending on the frame rate that the clip was recorded at. The system will then show the selected clip at the playback speed users have selected for the clip. While selecting clips to analyze, users can play, rename, or rerate clips to their liking, as well as, move clips from internal storage to external storage if such a device is connected. A flow chart can be found in Figure 13 which outlines how user movement through the UI is meant to happen.

Figure 11

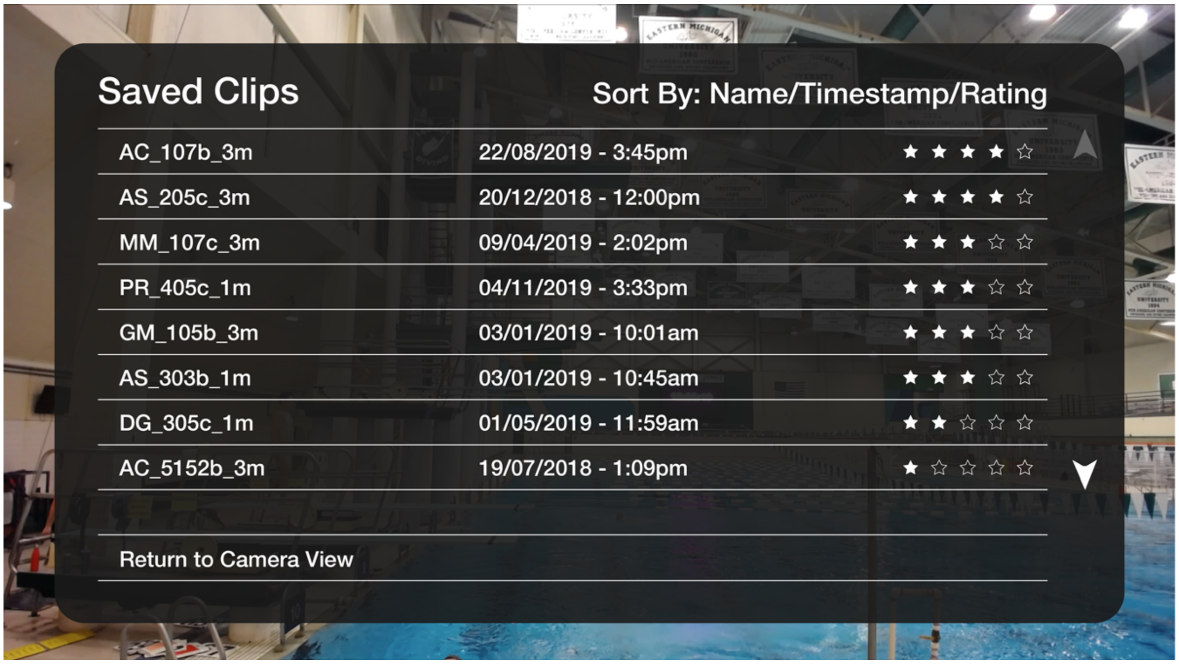
Proposed System Clip Save Panel



Note. UI prototype. This figure depicts the design of the clip saving screen.

Figure 12

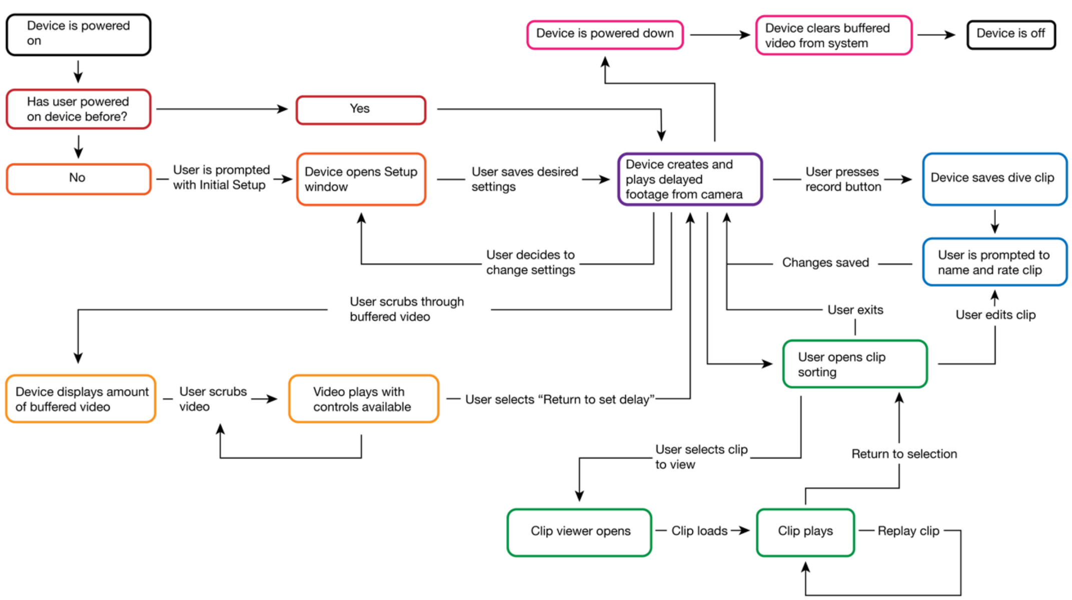
Proposed System Saved Clips Panel



Note. UI prototype. This figure depicts the design of the clip sorting screen.

Figure 13

Proposed System User Flowchart



Note. User flowchart. This diagram depicts the intended way users will interact with the system throughout a practice session.

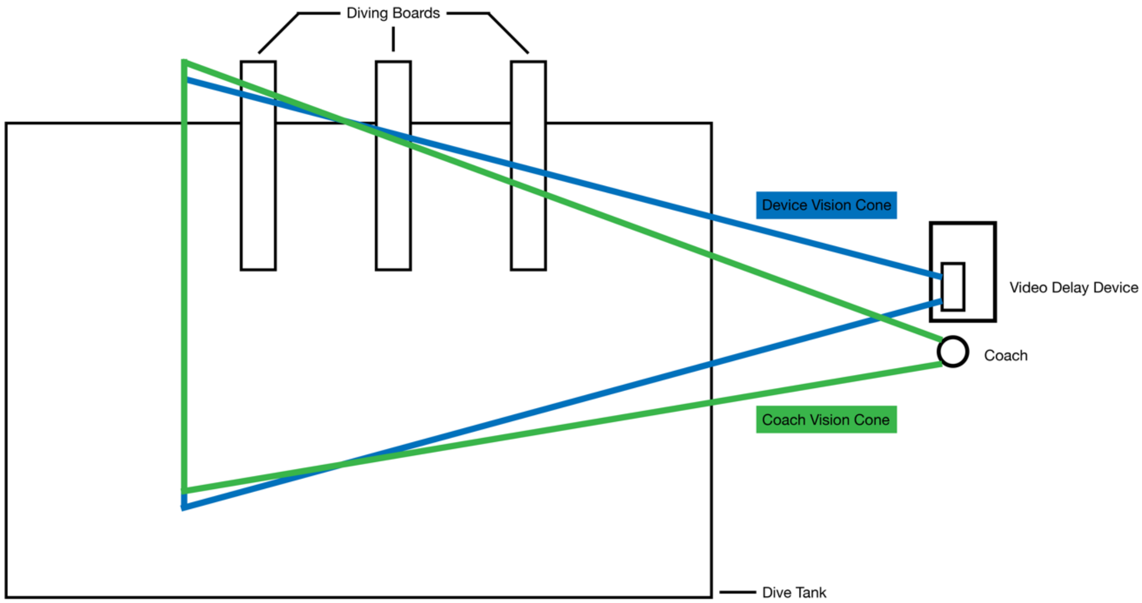
4 - User Scenarios

The following scenarios are used to demonstrate why significant features are included in the system. Each scenario seeks to address potential uses for each feature and includes detailed reasoning for its inclusion.

Live Video Delay - Live video delay is a feature that allows the system to take live video input from a connected camera and delay it by a user defined amount of time, in seconds, to create a lag in the video. This allows athletes and coaches to review actions that were made seconds prior to viewing. The positioning for the device, a diagram of which can be seen in Figure 14, allows for divers to understand how their dives look from the vantage point of both coaches and judges during competition. Every aquatic facility has a unique setup that will not always conform to Figure 14, but, in general devices of this nature are set up on a 90° angle to the diving boards and look towards the pool. In this setup, the device generally sits on a cart connected to a TV or monitor which all are plugged into a shared power source, which creates a large setup that allows both coaches and divers to access. This setup configuration does not usually allow for a scenario in which the device, the TV, or the cart are close enough to the water to make them susceptible to being subjected to a high volume of water be it splashes or full submersion. This is not to say it is impossible for the setup to be lightly splashed, but a case where the entire setup becomes drenched in water or would fall into the pool is highly unlikely. This viewpoint helps divers and coaches understand how to adjust movements to make dives look technically better from the judging perspective. This delay also allows athletes to see their dives moments after performing them, helping athletes see how their dives look from the coaches and judges angle.

Figure 14

Delay Device Placement Location



Note. Top down diagram. This diagram depicts where the device would be setup in a diving pool.

Saved Settings - For some of the current systems available, users are required to input the settings they want every time they start the system at the beginning of a practice. This would include settings such as the amount of delay to the video feed. This can be time consuming to coaches or athletes when they choose to review the footage during a certain dive. Stopping the video to analyze dives creates a significant amount of delay in the feed when analysis is complete. If, for example, a coach stops the feed to analyze a dive with an athlete and it takes five minutes to talk through the problem the athlete is having, when the coach goes to resume the video feed, there will now be 5 minutes of delay in the video. Due to the nature of this system being built around a computer, saving system settings is easy and allows for streamlined use by both athletes and coaches. During the first-time setup, the system opens the settings panel and directs users to adjust the settings to their liking. Settings such as where the system saves recordings or the amount of delay the system will implement to the video feed will be permanently stored for future use thus eliminating the need to reset settings after each use. If a user is not satisfied with the settings they input during the initial setup, they are able to access the same settings panel anytime to readjust the settings to better suit their coaching style and needs. If any change is made to the settings, they will be saved automatically, and the system will reflect that once users close the settings panel.

Video Clip Recording - During any given practice session, divers can do anywhere from 40 - 100+ dives. The number of dives grows even more when the number of divers is put into context: a coaching group can range from one diver to eight divers under a single coach, meaning a coach can watch 40 - 800 dives per practice session. In doing so, coaches will try to obtain footage of a dive for later reference through any means, whether pre-recording the dive with their phones or recording the footage from a delay system connected to a TV. Recording in this manner reduces the quality of the footage captured which results in less information the coach can work with when analyzing a dive with an athlete. Implementing a clip saving feature where all the coach must do is click a button can vastly improve their ability to watch more dives which, in turn, allows them to help more divers through various problems that they experience. The clip saving feature is accessed through the settings menu and asks users to input the amount of time they would like the system to cut the footage and save. For example, if a coach has selected a timeframe of 10 seconds for clip saving, the system would save 10 seconds of footage after the save button has been pressed. The clip is then saved by date and time and stored in the user specified path either on internal storage or onto a connected external drive.

Rating System/Sorting - As athletes and coaches progress through their practice sessions, it is often likely that divers will perform good or excellent dives. Due to the nature of diving, athletes may have plenty of good dives during a practice or have no good dives. To help coaches sort through saved clips, a rating and sorting system has been developed. In this system, once a clip has been saved, it can be renamed, and it can be rated on a scale from 1-5 stars. The rating scale has been developed to mirror the FINA rating scale with 1 star as a "satisfactory" dive, 2 stars as "good", 3 stars as "great", 4 stars as "very good", and 5 stars as "excellent". Labelling the rating system in this manner is thought to help provide some context to coaches when deciding how to rate a dive. The rating system lines up almost identically to the high end of how judges will score a dive based on their technical observations of the performance. In diving, judges rate performed dives on a scale of 0-10, in half number increments, based on their technical observations of the dive. The higher the number scored by a judge, the closer a dive is deemed to be perfect based on these observations. An average dive is scored between 5 - 6.5, with 6.5 edging towards the higher side of good depending on the judge. With this rating system, coaches are encouraged to save dive clips when they deem a dive in practice aligns with the higher judging scores. The clip rating system has an added benefit of assisting in sorting clips, allowing for clip searches to yield results based on the rating search criteria. Coaches and athletes can search for clips based on a rating, or search based on other criteria such as name or date and time.

Coaches can use this rating and clip saving system as part of their teaching methods by saving clips for future use. Clips are typically used for positive reinforcement for athletes and benchmarking performance throughout the year. Coaches will often benchmark performance throughout the season, starting from the beginning by taking videos of dives to assess where athletes are after coming back from the off season. This is usually done to help athletes get a gauge for how much progress they have made throughout the season by allowing them to compare dives from the beginning of the season to where they are when reviewing the footage. This type of evaluation is similar to, but not the same as, recording good dives for positive reinforcement. Coaches will record good dives for athletes as a way to help positively reinforce their actions in an effort to get athletes to retain the thoughts and feelings they had while performing the dive in practice. By doing this, coaches seek to instill confidence in the diver so they can perform the dive well while under the pressures of competition.

There are other scenarios and use cases for features such as the ones detailed above. The above use cases are necessary ones in expressing the reasoning for including these features in this device. It is also necessary to outline such scenarios and features to express why such a device is needed and why these use cases could not be simply solved with the use of a mobile device or tablet. Everything in diving revolves around judging the performance of the dive, it makes sense to develop tools that are built around that understanding.

5 - Conclusion

Various studies have concluded that video analysis is a beneficial training tool for the overall performance and retention of skills in athletes who participate in reviewing skills with a coach. Guadagnoli et al. concluded that athletes who are given verbal instructions paired with video analysis had increased skill acquisition over time (Guadagnoli et al., 2010). The research by Boyer et al. suggested that younger athletes who observed videos of Olympic level athletes were able to perform their skills with better precision after watching the Olympians perform the skills (Boyer et al., 2013). Research by Maslovat and Franks determined that athletes who participate in repetitive performance sports are able to increase their error detection while doing video analysis with their coaches, which in turn positively impacts their future skill learning (Maslovat & Franks, 2020). Franks also noted that video is beneficial for athletes as it presents feedback in the skill learning process and when given instruction from a coach, it can positively benefit athletes (Franks, 2004). Whether it is reviewing their own performances to better understand how to manipulate their bodies or reviewing the performances of the top athletes in their field, studies have shown that both result in a positive training outcome and create a lasting impression on how athletes learn and acquire new skills (Boyer et al., 2013; Franks, 2004, Guadagnoli et al., 2010; Maslovat & Franks, 2020).

The research in this study demonstrates that the creation of a low-cost video playback system is viable. The current systems available in the market produce the desired outcome, but many have significant limitations due to a lack of interaction with real world users. Because of this, there is a technology gap present in the video delay devices market that could be filled by a device such as the one outlined in this Major Research Project. Currently available solutions on the market fail to meet all the needs of both coaches and athletes thereby demonstrating the need for a competitively priced, feature filled, device that allows users to delay and review live video, save clips internally or externally, and allow users to connect external cameras to record separate vantage points. From a cost perspective there is significant room to place the project under the two feature leading solutions: Sideline Scout and Dartfish. Both solutions sit at a price point above $1000, creating a significant window of opportunity to price below them, and evaluate a retail price within $100 of the solutions available on iPads. In doing this, it is hoped that the proposed solution is seen as on par with the competition for everything included in the system, but with the added benefit of coming in at a significantly lower price point.

5.1 - Future Developments

The final steps of this project will be to develop a fully functioning prototype, test and validate it, and develop it into a fully functioning product that is ready to be sold to the public. These steps are determined to be outside of the scope of this MRP.

The next steps for the project would be to evaluate the UI in user testing. User testing can address potential issues that were not thought of during ideation. Engaging in user testing can also help figure out what, if any, features should be included or removed based on actual user testing. After user testing, integrating the UI into the current dashcam program would be the next step. Putting the UI into the system and, again, having real world experience stressed on the system to validate whether it is easy to understand and use from a new user's perspective. The goal of the system is to be intuitively easy for new users to unbox, plug in, and use right away. User testing would be conducted in the field and would validate the UI for various groups including, athletes, coaches and judges. By conducting user testing with these groups, the UI will be optimized to fit specific needs of each of these users. Doing user testing around these aspects would be beneficial to the overall outcome of the product and encourage a more user-friendly approach to building the system.

After user testing is complete and a fully functional user interface is in place, the physical design of the waterproof case for the device would be completed. Users will be asked for input during the UI testing to ensure the design meets both the needs of users and the demands of the harsh pool environment. The prototype design for the housing, will initially repurpose a Pelican style box to fit the device. Sections of the Pelican will be cut out to allow for external connections to the Raspberry Pi that is held within, and will also ensure no external contaminants, such as water, cannot get in. Given the nature of a pool environment, waterproofing the case effectively may require many design iterations to perfect properly. On top of creating a case that is watertight, some consideration needs to be made on how to effectively keep air circulating on the inside of the case that allows the Raspberry Pi that is inside to not overheat with use. This problem is of paramount importance because a swimming pool is naturally a hot and humid environment which isn't an ideal place to locate a computer. Overcoming efficient waterproofing and effective heat dispersion problems are posed to be the biggest design challenges for bringing this device to market.

There are various avenues for distribution of the device that are available depending on the method. There is the completely free distribution method, in which all the plans and software are posted to the internet to help people build their own devices. The device would be heavily documented, outlining how exactly to set up, assemble, and load software onto users' devices. Another option would be for word of mouth to help distribute it and charging users a one-time fee for licenses to the software code and leaving the assembly of the device up to the users. For other not savvy users, they could be charged the license fee and an extra assembly fee to put an out of the box solution together for them. A third option would be to partner with various bodies in the Canadian diving community to help spread awareness of the device. Partnering with bodies such as various athletic equipment manufactures and dive clubs for sponsorship and good word of mouth interaction with other clubs all over Canada and beyond or partnering with the overarching diving body for the country, such as Dive Plongeon Canada (DPC). In partnering with DPC, that gives credibility to the product as a whole and increases the likelihood of clubs around Canada purchasing the system. Partnering with DPC also adds credibility to the device on the international competition level. If the system is partnered with the Canadian diving body, other countries around the world will see that Canadian national divers are using this device and would be interested in acquiring it for their national level teams to use.

Once the device is created and sold freely in the diving market, other sports can be marketed towards as the benefits of video analysis does not stop at just diving. All sports, whether individual or team based, can benefit from the use of video analysis much the same way that it benefits divers. Expanding to other markets serves as a potential challenge as they all have varying styles of how they analyze video and coach movements, resulting in different marketing tactics being needed to break into these other markets.

Following these steps that are outlined above, it is believed that this would position the project in such a way that it could become a competitor in the broader video delay device industry both price wise and feature set wise. This would allow continuation of development into more features and allow the project to be further refined over a longer period of time.

5.2 - Continued Research

The following ideas are meant to illustrate where the current technology can progress, as well as demonstrate some potential areas in which future research could go. The ideas are based on expanding current technologies and exploring where they can go, while also remaining grounded in their possibilities. They venture in both a Digital Media realm, as well as, a general athletics realm and seek to invigorate future innovations.

The proposed device as it currently stands, is run off a Raspberry Pi SBC required AC power from an outlet in order to work. This can be a potential electrical safety hazard in a pool setting as running live wires around bodies of water is problematic. Despite the obvious safety risks, dive clubs currently run extension cords on the pool deck to power equipment. To make a safer environment for everyone involved, a DC based battery powered system would mitigate this safety risk. As a solution, a battery power backup can be integrated into the inside of the case to power the unit. If space is not a constraining factor to users, larger capacity batteries can be included to greatly increase the amount of time the device is usable for during each practice session. To get around the need to charge the device after every use, a mini solar panel can be attached to the outside of the case which would be used to harvest light energy from the building illumination system, or if windows are nearby, the energy of the sun.

The current design for the device housing allows it to be water resistant, meaning it can repel water from entering the inside, potentially causing damage to the Raspberry Pi encased inside. A future development for this could investigate securing the case in such a way that it could be more than just water resistant, but also waterproof. This would completely negate any damage in such a scenario where the device is somehow knocked into the pool or is subjected to larger amounts of water than small splashes. Developing this would prove to be a challenge as the current design incorporates holes in the case to allow other devices to be connected such as an HDMI cable or USB cables. In developing a full waterproof housing, there would be an insignificant chance of a scenario in which the device would fail due to exposure to water in any way.

With the rise in Artificial Intelligence (AI) and machine learning, it could be theorized that those technologies could be applied to video analysis in sports. By implementing these technologies to analyze sport video data, they could learn to read potential patterns in athletes that would not be recognized by coaches in normal circumstances. These patterns could include things such as errors in gross motor movements that negatively impact the athlete’s performance or recognizing new patterns that are not currently realized. Machine learning could be trained to recognize judging patterns from live diving footage at meets and this could be used to understand judges and their scoring preferences which would help athletes and coaches perfect minor movements that push top tier athletes from being scored 9.5’s to being scored perfect 10’s. By allowing AI and machine learning to interact with various sports videos, athletes and coaches could potentially push their sports to new performance peaks not thought to be possible before. This technology can also be applied to combat judging bias at higher competition levels where judges may be more prone to score higher for athletes that are representing their home country. Allowing machine learning to analyze how each judge scores dives and divers can help understand and analyze the bias that each judge exudes in their scores. This kind of technology can help create a more equal playing field where everyone is judged fairly, and scores are given in an unbiased manner.

Talk-to-text can be added as a feature to help coaches who are busy and do not have time to name individual clips they wish to save. This feature allows users to use their voice to talk to the system and have it dictate their words into text, and saving those words as the file name. For example, if a coach saves a clip, the system would ask them to name it verbally, the coach would say the file name they would like, and the system would save it as such. Implementing a feature like this could greatly help streamline the clip saving process as coaches would not have to focus on renaming the clips, rather they could speak the preferred name of the clip and continue their coaching.

AI and machine learning can also be used to help users sort and rate clips saved to the system. By allowing AI and machine learning to analyse and understand what makes certain dives good, it can be used to automatically rate saved clips for users based on either their past ratings of dives or it can rate saved clips based on clips of Olympic level divers and how it would rank against them. Utilizing AI and machine learning in this way benefits users as it streamlines the saving process and integrates well with talk-to-text naming. Both features would greatly streamline clip saving for coaches who are busy concentrating on giving divers corrections during practice.

Further research can be done into the performance-divide that is mentioned in this MRP. Researching the performance-divide between different levels of athletes that receive different types of funding to pursue careers into their chosen sports and whether that funding has a significant impact on the outcome of an athlete's performance level. Researching and documenting whether the performance-divide hinders athletes at a certain level can help to address problems in how athletics are funded at both a Provincial level and a Federal level. As it currently stands, athletics get very little funding and money to train typically comes out of the pockets of both athletes and their coaches. This creates a somewhat uneven playing field if athletes who have more funding can secure better coaching or services to help push their athletic career further than someone who has less available access to funding. The touched upon aspect of the performance-divide mentioned in this MRP is merely a starting point and can easily be expanded upon.

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