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### Camera-based deep learning AI assistant system for basketball training

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CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL  
TRAINING

RIT

Camera-based deep learning AI assistant system for  
basketball training

By

Guangkun Zeng

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Fine  
Art in Visual Communication Design

School/Department of Design College of Art and Design

Rochester Institute of Technology

Rochester, NY

December, 2021

**Thesis Approval**

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Thesis Title

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Thesis Author

Submitted in partial fulfillment of the requirements for the  
degree of  
The School  
Rochester Institute of Technology | Rochester, New York

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Name

Title

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Electronic Signature: Use Adobe Acrobat

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Title (Optional for some programs)

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# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## **Abstract**

The YOLO, a Computer Vision Algorithms, is brought out to analyze the basketball player's status as a dataset. It can record the players' behavior on the court including dribbling, shooting, and running. In this way, the app could collect the field goal you made and missed. First, you should use this app to record a video of your shoot training. After that, the AI would analyze and brings out a 3d virtual diagram interpret your performance. This diagram will show the hot zone and cold zone for your field goal. Also, the track of your ball will be displayed on the video so that you can know if the angle of your shooting is too low or too high. In the end, the AI-based on machine learning will give out a plan according to your performance on shooting.

As a training mobile application supported by camera-based action recognition, the target audience is the basketball amateur players who don't have the resources as pro players do. This project will be designed as a new training experience and will be delivered as a promo video that shows how to use the application and also the scenario people use.

## **Keywords**

MR, virtual environment, camera-based, training system, deep-learning, machine learning, motion capture, AI

## Critical Analysis and Summary

### Context

Many basketball enthusiasts want to upgrade their skills to a far better level, but unfortunately, not everyone has the funds to hire professional coaches to train on the best court. And what's more, many amateur players do not even know how to practice in a proper way because the video tutorial is not as intuitive as the real coach or as the professional human coach is. What's more, it is almost impossible for the basketball player to quantify how good his/her shooting is. But people do need very good shooting form and technique to shoot consistently. How might we improve players' training experience?

Nowadays, MR (mixed reality) has changed our life. Research by Visual Capitalist projects that the XR market will be worth \$209 billion by 2022, marking an eight-fold increase from 2018<sup>1</sup>. Furthermore, 63% of shareholders in XR technology companies believe the technology will be mainstream by 2024. At the same time, Mixed Reality is quite within the middle but also the longer term of the entertainment industry.<sup>2</sup> This type of technology could provide a customized and unique training experience even compared to the best court and trainers could do.<sup>3</sup>

The Mixed Reality is the technology that could provide an immersive experience and direct data visualization. I propose to bring out a Mixed Reality mobile application that can generate 3d virtual diagram of the basketball court to assist players to understand their shooting performance. At the same time, the app will collect the player's data and make the training plan according to the AI-based analysis system.

### Methodology

To implement this system, multiple technologies will be integrated. The YOLO, a Computer Vision Algorithms will recognize the ball trace and collect data of your training.<sup>4</sup> The motion capture with 3D virtual environment technology will interpret the shooting gesture and movement. Then the machine learning will generate a specific training plan.

The phase of interview and user research will not proceed because this design puts more emphasis on conceptual design. This design focuses on 3 problems that players often meet. First, it's hard for amateur players to quantify their skill level. Second, not every player can make a precise plan as professional

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<sup>1</sup> Emrich, T. (2020, February 25). 20 for 2020: Augmented Reality Trends and How They May Play Out This Year [Web log post]. Retrieved from <https://medium.com/@tomemrich/20-augmented-reality-trends-to-keep-an-eye-on-in-2020-d2b0258edbb>

<sup>2</sup> Terry, Q. (2019, July 23). AR is elevating the playing field for sports by creating smarter training methods. Retrieved from <https://medium.com/futuresin/ar-is-elevating-the-playing-field-for-sports-by-creating-smarter-training-methods-77db01a84d64>

<sup>3</sup> Lee, David. "Our First Shot(s)." Medium (blog). July 17, 2018. <https://medium.com/nex-team/our-first-shot-s-272c67d0349d>.

<sup>4</sup> Terry, Q. (2019, July 23). AR is elevating the playing field for sports by creating smarter training methods. Retrieved from <https://medium.com/futuresin/ar-is-elevating-the-playing-field-for-sports-by-creating-smarter-training-methods-77db01a84d64>

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

coaches can do. Third, players are not sure the practice is executed perfectly. People also sometimes forgot how many shots they've made.

Three solutions have been given out: First, A 3d diagram of your plays can help users to quantify their performance. Then AI Deep learning can give you advice as good as a coach does or even better. Finally, A smartphone camera-based real-time system can record your plays with no mistakes.

As the result of the problem solutions, HoopLab identified 3 specific design goals that are used to prototype:

1. Friendly to use  
Create an experience that users can enjoy. Users can customize their 3d avatar and pick up favorite cloth and haircuts for it. The avatar will be rigged and motion captured by users as a way to understand your shooting movement.
2. Easy to understand  
A 360 degrees 3D diagram will be generated according to the play recording. It is able to turn your still camera recording into 3d version environment. The AI will calculate the distance between objects (player-player, shooter-hoop, defender- ball)
3. Convenient to record  
The user only needs a smartphone camera to do the basic function. Using a smartwatch to unlock advanced features.

After three rounds of prototyping, the corresponding interface lo-fi wireframes are designed. Based on those interaction wireframes, the output of the UI visual wireframe is finally completed. A promo video that combined UI elements and application functions is also be made.

A game design theory is also brought in for this system. Users can earn coins by finishing the tasks. Then they can use game coins to unlock avatars and new advanced tasks. The circular economy is formed in this process.

I think there will be sustainable iterations to evaluate my proposal. At phase one, which is the initial state of a product, a large number of A/B tests will be given to the users. According to the A/B test results that we collect, it can be decided which feature is better for users. In phase two, the product starts to operate smoothly, then plenty of data can be analyzed by machine learning. Due to AI, we can decide what new features that may satisfy users should be built further.

## **Conclusion**

It's difficult to quantify the experience of the system. If the system could present a customized training plan for the user and create a virtual 3d environment of a real court that the player doesn't feel strange about it, this design will be a satisfied solution.

However, with the limit of real-time render technology and hardware hashing power, it is still impossible to implement an application like this in a mobile phone. This project is an approach that represents one possibility of what AI algorithms can do for sports games.

## Appendix A: Expanded Thesis Defense Presentation

### Initial design

### Initial Research

Background



Recently, deep learning methods such as convolutional neural networks and recurrent neural networks have shown capable and even achieve state-of-the-art results by automatically learning features from video clips.

The human activities which include basketball movement could be detected and analyzed by camera in real-time.

The HoopLab idea is based on this deep learning technology. A 3d diagram will be generated to support users.

*About Camera based Action recognition*

### Initial Research

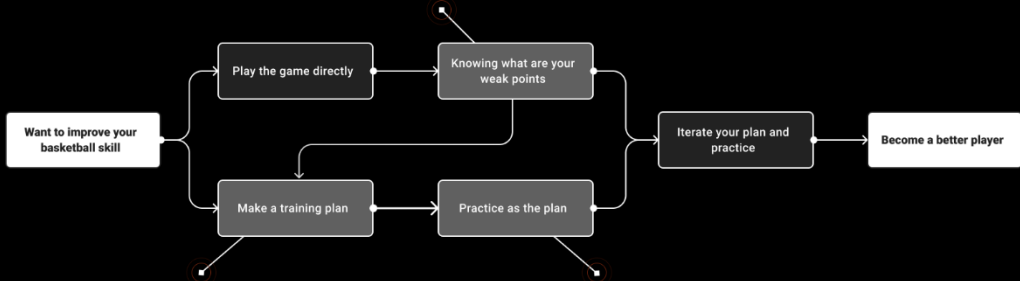
Problem

As an amateur basketball player

**Problem 1:**  
It's hard for amateur players to quantify their skill level.

**Problem 2:**  
Not every players can make a precise plan as professional coach can do

**Problem 3:**  
Not sure the practice is executed perfectly. Also people sometimes forgot how many shots they've made.



```
graph LR; A[Want to improve your basketball skill] --> B[Play the game directly]; A --> C[Make a training plan]; B --> D[Knowing what are your weak points]; C --> E[Practice as the plan]; D --> E; E --> F[Iterate your plan and practice]; F --> G[Become a better player];
```

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Initial Research

### Solution



#### Solution 1:

A 3d diagram of your plays can help users to quantify their performance



#### Solution 2:

AI Deep learning can give you advice as good as a coach does (or even better)



#### Solution 3:

A smartphone camera based real-time system can record your play with no mistakes



# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Design intension

**Define**  
Product Goal



**Friendly to use**  
Create an experience that users can enjoy

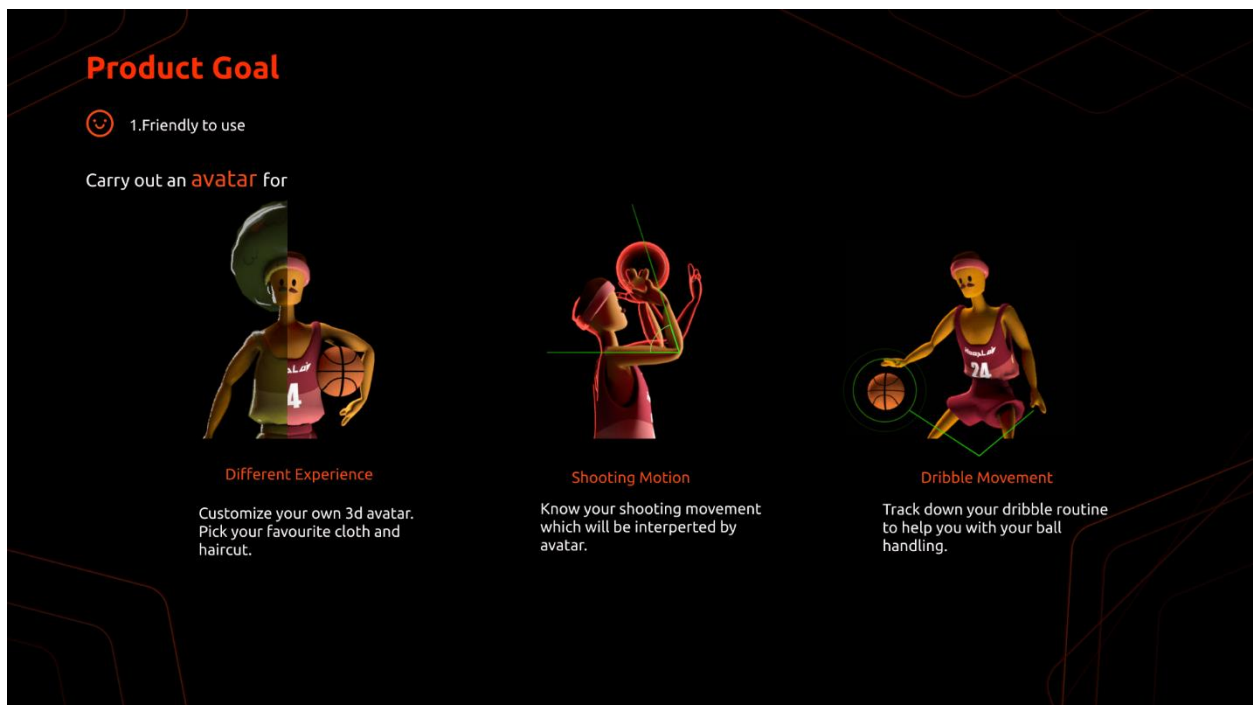
**Easy to understand**  
A 3d diagram of your plays can help users to quantify their performance

**Convenient to record**  
Use accessible devices to do the tasks

**Product Goal**

1. Friendly to use

Carry out an **avatar** for



**Different Experience**  
Customize your own 3d avatar. Pick your favourite cloth and haircut.

**Shooting Motion**  
Know your shooting movement which will be interpreted by avatar.

**Dribble Movement**  
Track down your dribble routine to help you with your ball handling.

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Product Goal

😊 1. Friendly to use

Carry out an **avatar** for



Different Experience

Customize your own 3d avatar. Pick your favourite cloth and haircut.



Shooting Motion

Know your shooting movement which will be interpreted by avatar.



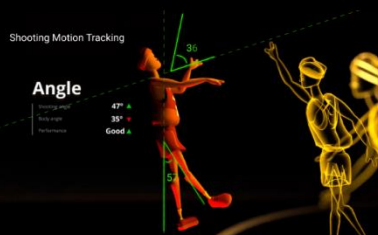
Dribble Movement

Track down your dribble routine to help you with your ball handling.

## Product Goal

🤖 2. Easy to understand

360 degree **3D diagram**



Shooting motion tracking

Turn your still camera recording into 3d version



Position Tracking

Calculate the distance of things

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Product Goal

- Convenient to record

Accessible devices

Use **smart phone** camera to do the basic function.  
Use **smart watch** to unlock advance features.

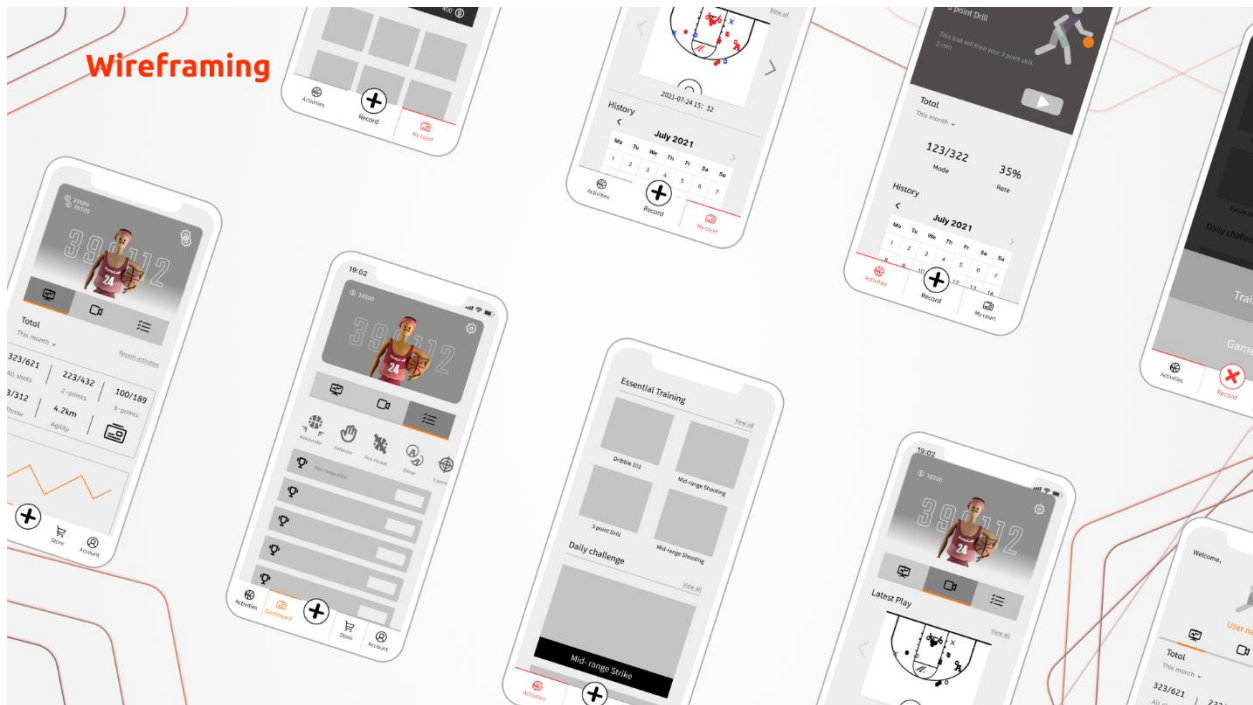


Smart watch      Smart phone

The image shows a smart watch and a smart phone, both displaying the HoopLab logo. The smart watch is on the left and the smart phone is on the right. The background is dark with red circuit-like lines.

## Wireframing

## Wireframing



The image displays several wireframe sketches of mobile app screens for basketball training. The screens are arranged in a cluster, showing various views such as user profiles, statistics, training plans, and game logs. The wireframes are overlaid on a background of red circuit-like lines.

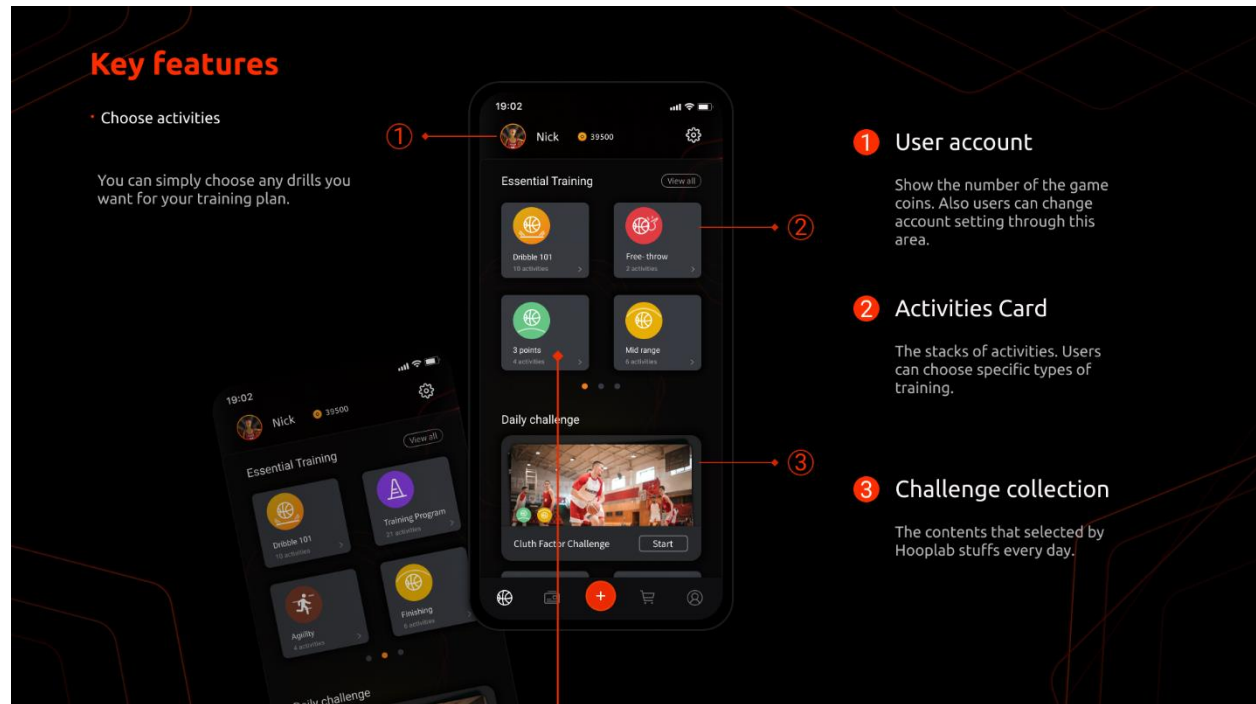
- Screen 1: User profile with name 'JAMES 2000', a basketball player image, and statistics: Total (323/621), All shots (223/432), 3-point (100/189), Dunks (3/112), 4.2km, Agility.
- Screen 2: Training plan titled 'Essential Training' with sections for 'Dribble Drill', 'Mid-range Shooting', 'Daily challenge', and 'Mid-range Shooting'.
- Screen 3: Game log for 'July 2021' showing a calendar view with a total of 123/322 (35%) made.
- Screen 4: 'Latest Play' screen showing a basketball court diagram and a player image.
- Screen 5: 'Welcome' screen with a user name and statistics.

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

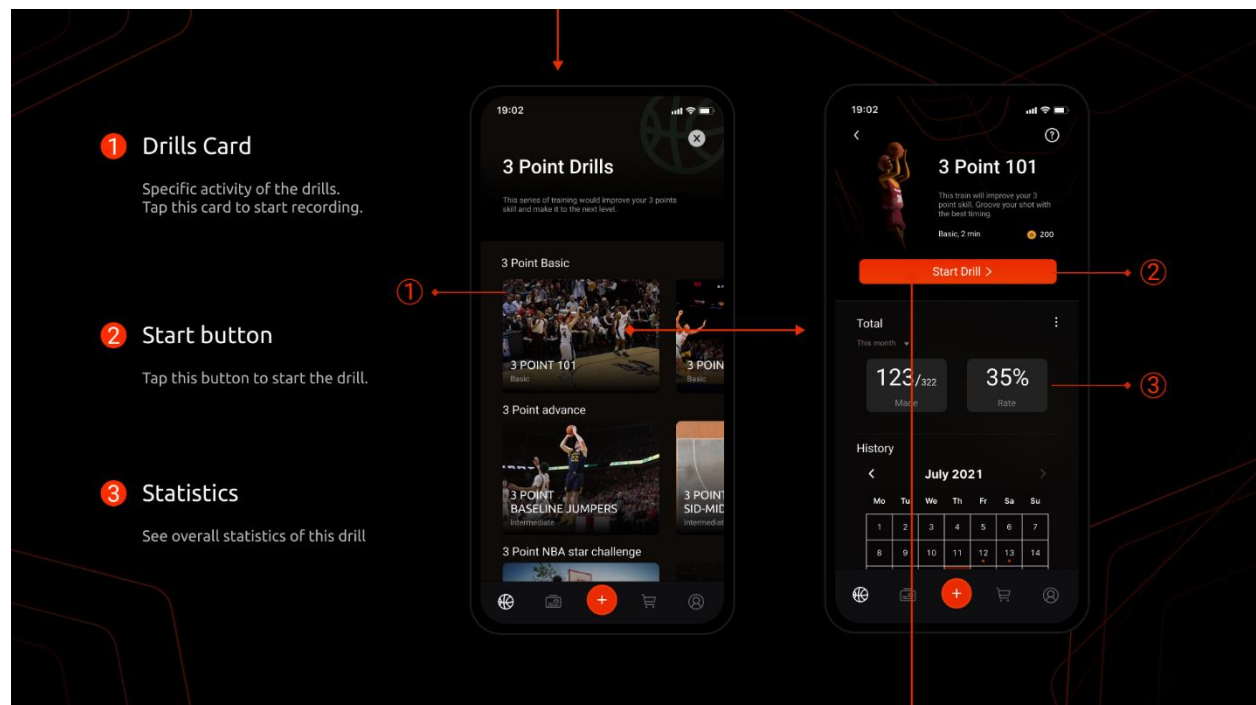
## Key features

### Key features

- 1 Choose activities  
You can simply choose any drills you want for your training plan.
- 2 User account  
Show the number of the game coins. Also users can change account setting through this area.
- 2 Activities Card  
The stacks of activities. Users can choose specific types of training.
- 3 Challenge collection  
The contents that selected by Hooplabs every day.

The image shows a mobile app interface with a dark theme. At the top, the user's name 'Nick' and a coin balance of '39500' are displayed. Below this is a 'View all' button. The main content area is divided into two sections: 'Essential Training' and 'Daily challenge'. 'Essential Training' contains four activity cards: 'Dribble 101' (10 activities), 'Free-throw' (3 activities), '3 points' (4 activities), and 'Mid range' (6 activities). 'Daily challenge' features a video thumbnail for a 'Clutch Factor Challenge' with a 'Start' button. A red '+' icon is visible at the bottom of the screen.

- 1 Drills Card  
Specific activity of the drills.  
Tap this card to start recording.
- 2 Start button  
Tap this button to start the drill.
- 3 Statistics  
See overall statistics of this drill

The image displays two screenshots of the app. The first screenshot shows the '3 Point Drills' screen, which lists several drill options: '3 Point Basic', '3 POINT 101 Basic', '3 Point advance', '3 POINT BASELINE JUMPERS Intermediate', '3 POINT SID-MIC Intermediate', and '3 Point NBA star challenge'. A red '+' icon is at the bottom. The second screenshot shows the details for the '3 Point 101' drill. It includes a 'Start Drill >' button, a 'Total' section showing '123 / 322' (Made) and '35%' (Rate), and a 'History' section for 'July 2021' with a calendar grid. The calendar grid shows the following data:

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	4	5	6	7
8	9	10	11	12	13	14

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Key features

- Start a drill
- Start a drill after choosing one.

1 Recognition Frame

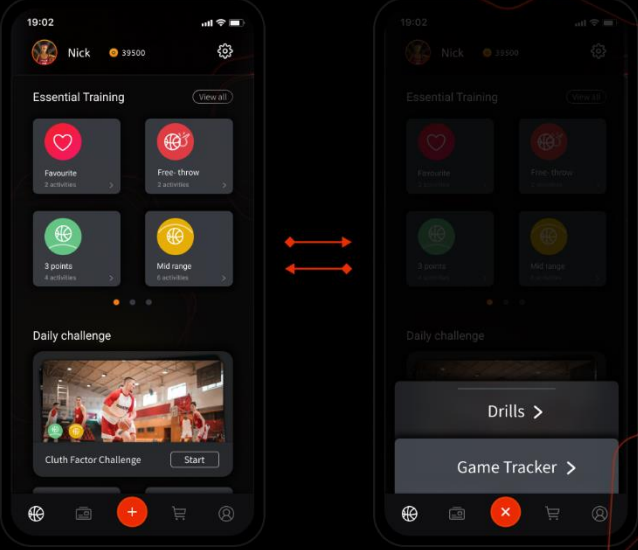
Use deep learning



The image shows two sequential camera views of a basketball court. The top view displays a white rectangular frame around the hoop and backboard, with the text "PLEASE PUT THE HOOP INTO THIS FRAME" at the top. A red circle with the number "1" points to the frame. The bottom view shows the same scene, but the text "Ready" with a green checkmark is displayed at the top, indicating that the system has successfully recognized the hoop within the frame. Red arrows connect the two views, showing the progression from recognition to readiness.

## Key features

- Start a drill
- You can also start a drill from the add button.




The image displays two smartphone screens side-by-side, illustrating the app's interface. The left screen shows a user profile for "Nick" with a score of 29500. Below the profile, there are four "Essential Training" buttons: "Favourite" (2 activities), "Free-throw" (2 activities), "3 points" (8 activities), and "Mid range" (6 activities). At the bottom, there is a "Daily challenge" section with a "Cluth Factor Challenge" and a "Start" button. The right screen shows the same interface, but with a "Drills" button and a "Game Tracker" button highlighted in a dark grey box. Red arrows between the screens indicate a transition or interaction between the two states.

# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

## Key features

Dashboard

- 1 Statistic**  
Look up your statistic from this section. You can compare your performance with history.
- 2 Replay Card**  
Your history plays are saved in this section. Tap in each cards to see details of the games.
- 3 Achivement**  
Complete the tasks to earn the game coins which could be used in app store to unlock your avatar.



## Key features

Dashboard

In detail page, you can see your shoot motion in 360° in 3D mode

- 1 Video HUD pannel**
- 2 Video play controller**



## Appendix B: Bibliography and References

"Worldwide Spending on Augmented and Virtual Reality Expected to Reach \$18.8 Billion in 2020, According to

IDC." IDC: The Premier Global Market Intelligence Company. Accessed April 7, 2020.

<https://www.idc.com/getdoc.jsp?containerId=prUS45679219>.

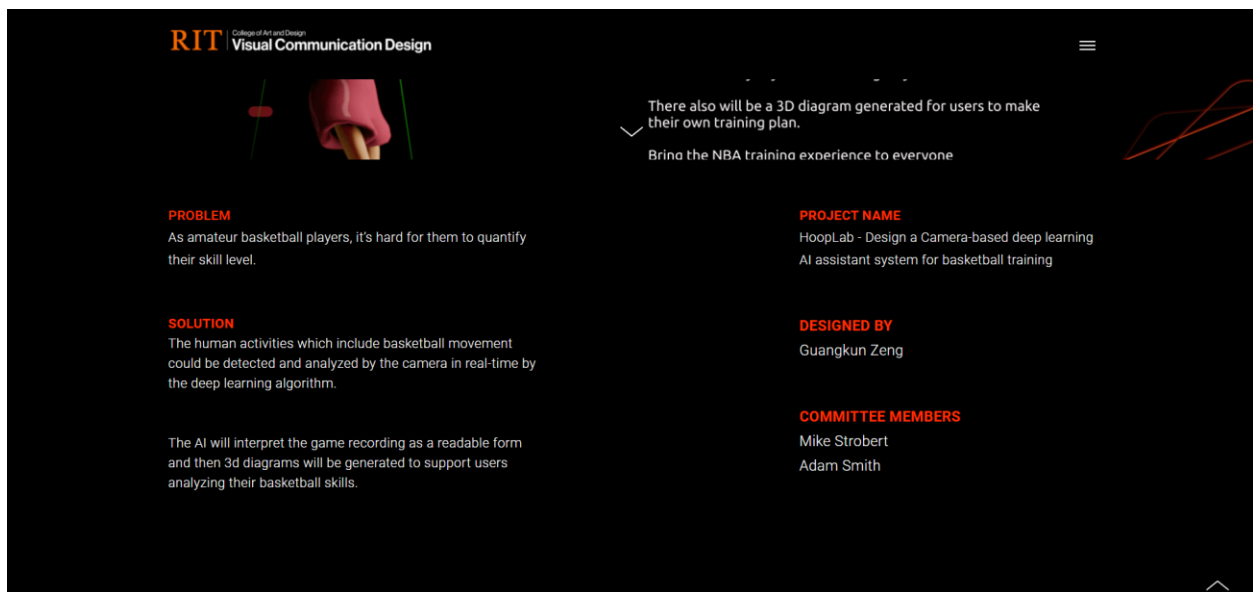
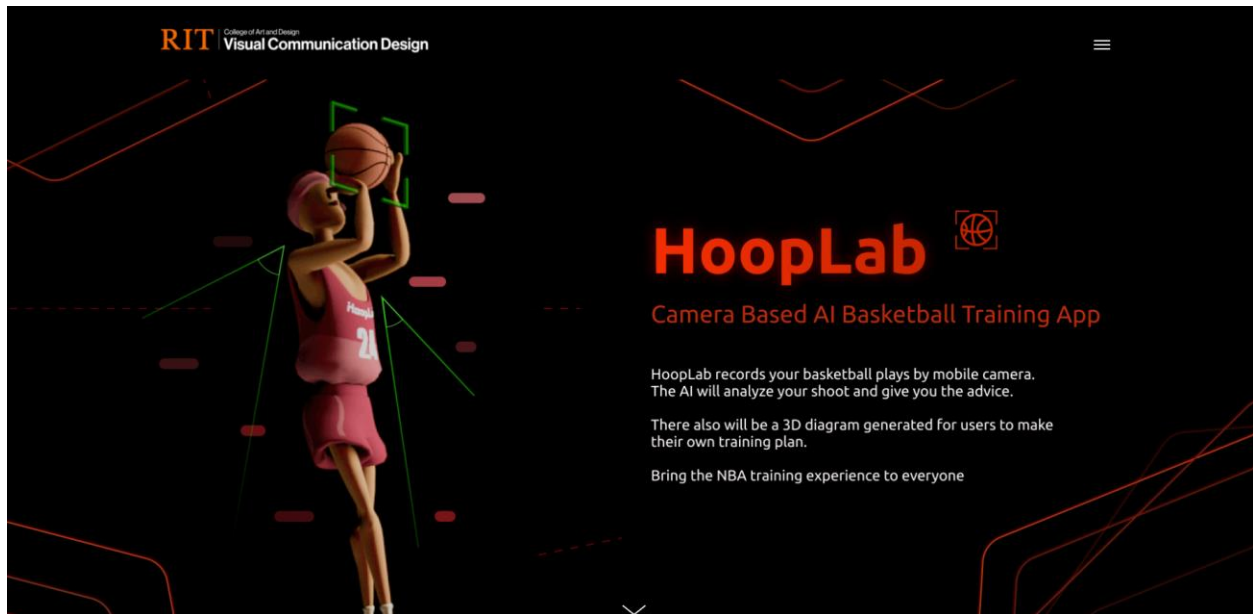
Emrich, T. (2020, February 25). 20 for 2020: Augmented Reality Trends and How They May Play Out This Year [Web log post]. Retrieved from <https://medium.com/@tomemrich/20-augmented-reality-trends-to-keep-an-eye-on-in-2020-d2b0258edbb>

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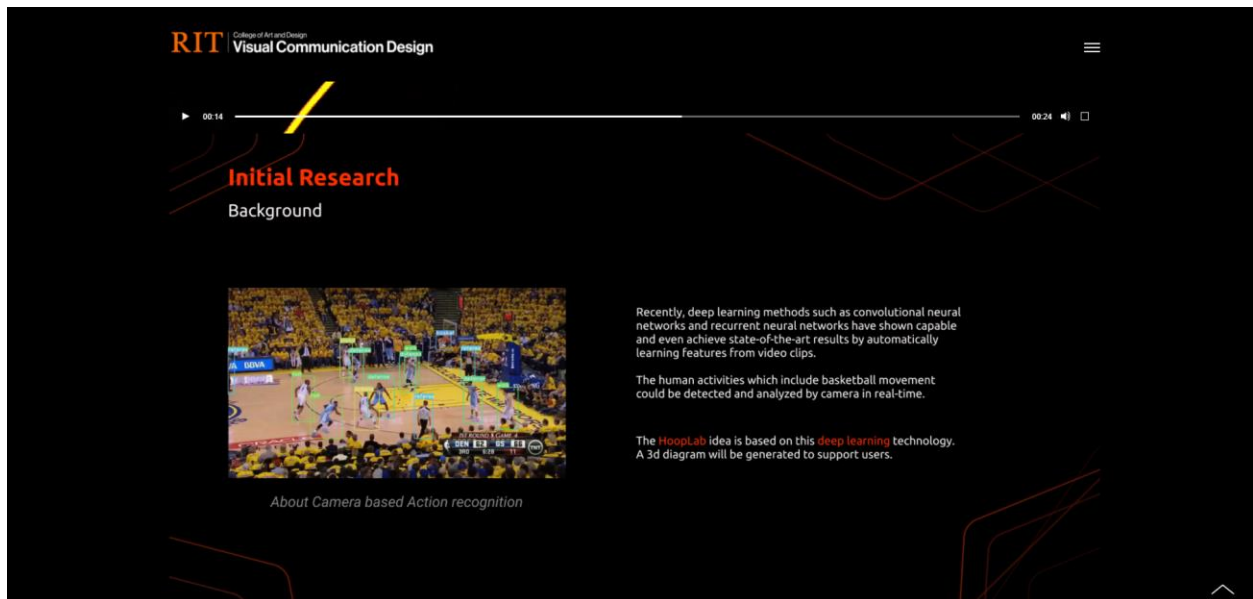
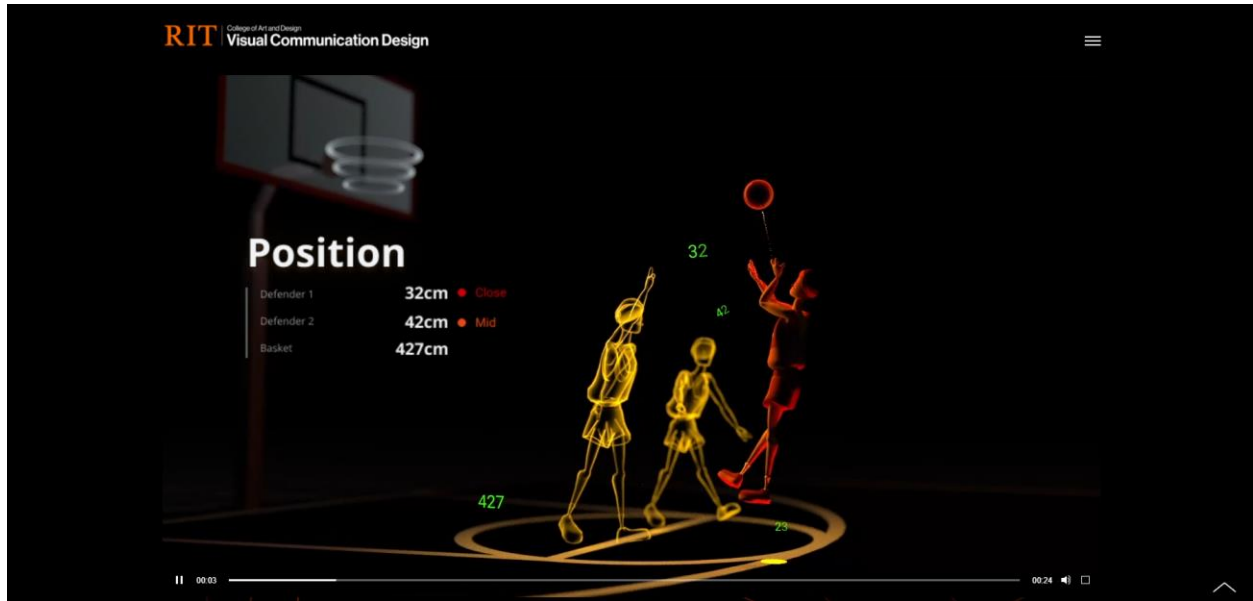
Retrieved from <https://medium.com/futuresin/ar-is-elevating-the-playing-field-for-sports-by-creating-smarter-training-methods-77db01a84d64>

## Appendix C: Screen Capture of Semplice Case Study Page and Optional screens of project or animation

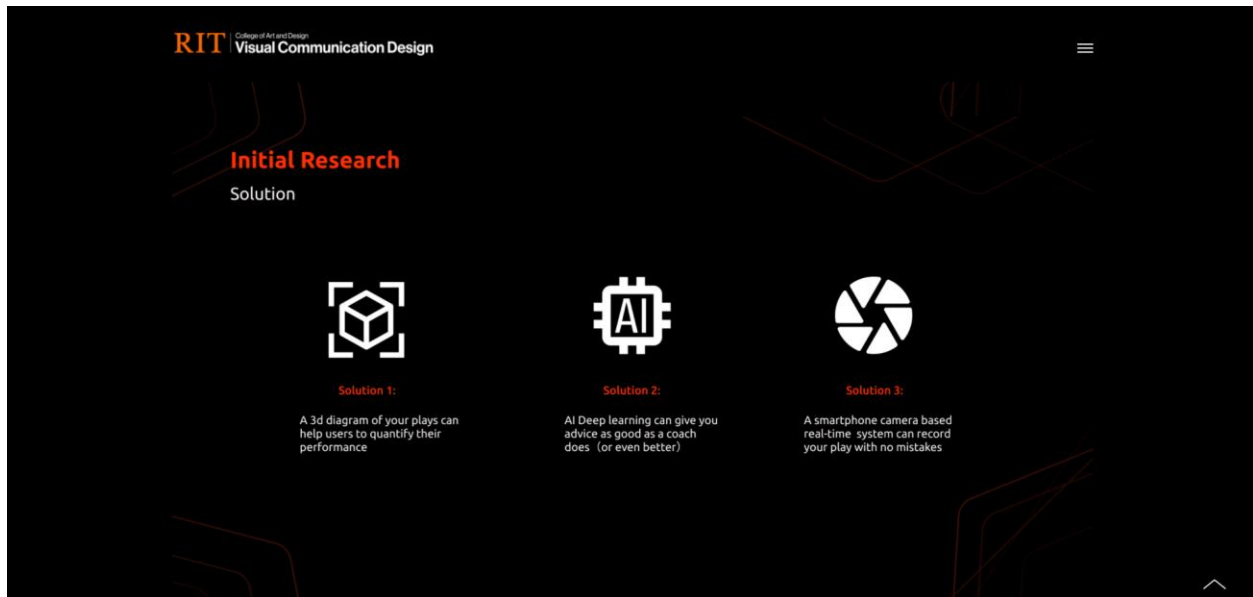
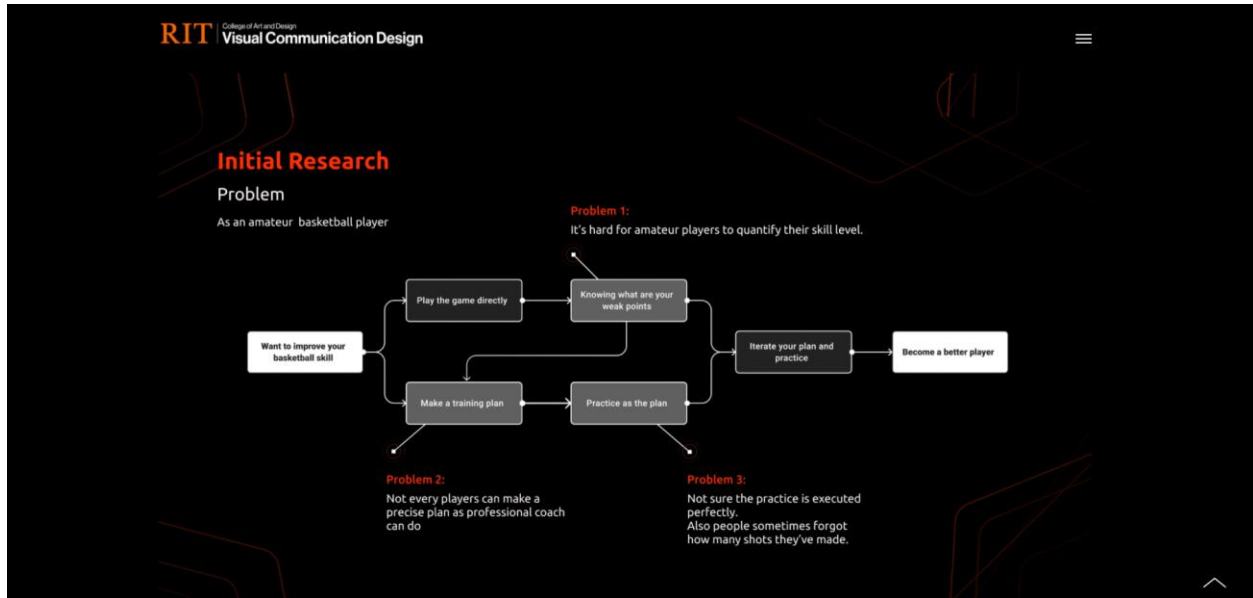




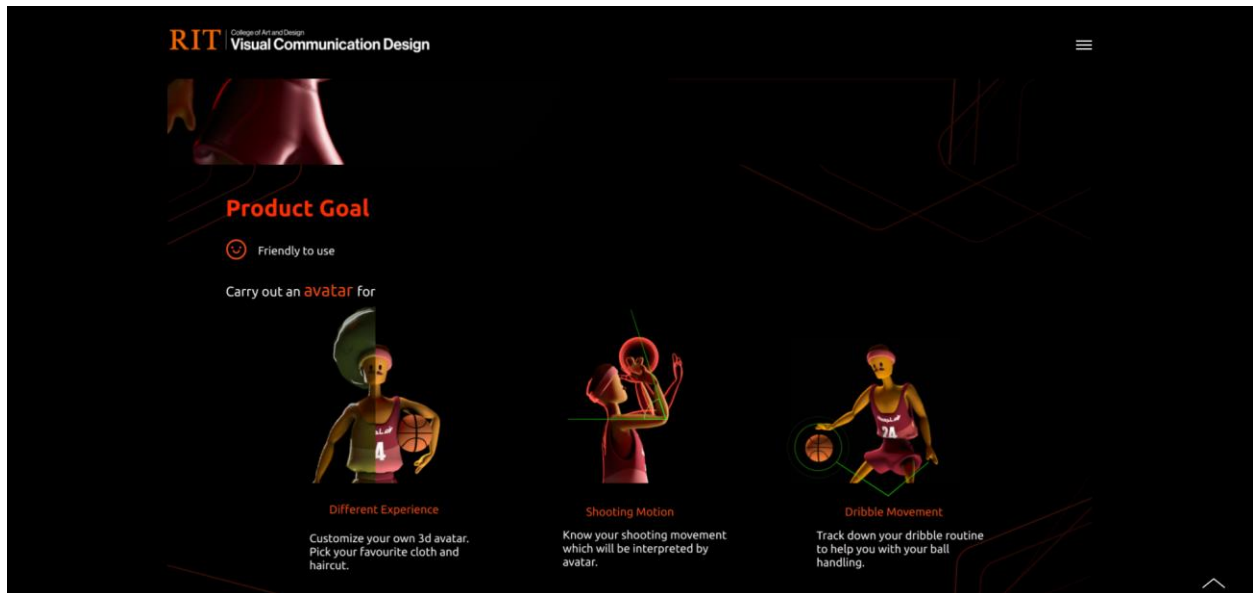
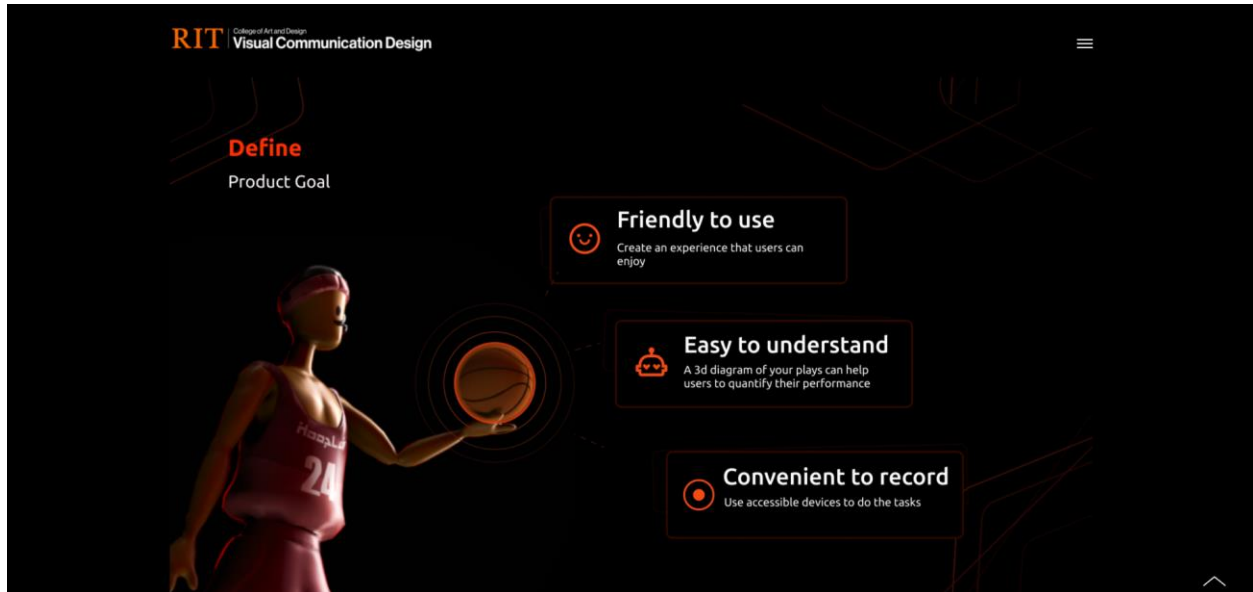
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# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

RIT College of Art and Design  
Visual Communication Design

## Product Goal

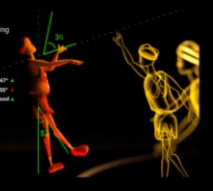
- 2. Easy to understand

360 degree 3D diagram

Shooting Motion Tracking

Angle

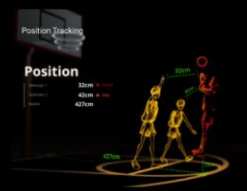
Horizontal	47°
Vertical	38°
Ball	88°



Position Tracking

Position

Ball	32cm
Player	40cm
Goal	427cm



Shooting motion tracking  
Turn your still camera recording into 3d version

Position Tracking  
Calculate the distance of things


RIT College of Art and Design  
Visual Communication Design

## Product Goal


- Convenient to record

Accessible devices

Use smart phone camera to do the basic function.  
Use smart watch to unlock advance features.

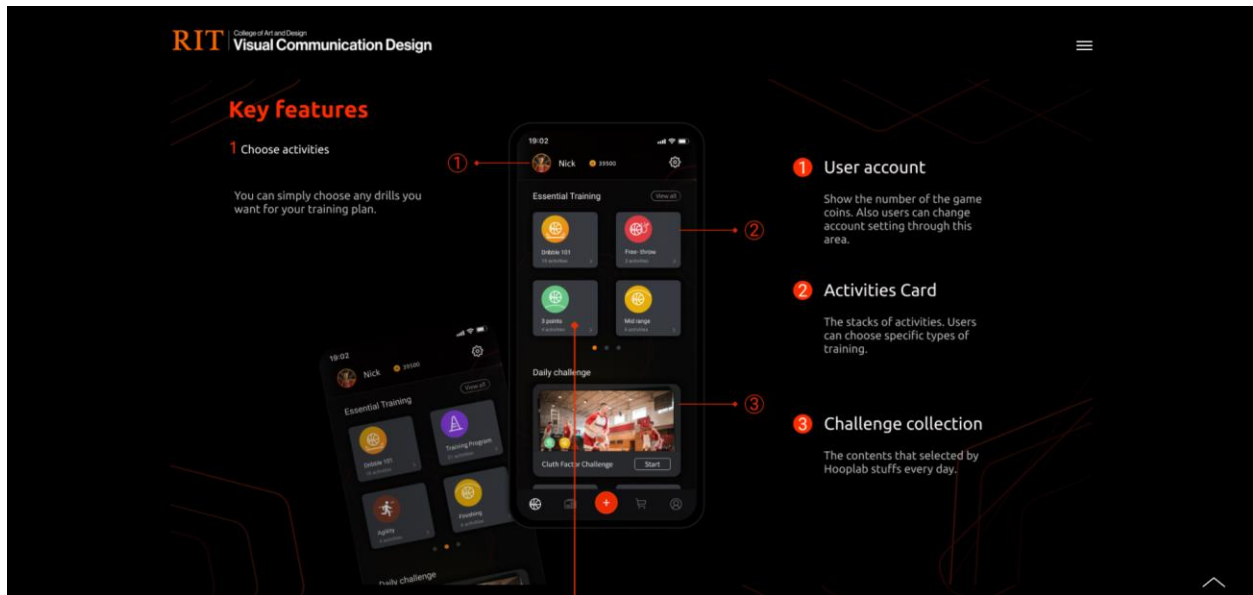
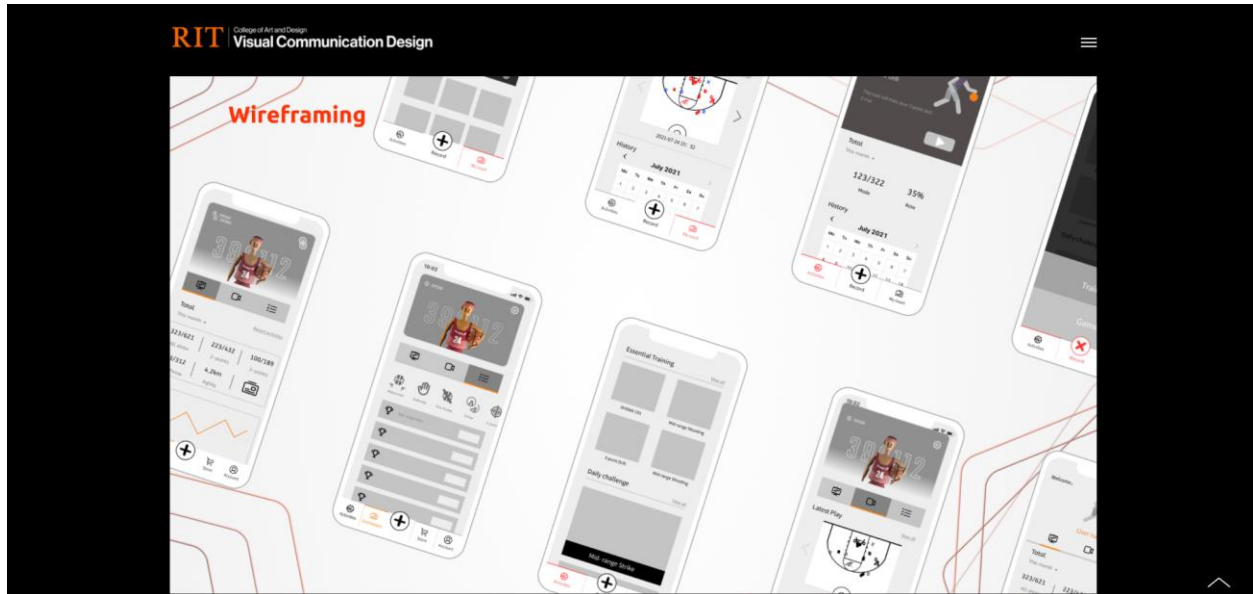


Smart watch

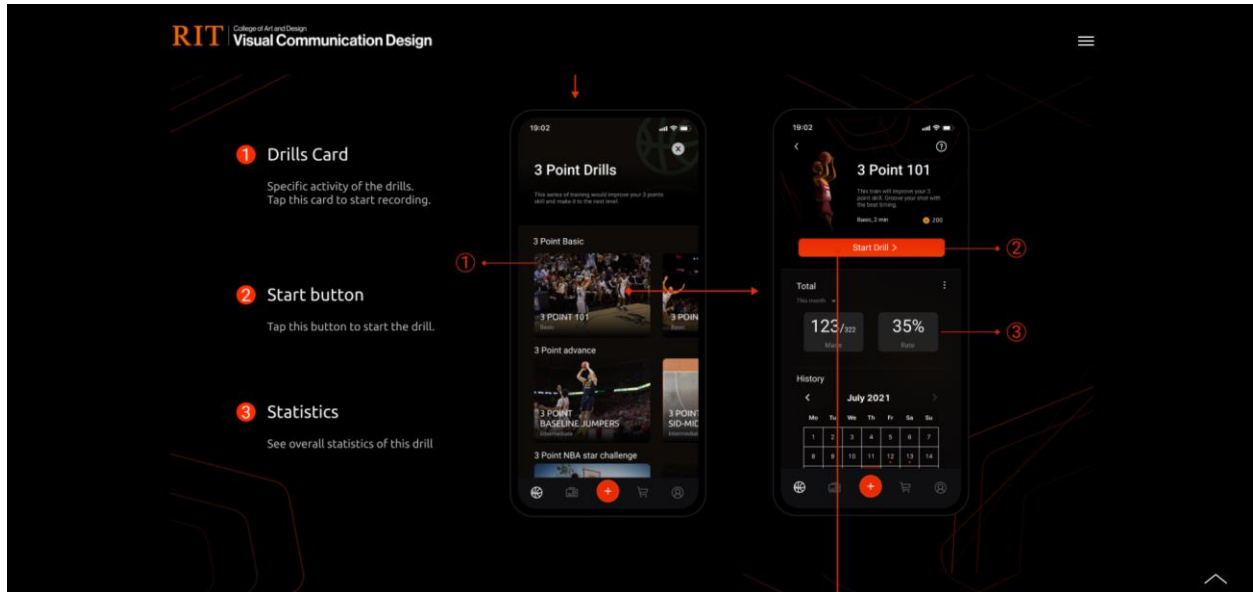


Smart phone

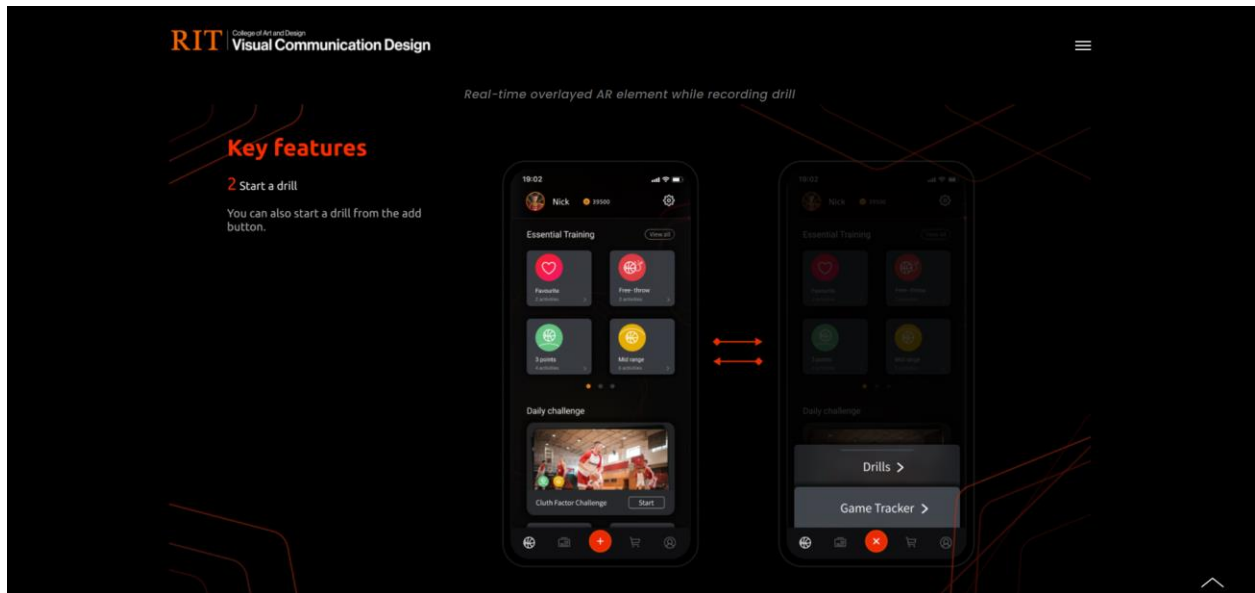
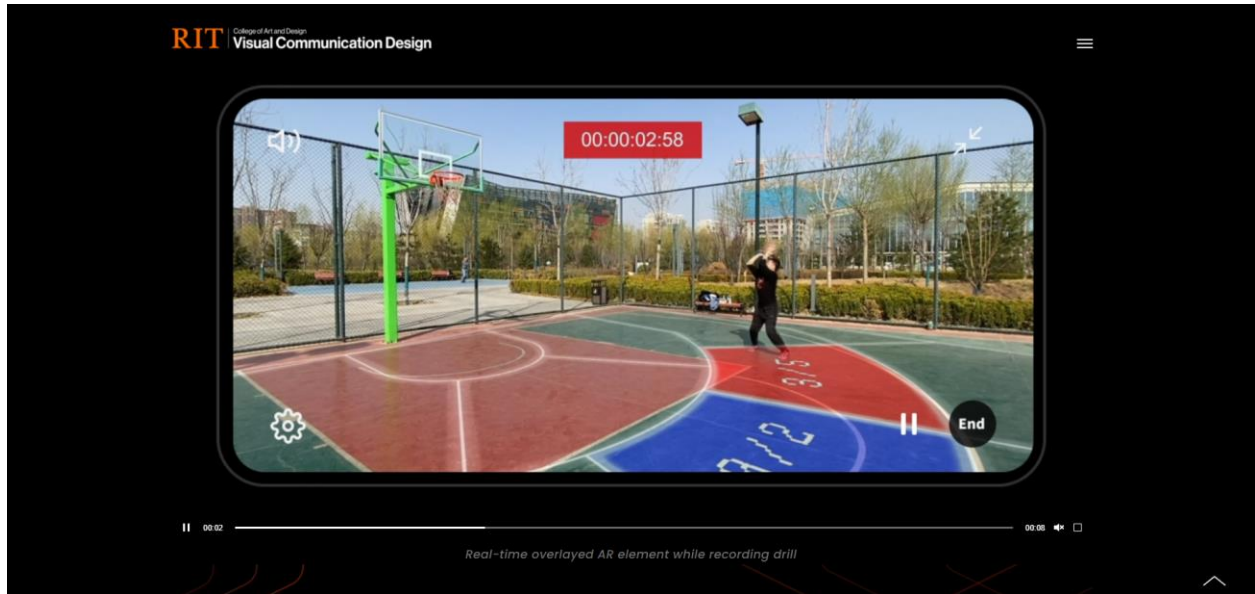
# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING



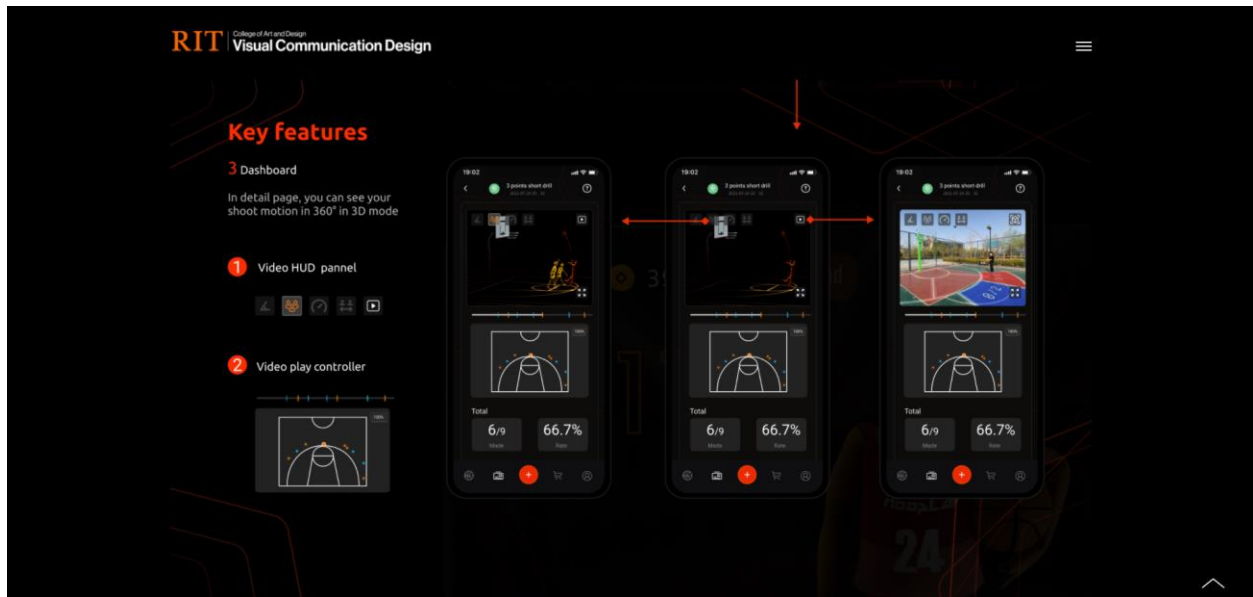
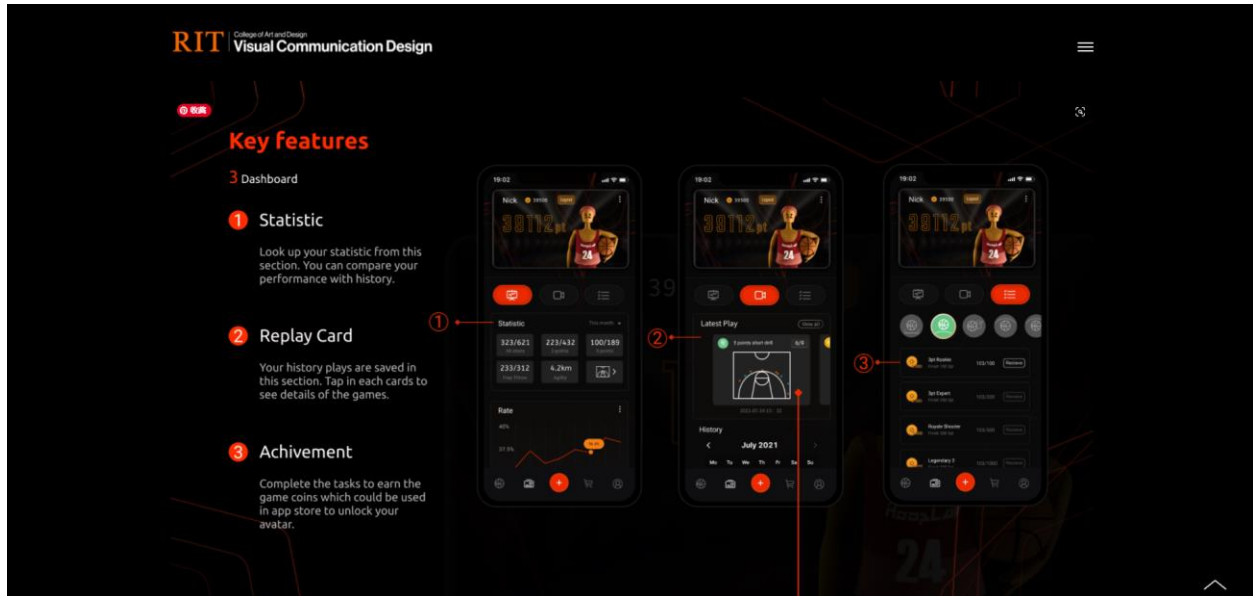
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# CAMERA-BASED DEEP LEARNING AI ASSISTANT SYSTEM FOR BASKETBALL TRAINING

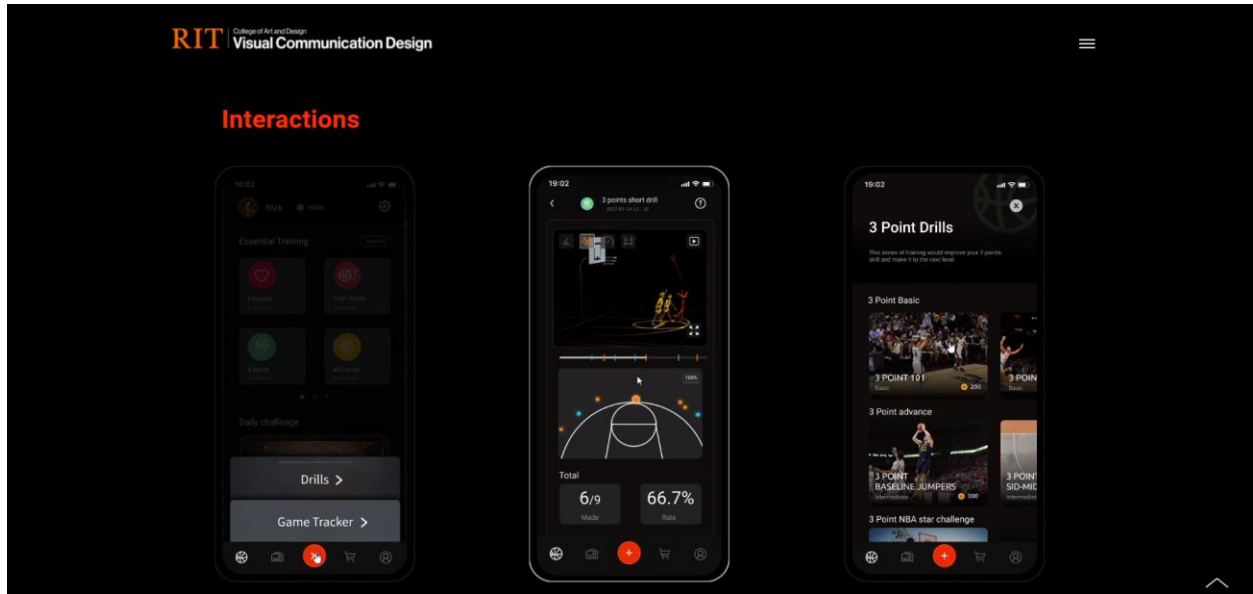


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