Plan for data collection and Creating

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# Collection:

Over the next few weeks swimming video data will be collected and processed for Machine learning purposes. The goal is to find a **large variety** of data to help any model create the largest possible generalization of all possible video race recordings.

## Sources of Variety:

There are three main contributors to variance when it come to capturing swimming races in pool environments.

1. Venue
2. Camera angel
3. Swimming

In these categories there are subcategories

Venue:

* Pool setting (indoor, outdoor)
* Number of lanes in pool (6, 8, 10)

Consider these when final overview of collected data in completed

* Depth of pool (shallow, deep, shallow and deep)
* Color of pool (dark, light)
* Color of lane ropes (ropes are generally: red, yellow, blue, green, black)
* Type of blocks (more research needed)
* Flags or no flags

Camera angel:

Each camera can have one vertical position in space relative

* Pool level (can only really see first 2 swimmers)
* Mid level (not able to see the last 2/3 lanes of swimmers due to angel)
* High level (can see all swimmers)

Each camera can have one Horizonal location in space relative to the pool

* Mid pool
* Dive end
* Turn end

Typically, there are three main angels used: Mid level and Dive end, High Level and mid pool, Pool level and turn end. Lastly races can start on either side of the of the camera view (left and right). Thus, there is a total of 18 different angel combinations. More effort will be put into choosing which ones are most important.

Swimming:

* Race name
* Two genders

Consider these in variance post analysis

* Thoughts on swim relays…. Forgot about that in the initial plans
* Age (we are going to start with national level swimming, which is not an age but limits the age drastically and more importantly the specific style of swimming)

## Preprocessing:

When a video with appropriate footage is found it will be preprocessed into a video that includes only race footage **without jumps in the footage** (camera changes).

1. The video will be renamed according to its place in its file destination.
2. A data file will be mapped to its name, this data file will initially contain header with, video frame rate, video resolution, the frame skip size, and total number of frames in video.
3. It will then be saved into the storage system in the appropriate section.

Appropriate footage (for now) is defined as video that contains no zoom action and contains the entire vertical view of the pool 95% of the time. This is because we want footage of the entire pool for swimmer detection in later work.

If swimmers are lost in the video due to race circumstances (swimmers falling out of the horizonal view because they are slower than the first-place person) that is okay.

## Video storage:

All videos will be collected and stored in a storage system containing all possible combinations of variance for swimming environments.

Example file structure.

Indoor

outdoor

|---- 6lanes

|---- 8lanes

|---- 10lanes

| |---- comp\_name or pool\_name (must be unique)

| | |---- LCM

| | |---- SCM

| | | |---- right\_diving

| | | |---- left\_diving

| | | | |---- male

| | | | |---- female

| | | | | |---- 400IM

| | | | | |---- Other\_races\_names (will not depend on SCM and LCM)

| | | | | | |---- mid\_pool

| | | | | | |---- dive\_end

| | | | | | |---- turn\_end

| | | | | | | |---- pool\_level

| | | | | | | |---- mid\_level

| | | | | | | |---- high\_level

# Creation of data

When data is created, bounded boxes will be mapped to frames of swimming footage to locate a swimmer in a specific class (Starting, Diving, Underwater, Swimming, Turning, and swimmers finishing/finished). After boxes are made stroke analysis will be created next by saving frames with specified stroke positions.

## Box Class definitions

This section outlines when one class starts and the other begins. It is obvious to determine what action occurring at a given moment in general. There are points in a race when a swimmer must transition from one class to the next. In retrospect I could have even decided to create a 7th class called a transition class however I reason that one can be created once after all the classes have been created, if needed.

There are 6 different classes and there are strict rules on how a swimmer can transition classes. Thus, in total there can only be 6 transitions. They are

1. Start -> Dive

The transition will be defined as the point when the swimmer is no longer touching the blocks. **Touching blocks == Start, not in contact with blocks == Dive**.

1. Dive -> Underwater

The transition will be defined as the point when the feet of the swimmer become occluded by the water. **Feet can be seen in the air == Dive, Feet no longer visible in air == Underwater**.

1. Underwater -> Swim

The transition will be defined as the point when the swimmer breaks the water with any part of their body, in general. **Swimmer is completely submersed == Underwater, swimmer brakes water to take a stroke == Swim**.

1. Swim -> Turn

The transition will be defined for two scenarios.

**Scenario one**, the swimmer is preforming a touch turn. The turn commences when the swimmer touches the wall. **Swimmer yet to touch wall == swimming, swimmer touched wall == turning.**

**Scenario two**, the swimmer is preforming a flip turn. For backstroke to backstroke, **the turn commences when the swimmer is on their front with both hands down**. Or the swimmer is preforming a free to free turn, **this turn starts when the head is underwater for the flip**.

1. Turn -> Underwater

The transition is when the swimmer’s feet leave the wall. **Swimmer still touching wall with feet** == **Turning, Swimmers feet completely off the wall == underwater.**

Due to splash and bubbles this will be estimated. The point when a swimmer completely strait can also signify the underwater starting.

1. Swim -> Finish

The finish starts when the swimmers hand touches the wall. **Swimmer still has not touched the wall == swimming, Swimmer has touched the wall == finishing**

## Box specification procedure

This section outlines how to how to put a box around a swimmer. This is very important as it is critical that every labelled swimmer is labelled the same way so that a machine learning algorithm can learn them effectively as ground truths. The current goal is to make sub videos with the boxes to use for a stroke counting model. The boxes will also be used for swimmer detection. The rules for the creation of the boxes will be loosely based on the VOC2011 Annotation Guidelines created by PASCAL visual object classes homepage [1] <http://host.robots.ox.ac.uk/pascal/VOC/voc2007/guidelines.html>.

With this documentation in mind, in general the box must be the smallest possible box containing the entire swimmer. Because there are a variety of situations where this statement becomes ambiguous there will be some general guidelines for specific classes. They will be general to account for the different angels a camera can take.

* On the blocks. Put the tightest box possible around every swimmer on a block. For swimmers in the farther lanes and behind other swimmers, add the tightest box possible around all visible parts of the swimmer.

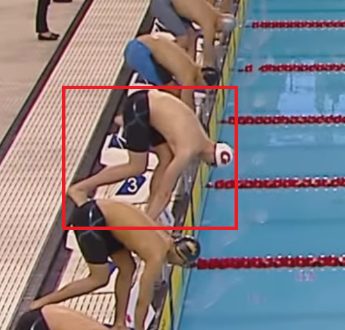


Figure 1: swimmers on the blocks

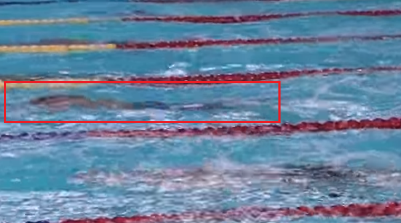
* Swimming. Add the tightest possible box around the swimmer. Stretch the box to include arms and hands. If the legs or feet are hard to see don’t include them.

A picture containing outdoor, fence

Description automatically generated

Figure 2: Swimmers swimming

* Underwater. The hardest class to label. When a swimmer is visible, create the smallest possible box that encompasses the swimmer. As seen in figure 3 swimmers can be labeled underwater. But when a swimmer becomes to difficult to see due to the camera angel then a box can’t accurately be put around it, as seen in the far lanes in the left picture of figure 3.

A close up of a swimming pool

Description automatically generated

Figure 3:

left image: labelled swimmer underwater

Right image: Example of lanes, too difficult to label

* Turning. Another difficult class as the swimmer can’t really be seen all the time because of water and splashing. The general position of the swimmer is obvious as they must be on the wall. So, the smallest box shall be made around the swimmer such that it encompasses the swimmer visible swimmer (use best estimate). If a swimmer is visible and it is possible to select a minimal box, then do so.

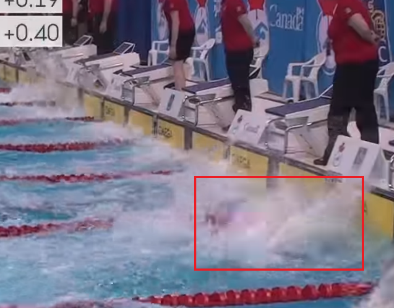


Figure 4: Turning swimmer

* Finishing. Put a box around the visible part of the swimmer. As a swimmer finishes, they generally look for the clock to see their time. As this happens, they transition from swimming and being in horizontal body position to standing a being in a vertical body position. Due to the refraction of water and bubbles formed by the swimmer the body of the swimmer becomes invisible to the camera. Thus, a minimal box around what is viable is all that is required. In retrospect to making figure 5, I would say that the top of the box is too high and thus it is an example of a non minimal box. The top of the box should be bought down closer to the position of the head of the swimmer.

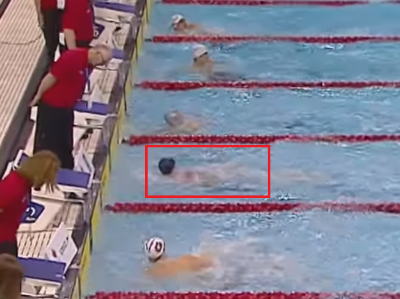


Figure 5: Finishing swimmer

* Diving. As you can see in figure 6, this is a reasonably easy class except for the odd shape of the swimmers. For diving swimmers put the tightest box possible around every swimmer in the air. For swimmers in the farther lanes and behind other swimmers, try to add the tightest box possible around what is visable.

In Figure 6 at first glance it is somewhat difficult to determine exactly what swimmer is being boxed because the minimal box including the entire swimmer must also include the swimmer below. The two swimmers above present an even more drastic example of this problem. This analysis will be considered later in research. However, it shows that the swimmers can still be distinguished by the human eye.

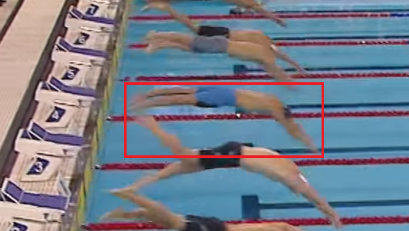


Figure 6: Diving swimmer

## When to put a box around a swimmer:

Given the definition of how boxes shall be administered to swimmers it is important to make it clear when a box should not be included in a frame.

Generally, if 80% - 90% of a swimmer is cut off by the camera do not give them a box.

* Swimming. Put a box around a swimmer that can be identified in any way. Unless it is cut off by the camera or camera angel.
* Underwater. **Don’t** give a box if swimmer can’t be seen (90% of swimmer behind non swimmer object) due to angel and lain ropes.
* Turning. Due to the rules of boxing turns, there should be no point at which a turn should not be boxed unless it is cut off by the camera or camera angel.
* Finishing. Again, there should be no reason not to box a finish unless it is cut off by the camera or camera angel

## Storage of box parameters:

Box parameters will be stored in a data file with the same name as the video file, as mentioned in the prepossessing section. The data will be stored in a text file as 2D array of size nxm, where n is the frames number, and m is a rectangle in frame n. Each rectangle is defined by a rectangle object. This object will define a rectangle in terms of the pixel position of top left corer of the box relative to the to left corner of the frame, and the height and width of the rectangle in pixels. A box object will also hold the class of each box and the swimmer lane number. This will require 6 numbers, they will be x, y, h, w, c, and l always in this order. For example: a line in the text file says {300, 245, 500, 500, class\_num, lane\_num} (Figure 7). This says there is a swimmer in the nth frame. In a box where the top left corner of the box is located 300 pixels from the left top corner of the frame in the x direction, and 245 pixels from the same origin in the frame in the y direction. This box has height 500 and width 500 (it’s a square). Finally, it contains a swimmer doing the action represented by class\_num in lane lane\_num.

A screenshot of a cell phone

Description automatically generated

Figure 7: Example box in green, in frame n of arbitrary size

The size of m depends on the number of swimmers in a frame and how many are visible. Thus, if all pools are not larger than 10 per lane there will be no more than 10 boxes a frame, so 60 numbers a line. If a box is left out it, simply is not added.

The order of boxes will not matter.

If there are 200,000 labeled frames all containing 10 boxes. The text files would have to hold 12,000,000 numbers of size 4 chars or less. That would be 48MB of data, roughly.

## Method of creating boxes

A semi automated box making application needs to be made to increase speed of swimmer labeling! I have created a GitHub account and I will be developing the project, swim\_annotate. Ideas planning will follow in the next section.

### Preliminary research: Before creation

After some research I found a function selectROI() that produces a window of an image that can have rectangles dawn on it, the function returns the rectangle object that was dawn in the window. This will be the brut force function of the labeling mode system.

### Box Project Goal Looking back… could have used Yolo\_Mark on GitHub.

Main goal of box project is to take a raw video downloaded from YouTube and create a video or sets of videos (depends on if there are camera angel changes in the video), with boxes around the swimmers.

### Specifics of what needs to be done

Based on the requirements set beforehand, there will be 4 main modes that allows for the completion of this task.

1) Preprocessing mode

2) Labelling mode

3) Storage mode

4) Start up mode

#### Preprocessing mode

In this mode the raw video will be loaded from a file and added to the program.

* The video will be able to be played by the program and reviewed frame by frame. In this step the original video can be trimmed and cut into sub videos if necessary.
* This mode can also be used to look at annotated video that has been saved and completed.
* The resolution will not be adjusted.
* When sub videos are made, they will be labelled by camera angel and order of camera angel, that is if 5 sub videos at camera angel “x” occurred they will be stored as x\_1, x\_2, … and so on. The program will keep track of each video to be labelled for the next section.
* When the video cutting and trimming section is complete header files for each sub video will be created containing the specified information from the documentation above.
* At all times the frame number of the current image will be available.
* All videos that have not been finished and packaged for labelling will be saved in a preprocessing folder for later use.

In this mode the following options will be available

* View video options

1. Go to selected frame
2. Give frame number
3. play video
4. pause video
5. Go to next frame
6. Go to last frame
7. Exit video view options
8. Show annotations, remove annotations (toggle)
9. Trim video options
10. Give start and end frames
11. Make sub video
12. Give start and end frames

* Mark as finished for labelling
* Save current progress and exit mode
* Delete current video
* Load a video in the prepossessing file
* Leave preprocessing mode

After working with openCV and Qt I have decided that the best thing to do would be to download a video editor…. Duh. So, the Machete Lite app was chosen for its simplicity and light weight to act as the “preprocessing mode”. I will use Machete Lite to preprocess the videos and then save them manually in an organized file to be processed by Labelling mode. Bellow is the important part that must be done manually.

* When sub videos are made, they will be labelled by camera angel and order of camera angel, that is if 5 sub videos at camera angel “x” occurred they will be stored as x\_1, x\_2, … and so on. The program will keep track of each video to be labelled for the next section.

#### Labelling mode

In this step the trimmed and cut video will be annotated using a variety of methods.

* The labelling process will skip every other frame to save space and because there is not much new information from frame to frame.
* For the annotation of a swimmer, a ROI (region of interest) will be defined, then next fames (this would be frame 3 as we are skipping every other frame) ROI will also be defined. Using these frames, the third frames annotation will be predicted for the same swimmer. This prediction will be confirmed by the user or redefined if it is incorrect. Then the recently confirmed frame and its previous frame will be used to predict the next frame, and so on.
* A lane number will also be assigned to the swimmer and every frame annotation that corresponds to that swimmer.
* Each time an annotation is saved to its corresponding text file and will be updated every time a save current annotation command is executed.
* Every video that has not been filed to the final folder will be saved in a labeling mode folder unfinished folder.

In this mode the following options will be available.

* Start annotating video

1. Select lane number of annotations
2. Create ROI
3. Save current annotation and move to next frame. Will create a new annotation if one does not exist or update one that already exists
4. Create better prediction/try harder to make a better annotation?
5. Go back to last frame
6. Go to next frame
7. Move to any arbitrary frame
8. Stop annotating video

* Quit labelling mode
* Load new video
* Mark video as finished for storage

#### Storage mode

In the last part of the labelling process the work that was completed is filed correctly into a database, based on what is in the video.

* When the name of pool is requested the user will be prompted to first choose from the already available pools before creating a new one to limit pool repeats.
* There will be a text file that holds general statistics of the total amount of labelled data in each category in the file system.
* At any point if the use quits the information that was entered will be saved in a temporary file

The following information will be requested

* Indoor or outdoor pool
* Number of lanes
* Pool name
* SCM or LCM
* Direction of the dive
* Gender in race
* Race name

In this mode the following options will be available

* Refile a video and its data or finish a file that has not been finished
* Store a labeling mode file
* Exit storage mode to start up mode and save current progress

#### Start up mode

At start up there will be a main screen that allows the user to move to any one of the other modes.

* This mode will be able to display data stats

In this mode the following options will be available

* Go to prepossessing mode
* Go to labelling mode
* Go to storage mode
* Exit application
* Show data stats

#### General Requirements

General design of system and system requirements

* At all times progress needs to be saved
* When things are deleted, ask before continuing
* Things should be able to be edited at any point in this process
* The application will be shell based but will a single window that allows for video viewing
* Any work that is repetitive needs to be optimized for optimal output speed

2019-06-12, Current work completed since start / current state of things:

Summary:

Program can…

* load in a text file with annotations and displays the annotations made.
* It can specify what lane number it is working on and displays the appropriate lane numbers annotation
* It can move frames, frame by frame
* It can move to an arbitrary frame
* It can update the data created by manually inputting a ROI
* It has a proper destructor
* Displays the annotation options available
* Change the current annotation class

Work still to be completed:

* Need to be able to update text file when quitting application – done
* Need to be able to predict next frame – final thing, use DSST?? Downloaded the extra modules (includes the tracking API) we can try a bunch of the tracking API functions to find the best one for all situations.
* Need to think of a fast way of implementing button pressing to streamline labelling process (specifics are in display options, need to change things to mouse button clicks) – tried my best
* Want a function that moves the current frame to the biggest frame with unannotated data for that lane – done
* Would like a way to update text file without closing app (can be done by exiting annotation mode and then entering again) – done
* Have a temp text file to save work if crash occurs – done
* Update the text file with every class change and lane change – done

**Choose best tracking API:**

Needs to work in all situations (on blocks, diving, underwater, swimming, turning, finishing) to find best method do a test with all methods on the same data and calculate guessing accuracy for each in each situation.

**Boosting** (OLD AF) For diving it sucks as it stays in the same place. Almost follows swimmers.

**MIL**: For diving it sucks as it stays in the same place. Almost follows swimmers.

**KCF**: For diving it sucks as it stays in the same place. Might be due to improper implementation. Fails to track anything at all. Must give large ROI for training or will have problems tracking.

**TLD**: For diving it sucks as it stays in the same place, but it changes the size of the box which is nice. For swimming immediately tracks non swimming things.

**GOTURN** (DATA NEEDED): This one crashes, this is because there needs to be a cafe model in the directory.

**Median Flow:** Useless for diving, worst one! Sucks for swimming.

**MOSSE:** Basically, the same as Median Flow. Was able to follow swimmer, with ~30% accuracy.

**CSRT:** tries to make the best fitting square. Still can’t make it off the block. Sucks for swimming.

After much testing on raw pixels and doing more research the best tracking algorithm seams to be KCF. After reading the KCF paper I found out that its performance becomes better when used with the **HOG feature extractor**, but with further research the **Adaptive Color Attributes** feature extractor might work better as swimmers are easier to differentiate based on color rather than their gradients which I believe might be very chaotic due to water splashing. I shall try to implement both and compare results as well as look for any other tools to improve my results.

### Code Architecture: After most development has been completed (except stroke annotator)

As we all know, things don’t end up turning out as planned. In the end a video annotator was created however, it only contains the start up mode and the annotation mode. For future work another mode will be added so at start up mode the user can annotate boxes or strokes. This will be discussed in the stroke data collection section.

**After finishing annotating one video (2019-06-30):**

I have produced roughly 7000 annotations for 5 swimmers in LCM 200 IM race (men’s). I am happy with my custom-made annotator as it annotates at roughly 1 annotation every 2 seconds. I will not lie; hand annotating swimming footage is a very boring activity and reasonably tiring (or maybe I have HDHD problems or something). Thus, to avoid it as much as possible I have decided to look at how affective my work will be for a NN to identify swimmers in the same pool. Thus, I will be training multiple of the same models with different amounts of the same data and evaluating the optimal amount of data required for one pool.

Lastly, I would like to know if:

1. **The video quality is too low**
2. **I have too many annotations or too little and for which classes**
3. **Is it even possible to create a network, even with perfect data, that can identify swimmers?**
4. **It is possible to create such a NN, what is the minimum work I must do to generalize a pool**
5. **How small my ROI can be before I am wasting my time or creating noise**

### Swimmer detection quantifying network results

With the goal of detecting swimmers in a pool to create sub video to use to count strokes of individual swimmers. An optimal amount of data needs to be collected for an optimal number of pools to properly generalize all swimming environments. This will allow a network to create sub video for all possible environments allowing the stroke counting network to get stroke counts for swimmers. While reducing the amount of unnecessary work collecting data of swimmer boxes in videos. Thus, to find this optimal amount of data some analysis metrics must be created to determine how well a network has preformed.

#### Important metrics for creating sub video

A list of important metrics for creating sub video of swimmers in order of most important to least

1. Swimmer detection rate per frame (mAP)
2. Swimmer detection rate per lane (mAP)
3. Swimmer classification accuracy (mAP, for each class)

A swimmer is correctly detected by the model when the IOU of the predicted swimmer and the ground truth is grater than 0.5. The PASCEL VOC paper is used to qualify results.

Precision, fraction of correct swimmer detected out of all swimmers detected.

Recall, fraction of swimmers found correctly

## Stroke counting data

Stroke count data will be collected for NN training. This process will be simpler as all that needs to be done is record the frames that contain a point in each stroke’s, stroke cycle. The definitions will follow. With this data a 1D signal can be made to represent a swimmer’s stroke and this signal will be used for the NN.

### Stroke definitions

Each stroke will have well defined cycle start and end point (the start and end will be the same frame as this is the cycle nature of swimming), two strokes have half cycles and another two can only have whole cycles. When annotating swimming footage these definitions will be used to record the frame number for the appropriate action in the video

#### Stroke with half cycles and strokes without:

The freestyle and backstroke stroke, are asymmetric, meaning there are two different pulls in one complete stroke cycle. While fly and breaststroke have symmetric pulls and so each cycle contains only one pull at a time. For the strokes with asymmetry galloping can occur and can be characterized by defining half cycles. For fly and breast, the stroke can be completely characterized by one complete cycle.

#### Cycle definitions

Freestyle, this is an asymmetric stroke and so it will have two half cycles. The first half cycle will be defined by the right arm of the swimmer. The beginning and end of the cycle will be at the top of the stroke, or when the right arm is completely extended after the completion of the right arm recovery. The left arm is defined similarly but with respect to the left arm. In this case and all the following cases, the right and left of a swimmer is defined relative to the swimmer and not to the viewer. **In summary right arm == 1st half cycle, left arm == 2nd half cycle.**

Backstroke, this to is an asymmetric stroke and so it will also have two half cycles. These cycles will be defined by arm as in free style. So, the first half cycle starts and ends at the top of the right-hand stroke while the second cycle starts at the top of the left-hand stroke cycle. In this case and all the following cases, the right and left of a swimmer is defined relative to the swimmer and not to the viewer. **In summary right arm == 1st half cycle, left arm == 2nd half cycle.**

Breaststroke, this is a symmetric stroke and so it will be defined in terms of one complete cycle. The cycle will end at the top of the stroke which is when the breaststroke recovery has come to an end and it will start with the in-sweep of breaststroke pull is about to start. Once again, the end and start are in the same place.

Fly, this is a symmetric stroke and so it will be defined in terms of one complete cycle. The cycle will end at the top of the stroke which is when the fly recovery has come to an end and it will start with the initiation of the fly pull. Once again, the end and start are in the same place.

### Saving stroke count data

Stroke count data will be saved in raw format as a text file. The name of the text file that corresponds to the given video will be the videos name flowed by “\_str”, for example “videoName\_str.txt”.

All stroke count files will have data fields with three values, the first values will be for first half cycle (right arm), the second values will be for the second half cycle (left arm), and the third value will contain the stroke value (1 – 4, 4 == Free, 2 == Back, 3 == Breast, 1 == Fly). If the stroke is symmetrical the first and second columns will be identical. Each number in the row of numbers will be separated by a space and each data field will be in curly braces and separated by commas.

Each lane will have its own line so lane 0 will be line 10 and lane 1 will be line 11 and so on, up to lane 10 which will be line 19.If the lanes don’t exist or the swimmer are too small simply don’t add anything to that line. In summary, a stroke count file will have up to 10 lines of stroke count data with n data fields separated by commas for each swimmer.

### When to count a stoke

There will be points in time that a swimmer will not be visible or a stoke simply can’t be accurately determined. If there are occlusions but you can guess what is happening, make the best guess possible. If the swimmer is more than 90% out the field of view and it is not possible to predict the stroke do not add it to the column of frames, i.e. do not mark down a stroke.

### Methods of collecting stroke count data

A home-made app will be made for viewing videos and marking down strokes and recording the frames. It will be designed to make annotating fast and efficient.

#### Coad architecture

The app will be added on to the already existing architecture of the box application. At start up of the original app there will be an option to add boxes to a video or to add stroke count to a video. When the add strokes option is chosen the app will ask the user if they are ready, and the video will start when the user responds playing the footage at one third normal video speed.

The app will have the option to **pause**, **move forward and back frames**, **change viewing speed** (1x, 1/2x 1/3x, ex… ), **add an annotation**, **delete an annotation**, and **quit application**.

# Training YOLO network for swimmer detection

The once darknet is installed then it needs specific files to work with so that it can train the swimmer detection model.

* A “find\_swimmer” folder is needed containing a “JPEGimages” folder and a “labels” folder.
* The labels are relative to the height and width of the image look up “<https://www.learnopencv.com/training-yolov3-deep-learning-based-custom-object-detector/>” to see what that means. They to must also be floats.
* The images also **need to be JPEG images**.
* There needs to be a **text file associated to each image** by name that contains all the annotations.
* There needs to be a training set and a validation set, swimmer\_test.txt, swimmer\_train.txt.
* Need a darknet.data file.
* Need a classes.names file.
* Need a config file “darknet-yolov3.cfg”

Plan for testing YOLO network:

Use current framework to load current completed work. Then create a new file with data formatted properly and JPEG images with correct names.

# References:

[1] “VOC2011 Annotation Guidelines,” host.robots.ox.ac.uk, [Online]. Available: <http://host.robots.ox.ac.uk/pascal/VOC/voc2011/guidelines.html>