Large scale collaborative autonomous vehicle simulation and analysis using smartphones

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Abstract – *Simulation appears as an indispensable tool for automotive manufacturers to validate autonomous vehicle development, this latter reported to require billions of miles of driving. To involve the end users in this validation process, a project of large scale public application on smartphone allowing them to test and submit specific use cases, is presented in this paper. A first version of this application "3DAV Explore" has been released and is already available, allowing users to see in Virtual Reality traffic scenarios in subjective view from the autonomous vehicle and/or from an exterior view. This paper details more deeply the development steps and the libraries used for the second version of this application. Further development steps and implications are also detailed in the conclusion.*

Introduction

Autonomous vehicles development is one of the key challenges for automotive manufacturers. A large number of studies put forward billions of miles to run with different scenarios for an acceptable road safety level [Koo16]. Driving simulation may play a key role in its development, allowing to simulate a wide range of possible scenarios and automated behaviors. But even with cutting-edge software and infrastructure, running all the tests takes a lot of time, and often does not involve sufficiently man-in-the-loop simulation.

The objective of this research project consists in evaluating how large scale public applications deployed on major smartphone platforms could help with autonomous vehicles simulation and development. With hundreds of millions of capable devices being used daily by consumers, we estimate a massive gain into using even a fraction of this available computing power for the benefits of simulation, through dedicated applications.

The very first step of this project consists in the release of the 3DAV Explore smartphone application [3DA17] (Figure 1), which allows users to observe in virtual reality, in monoscopic or stereoscopic with VR glasses conditions (Figures 2 and 3), a running traffic made of autonomous vehicles into a lane merging situation. This application sets the basis for the main core components of driving simulation: a road network definition, a traffic model to manage autonomous cars, a rendering engine, a user interface, all in real-time and running in an interactive way.

Figure 1 - Screenshot of the first version of 3DAV Explore

Figure 2 - Screenshot of the first version of 3DAV explore in virtual reality mode

Figure 3 - A Homido mini VR viewer installed on a smartphone for stereoscopic view of the 3DAV Explore application

Moreover, a second version was developed, adding more interactions as well as networking functionalities. The users drive a car in an American city using a mobile device. The car's steering wheel is controlled by the device's tilt while two touch-controlled buttons serves as the brake and throttle (Figure 4).

Figure 4 - Driver's view and UI

Two different modes of transportation are available to the user in this second application. By default, the user is placed outside of any vehicle, flying above the road. In this mode, he can move around the city by targeting the pink dots scattered all around the scene (Figure 5).

Figure 5 - Outside view of vehicle and pink dots

In order to enter the second mode the user must target one of the red cars and tap the screen. He will then be transported to the driver seat of said car and takes control of it. A blue diamond above the vehicle signals to other users than the car is already being used and can't be entered (Figure 6).

Figure 6 - Vehicle currently under user's control

It is possible to exit the vehicle to go back to the outside view at any moment by simply tapping the center of the screen. The previously occupied vehicle will automatically return to auto mode and continue its own.

In both modes a button on the bottom of the screen allows to switch between 2D and 3D view to be used in a VR headset. While in 3D mode, the vehicle is controlled by the head's movements. Leaning forward and backward will accelerate and decelerate respectively and left/right movements will allow to turn the wheel and look around.

Figure 7 – Menu options

The menu is opened by tapping the top left icon. Among the features available in this menu are (Figure 7): Resetting the gyroscope to adapt to the user's position, turning shadow off/on and data regarding the current state of the network and scene (Number of users...).

Tapping the "Auto" button on the bottom left will instruct the vehicle to switch into autonomous mode and start driving on its own. However, because of the limitations of the traffic system currently used it is possible for a vehicle to get stuck while trying to reconnect to its driving path.

Application Development

On the technical side, 3DAV explore has been developed using the Unity3D software.

The road scenery was built using visual 3D tiles from the Highway Construction Set, from the Visual

Imagination Software company (http://www.vis-games.de/). This consists into a 4 lanes highway section, with a lane merging area, of about 600 meters in length.

The city used for the latter scene was created using assets from the Modern City pack (https://www.assetstore.unity3d.com/en/#!/content/18005). It contains a selection of building meshes (FBX format) as well as various props (Bus stop, signs etc…) made with the Autodesk software series, optimized for use on a mobile platform (Figure 8). The layout was designed to form a closed road network.

Figure 8 – American city model top down view

To handle the road network definition and the autonomous driving vehicles behavior, the iTS (Intelligent Traffic System) software component (http://www.dagagames.com) has been used. The component includes the road network definition, with parameters for maximum lane speed, width, car type and occupation density, as well as priority pass for each lane connector.

The traffic component also offers a simple car spawning component, which handles car addition during the simulation in real-time. It was configured to spawn cars in a 250 meters radius from the main point of interest of the scene: the lane merging point (see Figure 9).

Figure 9 - iTS Traffic component in action in the first version of 3DAV explore

The car behavior is handled through the "iTS Traffic AI" script component, which uses an algorithm based on waypoints and car sensing distance to decide when it should accelerate, slowdown or change lane. This component allows developers to handle all the behavior parameters such as the minimum distance to overtake, the time for lane changing, detections distances, position on the lane etc. (see all component parameters in Figure 10).

Figure 10 - "iTS Traffic AI" component parameters

On the graphical side, the full road scene weight is about 300 000 polygons, depending on the selected viewpoint. A car-paint shader is used to provide better rendering on cars, offering environment reflections on the vehicles (see Figure 7). It runs at 60 Hz on an iPhone 6 device, in stereoscopic mode. Even though the application was designed to run on middle-class devices (from iPhone 5C and above), the rendering engine can handle real-time soft shadows, and supports dynamic reflection probes, to get surrounding cars reflections in the car bodies and rear-view mirrors.

The city scene weights about 1.3 million polygons, depending on the selected viewpoint. It runs at 60Hz on the same iPhone 6 device. For low-class devices, an option to disable real-time shadows is available in order to increase performances.

In addition and also to further increase performances, the application uses the occlusion culling feature (see Figure 11). Every object not in direct view of the user's camera is not displayed, reducing drastically the number of polygons to compute on the screen. This functionality is especially effective in a city layout such as the one used in our application as the buildings hide most of the surroundings at any given time.

Figure 11 - Illustration of the Occlusion culling in the city scene

The rendering engine used depends on the device the application is built on: Metal for iOS devices, OpenGL ES for Android and DirectX for Windows

The next steps of the project are consisting in adding more interactivity: allowing the end-user to drive cars of the application; or allowing him to add obstacles and events that will challenge the autonomous vehicles AI. By involving end-users, and adding connectivity that will allow to turn this application into a true companion tool for driving simulation software, we will be able to introduce massive man-in-the-loop based scenario generation and simulation. There are already several realistic driving simulation tools using internet and different levels of driving and visualization and/or VR equipment on the market (The Good Drive, 2017 [Goo17]) and the trend is to see new more and more participative applications developed.

Network infrastructure & messaging

In order to allow for third-party software to inject their own vehicle behaviors inside the existing traffic the second application was created with an integrated networking infrastructure. The Photon Engine (https://www.photonengine.com/en/PUN) was used to handle synchronization between devices through client to server messaging. For this document, the third-party software used as an example will be SCANeR™ Studio 1.7 [Cla99].

Figure 12 illustrates the Photon Cloud working principle. The messages are sent through the Internet to the Photon cloud which hosts the server. The server then conveys the message to the other clients. On average, if 4 users are connected simultaneously, the server sends 200 messages (~200 bytes each) by second. The free version of the Photon engine allows up to 20 users connected at the same time. This maximum number can be upgraded to 5000.

One user, designated as the "Master client" (by default the first to start the application), handle all calculations regarding the iTS traffic as well as the

ones regarding its own vehicle. The resulting positions of the cars is sent to the server which will transmit to every other client. If the current master client disconnects, one of the remaining client is designated to take its place.
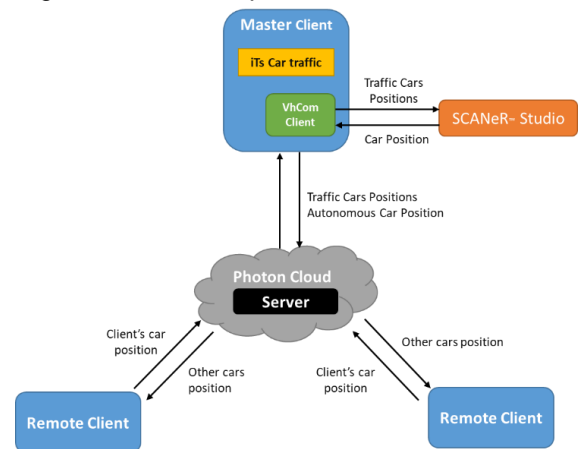

Figure 12 - Illustration of the Photon Cloud working principle

Each client, beside the master client, only handles calculations regarding its own vehicle and sends its position and rotation to the Photon Server. The positions of the other cars are received from the server and updated in real time on the local client. A script smoothens the motion between consecutives positions.

The next step of development will consist in creating the Vhcom client interface to permit communication between SCANeR™ Studio and the application. This will allow the injection of autonomous cars into the scene as well as intelligent traffic. The third-party software will serve as substitute for a human user, controlling the car through the VhCom client interface. In return, it will receive the information regarding the positions of other vehicles in the scene to react accordingly.

Application scenario & Conclusion

The application was designed to tackle a large variety of scenarios an autonomous vehicle might encounter. One example of such potential scenarios are the 25 cut-in scenarios as part of the NFI's research objectives "Autonomous vehicle" (http://pole-moveo.org/wp-content/uploads/2015/07/Objectifs_de_recherche-Veh_Auton_V1.2.pdf).

3D AV Explore will provide engineers and managers a unique tool they will be able to use while reviewing high-end simulation running, analysis and reporting, especially for worst case scenario, in a complementary way of more traditional AD simulation software tools such as CarCraft [Mad17] or SCANeR Studio™ [SCA18]. Smartphone with the

latest virtual, augmented and mixed realities technologies may thus be used to provide natural and collaborative review tools (Figures 1 and 13).

Figure 13 - A user of 3D AV explore, running the virtual reality mode

To complete the use of 3D AV Explore for extensive simulation trials integration in SCANeR Studio™ is planned in the next future as well as an open software implementation. Then, in-depth user studies should be performed to validate our approach of highly multi-collaborative simulation and check whether results could be transferred to real situations. Especially, as third-parties softwares will be able to communicate, it is possible to imagine collaborative driving not only between smartphones but also with heterogeneous platforms such as dynamic driving simulators.

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