DAR: IMPLEMENTATION OF A DRONE AUGMENTED REALITY VIDEO GAME

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RoCHI, October 2019

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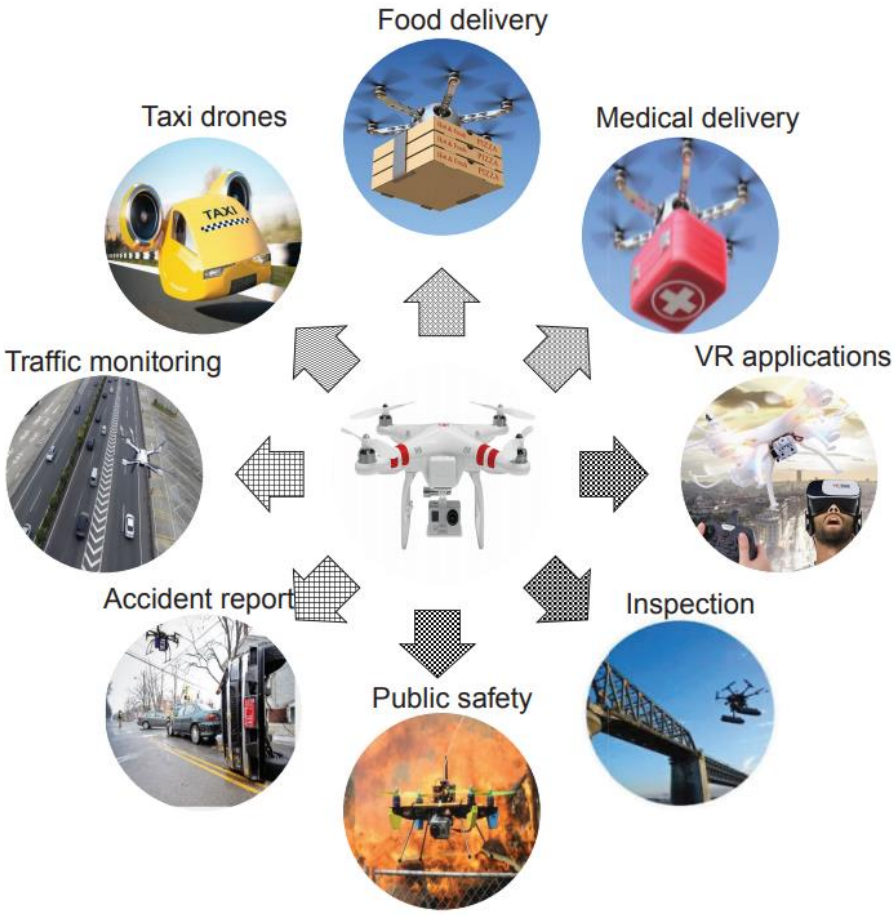
1. Introduction

- Nowadays, an **increase in the use of UAVs** has been noticed, for civilian applications like aerial photography, survey, inspection, mapping, package delivery or surveillance [1].



1. Introduction

- Augmented reality (AR) is a field of computer science that deals with the **combination between the real and virtual worlds**.
- It can bring improvements in various areas, like gaming, medicine, teaching, travel, marketing, and research [2].

1. Introduction

- One special field for the development of AR applications is the **video game domain**.
- Some examples of successful AR games are Pokemon GO [3], Ingress [4], Temple Treasure Hunt [5], and Zombie GO [6].
- Moreover, classic video games such as World of Tanks [7] consider expanding themselves with AR capabilities.

2. Motivation and Objectives

- Since the recent growth of the Unmanned Aerial Vehicles (UAV) business, **we take on the quest of creating an AR video game that is centered around a drone**.
- Having such an application, the developer learns the physics specific to such a system, and the users can interact and learn the controls of the drone.
- By making the player complete tasks and navigate in a real environment through AR capabilities, the levels of excitement increase compared to a simple virtual game.

3. Contributions

- For the previously mentioned objectives, we bring the following contributions:
  - accurate physics for the movement of the drone,
  - real-time control and monitoring of a UAV system,
  - interaction with elements from the scene – such as real objects or virtual enemies.

4. AR Game Development

- To create an AR digital game [8], researchers use the following components for the **hardware**:
  - a computer, either a PC or a mobile device
  - a monitor or display screen,
  - a camera,
  - tracking and sensing systems (GPS, compass, accelerometer),
  - a network infrastructure,
  - a marker – a physical object where the real and virtual environments are fused together.
- As for the **software** used, this is:
  - an application or program running locally,
  - Web services,
  - a content server.

5. Analysis

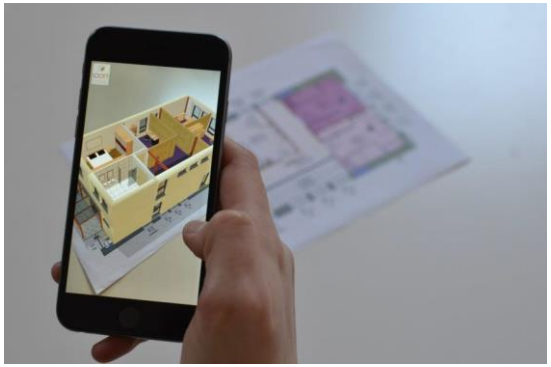
Topic selection

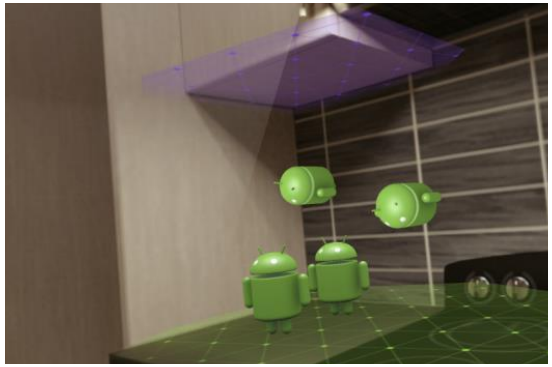
- Main idea: have drones that collect materials which are carried to the necessary location by means of a train.
- The player can control the drone's position using the buttons which are on the screen of the phone.
- To make the game more difficult, enemies that are controlled by Artificial Intelligence (AI) are inserted in the scene.
- The game can be extended by integrating a real-life drone with which the player can directly interact.

5. Analysis

Topic selection

- Options for the building in which materials are placed:
  1. object of type wireframe [9], with digitally mapped shape,
  2. 2D image with a map [10],
  3. the whole room.





5. Analysis

Game specifications

- The main functionalities of the application are:
  - the player can observe the game scene from multiple perspectives,
  - the building in which the materials are located is populated with AI which attacks the drone or destroys the materials,
  - the player can select the desired drone,
  - the player controls the drone's position using the buttons on the application's interface,
  - the player performs the grab/drop action with buttons placed on the screen of the smartphone,
  - the collected materials are placed in containers that are located in the game scene.
- The drone will not be affected by the movement of the phone, and its physics will have to be precise.
- The enemies will have a limited field of view and will attack only when the UAV is at a certain distance to them.

5. Analysis

Prototyping

- Mobile prototype; the scene is composed of the room (captured using the camera), while the drone is a virtual object.

5. Analysis

Prototyping

- In-game prototype – 1. the menu button, 2. the drone control buttons, 3. marker with virtual container, 4. marker for materials and AI enemy attacking the drone, 5. back button

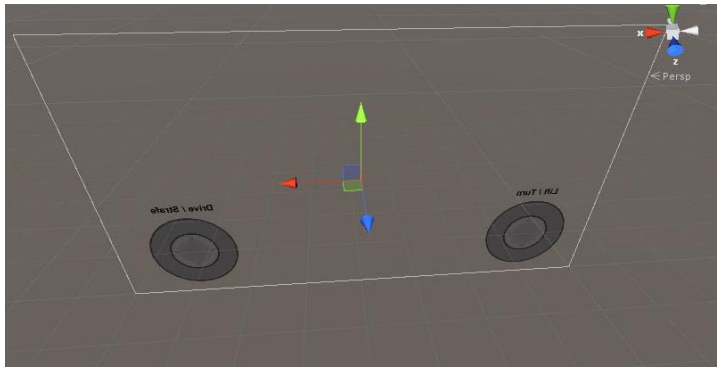
6. Implementation

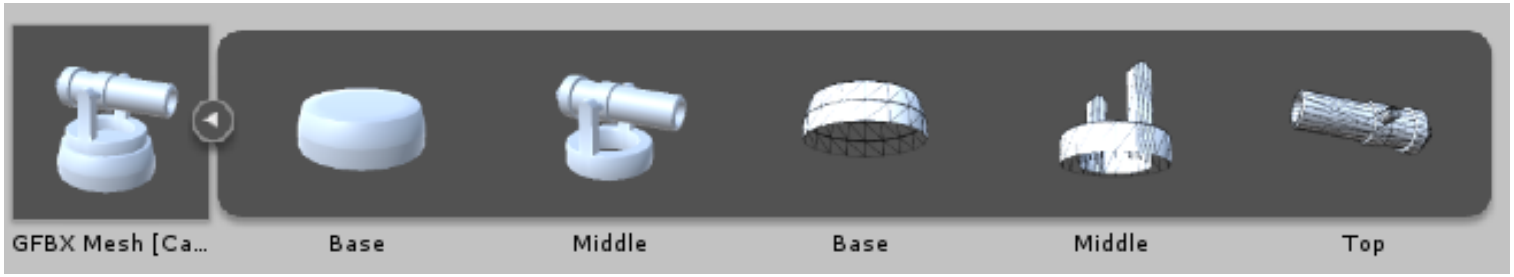
- For the development of the application, the software resources that were used are:
  - game development: Unity,
  - augmented reality: ARCore,
  - backend: C#,
  - 3D modeling: Blender,
  - prototyping and textures: Adobe Photoshop CS6,
  - Android development: Android Studio.
- The hardware resources used are:
  - for game development: a laptop with Intel(R) Core(TM) i7-6700HQ CPU, 2.60GHz, 8.0GB RAM, 1TB memory, NVIDIA GeForce GTX 960M,
  - for game testing: a Samsung S8 smartphone with Android version 8.

6. Implementation

Game objects

- Real: the room,
- Virtual: the drone, the cannon, the joystick buttons, and the planar meshes.



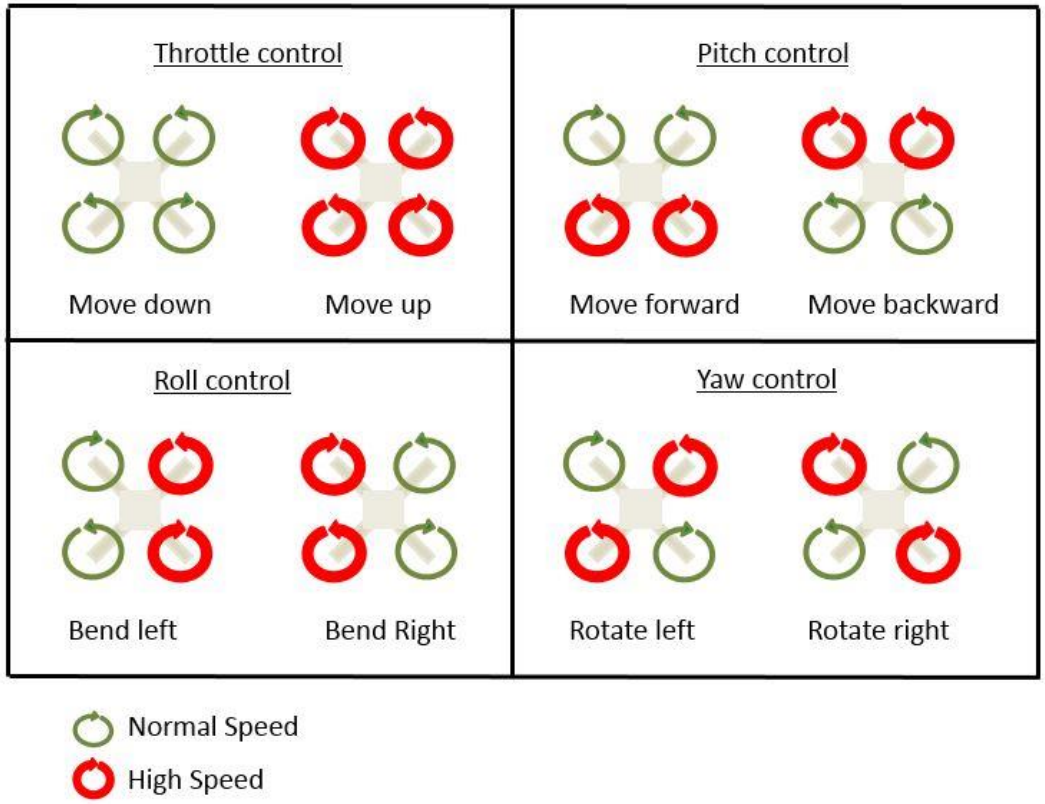


6. Implementation

- To create the drone, we first understood the basic physics it uses to move. We used the quadrotor as the basic shape, which has rotors that act as wings.
- Two adjacent rotors spin in opposite directions, while two opposite rotors spin in the same direction.
- We have created a script that controls the movement of the drone for the following motions:
  - hovering,
  - lift up,
  - lower down,
  - forward and backward movement,
  - left and right swerving,
  - rotation around the z-axis.

6. Implementation

- Motion rules for a quadcopter [11]



6. Implementation

- To control the motion of the drone, we created the joystick buttons.
- The user inputs are handled in Unity by the Input Manager, where we set up axis and button inputs for each controller.
- For the enemy cannon, a sphere was used as a cannonball, which directly collides with the drone, as both have attached materials that mimic real-life physics.
- The cannon will emit a warning sound before firing so that the player can know if the drone is close to the enemy, even when the turret is not seen on the image captured by the camera.
- The turret follows the movement of the drone using the Lerp function.

6. Implementation

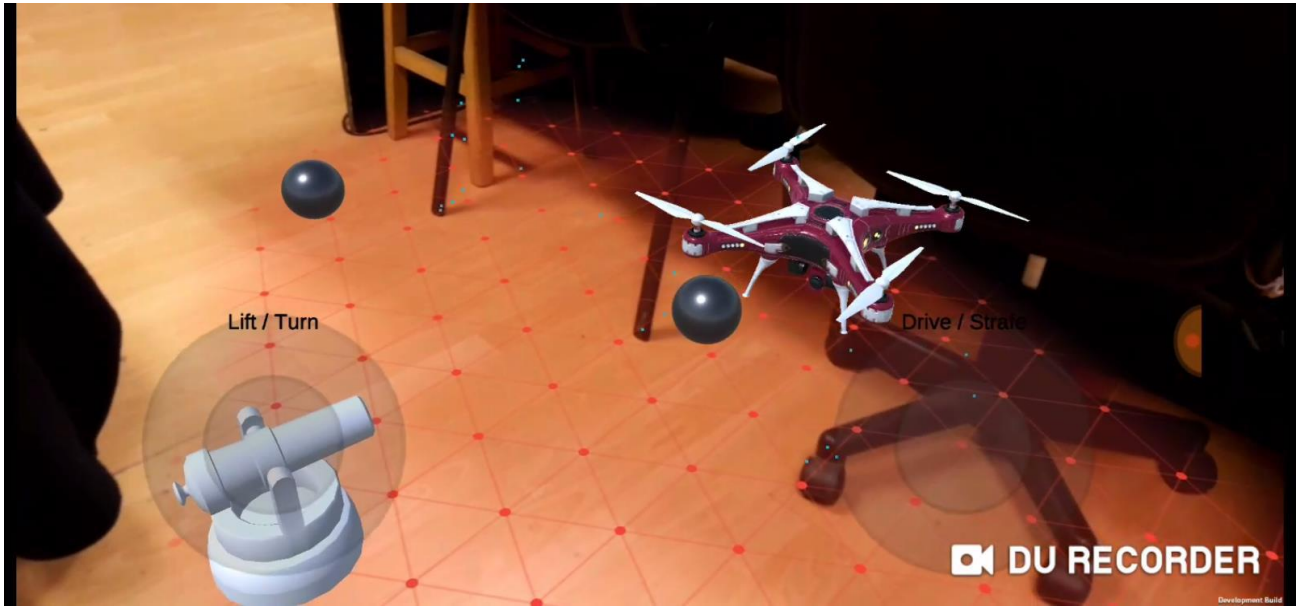
- The most important requirement for the application was the AR functionality, for which we used ARCore [12].
- The environment is recorded using the camera from the computer or phone, and on the recorded images, virtual objects can be positioned, making it possible for the user to interact with them in the real world.
- Additionally, the motion tracking capability enables tracking the position of the phone in relation to the objects around it.
- To detect the planar surfaces, we used the method provided by ARCore for planar surface detection.
- In it, we first detect feature points and then cluster them into a point cloud.
- We attach a collision mesh to the detected planes, to enable the interaction between them and the drone.

6. Implementation

- Drive forward action performed by the user, together with turret attack and collision of the cannonball with the drone

6. Implementation

- The virtual drone in the real environment. The planar surfaces have attached virtual meshes. The enemy cannon is placed on the floor and attacks the drone.



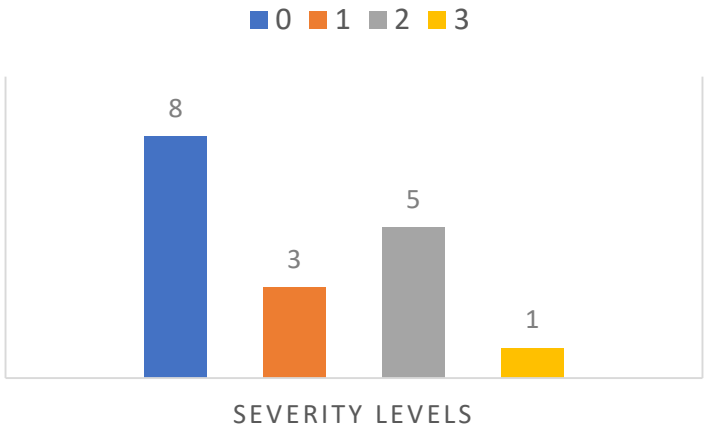
7. Evaluation

- Since game development is a user-driven process, an important aspect is evaluation.
- The components that we evaluate in order to assess the usability of an AR application [13] are:
  - goals – related to the aim of the video game,
  - user – related to the ease of use, understanding of the application and satisfaction,
  - tasks – the actions taken to achieve the goals,
  - technology – AR applications need special devices and sensors,
  - usability – how user-friendly is the interface.

7. Evaluation

- A series of 17 specific questions have been established for each of the 10 categories proposed by Nielsen [14], using a methodology adapted for AR applications [15].
- Additionally, we used Severity Levels to classify the type of problems that arise and decide their priority when we reiterate through the previous stages.
- These are:
  - 0 – there is no problem,
  - 1 – the issue must be solved if there is enough time,
  - 2 – a minor problem,
  - 3 – a major problem,
  - 4 – the issue must be solved immediately.

7. Evaluation



- After this evaluation, we have improved the application by addressing problems with SL of 1:
  - changed the joystick buttons – we made them bigger and transparent,
  - we created a video showing to the users how to interact with the interface and how to place the cannon in the scene,
  - we have decreased the speed of the drone, so the player can have more control on its movements,
  - and we decreased the attack speed of the turret so that the user can enjoy the game more.

7. Evaluation

- An issue that is more difficult to correct is the loading time of the cannon.
- There is a big latency between the time the user taps the screen to place the object and the time it actually appears.
- This is conditioned by the AR development tool, which severely limits the future development of the game.
- If we desire to use markers in order to place materials and a train, we must consider a trade-off between the number of objects and interaction capabilities, and the loading time and response of the application.

8. Conclusions

- Today we presented the development of a Drone Augmented Reality video game.
- We started from an iterative development methodology and incorporated Augmented Reality elements.
- As future developments, we consider adding more elements to the game and improving the issues discovered in the evaluation stage.

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