cats.ai: Personalized Sports Training Using OpenPose

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Abstract
cats.ai is a piece of software that democratizes computer vision in the context of sports training. The intent of cats.ai is to provide a means for personalized coaching, without the need for expensive equipment, or any other people, like a trainer. Built on the OpenPose Python library developed at CMU, and inspired by other software, like Homecourt.ai, cats.ai brings Computer Vision to any sport, creating personalized recommendations for improvement, using just a smartphone. We piloted cats.ai with basketball shooting, but its core technology can be extended to many other sport drills or activities. It is also designed with accessibility in mind, so that it can be customized to exclude parts of the body the user has limited or no mobility in.

Author Keywords
Computer Vision; Personalized Sports Analysis; Form; Technique; Coaching.

Figure 1: Example user of cats.ai

Introduction and Related Work

cats.ai stands for Computer vision Accuracy Trainer for Sports. There is a lot of technology in existence right now for improving sports performance, providing sports coaching, and enabling athletes to receive feedback on their form and technique. The KinaTrax system, which consists of 8 to 16 high-speed video cameras, leverages AI and machine learning to provide 3D data on form, mechanics, and injury risks for professional baseball players; the only downside of this system is that it could cost up to $150,000. Trackman is a company that offers solutions for swing and ball flight analysis and tracking for soccer, golf, baseball, and American football.

While technologies such as KinaTrax and Trackman are constantly improving via heightened analytics, advancements in sensor-based technologies, and robust AI capabilities, there is one major problem that remains, and that is that these technologies are prohibitively expensive for many amateur athletes. Technologies such as Trackman require cameras and sensors that cost thousands of dollars, which is probably a larger investment than what a new or amateur athlete can afford or is willing to spend. Oftentimes, many pieces of equipment require many cameras and sensors to even function, and this creates a high barrier to entry when it comes to leveraging technology to diagnose issues with form, technique, or performance in order to directly improve sports performance. As such, we propose to build a solution that allows users to simply use just a phone or inexpensive personal device to receive feedback on their form or technique instead of requiring athletes to possess expensive equipment or have another person or coach be present to receive coaching or feedback on their sports performance. More specifically, cats.ai will leverage computer vision technology via OpenPose to develop a system that analyzes images of a user shooting a basketball in order to record a number of angles and body measurements for the purpose of comparing these numbers to benchmarks for good form and technique. We hope that cats.ai will enable users to receive direct, instant, and actionable feedback for their basketball shooting form.

In terms of prior research, other mobile apps that profess to improve sports performance include 18Birdies (for golf), ServeSpeed (for tennis), and homecourt.ai (for basketball). 18Birdies is an app that allows golfers to track their scores and other statistics related to their performance on the golf course. The app is empowered with GPS technology to allow users to track distances from the hole on the course, which helps golfers pick the right club to hit when they otherwise wouldn't have been able to know precisely how far they are from a particular hole on the course. This app also uses an AI-powered swing analyzer and coach that professes to leverage breakthrough tech to provide users with instant feedback on their swing. The app also suggests custom-fit drill plans that can be used to make progress on fixing the issues that were diagnosed. 18Birdies is an example of a type of application that we are seeking to emulate with cats.ai, as it conveniently provides golfers with helpful statistics and feedback without any cost to the user. ServeSpeed is a similar app but for tennis, with the main value-add of this app being that it calculates a number of statistics regarding one's tennis serve and provides recommendations accordingly.

Perhaps most similar in nature to our system cats.ai, Homecourt.ai professes to provide guided and personalized feedback for basketball players. Homecourt.ai is essentially an interactive app that leverages the expertise of professional players and skilled trainers to help amateur basketball players improve their basketball skills. Homecourt.ai tracks data and statistics for basketball players, such as leg angle, release angle, speed, release height, and release time, when they take shots in order to allow them to benchmark and track their progress over time. The app also allows users to take part in interactive workouts and virtual competitions with friends, family, and teammates. The ethos of this system forms some of the inspiration for our system, and it is indeed apps like homecourt.ai that we want to develop and popularize in order to democratize access to sports technologies and analytics. Cats.ai, via computer vision and AI technology, will seek to provide athletes with instant feedback on their form and technique when shooting a basketball by analyzing images of users received by the system and comparing certain angle measurements to benchmarks that athletes should be meeting, and this will hopefully build on the progress made by apps such as homecourt.ai.

Overview of Solution

As we've mentioned, the goal of Cats.ai is to use computer vision technology to identify biomechanics of form and provide hyper-personalized suggestions based on an aggregation of personal reps. More specifically, Cats.ai leverages a real-time multi-person system called OpenPose to detect key-points on the body and calculate various angles for users when they are shooting a basketball. Cats.ai processes an image of the user shooting a basketball and identifies the location of various joins and calculates the angles between those joints (e.g., hip, knee, wrist, shoulder, and elbow) using OpenPose. The system contains a repository of images of users shooting a basketball that we classify as either successes or failures based on the result of the user's shot (whether it went in or missed), and this allows our system to aggregate the data to identify patterns that distinguish which angles are optimal for users shooting a basketball and which ones are not. Cats.ai then provides recommendations (e.g., "bend your knees more") to the user around what should be changed in their basketball shooting form, and these recommendations are compiled and displayed within an output file with the joint map overlayed.

As a user, it's very simple to use cats.ai. All one has to do is take a video of him/herself shooting a free throw, select the frames of their moment of release that they want to feed into the system, and view the recommendations produced by cats.ai based on what the system has learned previously.

Figure 2: Annotated output from cats.ai

Design Process and Preliminary Evaluation

In terms of the design process, we sought to build a minimum viable prototype for cats.ai that captured our essential functionality while also being easy to use for any user. We limited our initial scope to focus on the action of shooting a basketball, since this is a fairly common activity, relatively easy to perform, and relatively easy to capture via video. Our choice of OpenPose to analyze and process images made perfect sense for our use case because we wanted to give immediate and actionable feedback to our user while also being able to compare a given user's input to past data that has been aggregated all while doing so by allowing our user to upload a single image of them shooting a basketball. OpenPose allows us to take an image and instantly calculate various angles between a number of body parts as we've mentioned before, and we can then classify images based on if they correspond to a successful shot or a missed shot. This allows us to then provide recommendations around what to change in terms of body positioning and movement when shooting a basketball when a user inputs an image of their own. Our design process prioritized functionality and utility so that we could build a working MVP.

Our testing for cats.ai was limited and mostly limited to validation testing. One of the creator's brothers plays high school basketball, so he volunteered to provide testing footage of himself shooting free throws and 3-point shots. For testing, we manually annotated which shots were 'makes' and which shots were misses and used the built-in data entry component of the software to indicate as such with the data. We also selected the frames of the video in which the ball was released since that was the most valuable point in time for our use. Using the aggregated data collected from those frames and the body key points extracted by OpenPose, the software created recommendations for each of the left and right knee, elbow, hip, and shoulder.

Since the main functionality that we developed is the data processing and not a user interface, we didn't try testing the workflow from start to finish with a user outside of our group. However, from our brief internal testing, we observed that the program functions best with a larger number of "trials", especially if the distribution of makes and misses is roughly equal. While this isn't entirely necessary, including more data would improve the recommendations provided by cats.ai, since the software would have more data points to identify a pattern from. Additionally, the software would be less influenced by possible outliers if more data is present, since a lucky make or an unlikely miss could pollute a run with a small number of samples.

Conclusions and Future Work

Our design with cats.ai provides an accessible, extensible platform for personalized sports technique coaching. The platform offers a low-cost solution to digital coaching. We identified a number of qualities in existing solutions such as HomeCourt and 18Birdies, particularly the use of AI coaching in both of these systems and sought to expand on these areas. Our use of the OpenPose library to capture an individual's form and technique creates an experience that is centered around each individual user's unique characteristics, including any modifications they make to the activity. This generic approach to analyzing user form and technique also means that cats.ai is highly extensible to other sports and activities, and there are numerous opportunities for continued growth and development.

With cats.ai, we see a number of areas for future development. Firstly, we would like to extend the functionality of the software to be able to analyze full video clips, perhaps on a frame-by-frame basis. This would be a step forward from the current iteration of the software, which only accepts image inputs. In the future, the software could be developed to synthesize analysis from various camera angles to increase the number and variety of collectable data points, which could potentially also be used to generate 3-dimensional models for the user. If we extend our functionality to develop 3D models for the user, we could look into competing for customers who otherwise would opt for much more expensive software and hardware that is traditionally required for 3D data collection, which is indeed one of our long-term goals.

There is also development potential with respect to the user interface. Future improvements would make it easier for users to specify the success of each action or even add automated action success recognition through deeper analysis of input video clips. Additional work to improve the visualization of results and analysis for users would also improve user experience and help them better understand how to improve their technique. It might benefit us in the future to consider building our functionalities and UI into the form of a mobile application, like Home Court or 18 Birdies, since this format is probably most convenient for the user. If someone wants to take a video of themselves shooting a basketball, chances are they are carrying their phone with them and not a computer. It would make a lot of sense to allow users to upload the videos they take straight from their phone and also view the results/recommendations on their phone rather than having to do so later on their computer as our system currently stands. A mobile app with user accounts would also be beneficial because it would allow users to track their progress over time and keep track of their personalized recommendations in case they want to revisit them at a later time; our app as it stands right now does not allow for user accounts.

In addition to these functional and user interface improvements, we also see a couple of additional features that could be incorporated. Allowing the user to save and aggregate data and analyses from previous sessions would allow for the development of more personalized and detailed recommendations for users over time. It would also allow the user to visualize their development over time. We also see value in adding a side-by-side comparison feature. This would allow the user to compare their photos and technique with other individuals or even older data of their own. The user would be able to make comparisons with athletes or professionals with high success ratios and more precise form, which would help the user see and understand potential opportunities for improvement.

How to Download and Use cats.ai

You can get all the most recent code for cats.ai at https://github.com/sethdmay/cats.ai. Be sure to replace the model file as indicated in the repository README. Currently, you have to install the required packages listed in `requirements.txt` using pip. Put any image you want to process in `openpose/imgs_to_process` and run `userInput.py` with Python. Any newer instructions will be indicated on the repository README.