IVRUX PROJECT SPECIFICATION

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1. INTRODUCTION

IVRUX is a support platform for the evaluation of User Experience (UX) in Virtual Reality (VR). This tool, intended to be used in an academic context, offers a support system to facilitate communication of creators and/or researchers with participants, and therefore streamline the process of evaluating UX in VR.

Industry VR creators identify a market gap for tools that support UX in VR, during and after development [5]. To respond to this need, several support platforms for VR development emerged, mainly utilizing the basic concepts of eye tracking and gaze visualization and applying it to VR. Based on the type of media used, these platforms can be distinguished between: i) Model-based VR or ii) 360º Video. In conventional model-based VR, the virtual environment is entirely simulated by computer graphics renderings, therefore based on a computer model [4]. In 360° VR (Cinematic VR or Surround Video), the virtual environment is 360° video footage captured in the real setting [4].

Taking into account the needs of researchers, current existing support platforms and academic work on the subject of analytics for VR, we have designed IVRUX to be a flexible tool for the evaluation of UX in VR. Considering the scope of such a tool, we have divided the development of the platform into two phases. The first phase, sees IVRUX as a support platform for the evaluation of 360° VR experiences. The second phase, sees IVRUX as a support platform for the evaluation of model-based VR experiences. Each phase has different stakeholders and needs to take into account, but it is necessary to consider where they overlap in order to efficiently design the architecture of the system.

2. STAKEHOLDERS

We have identified several stakeholders for the system, but we only describe the end users of the system in this document.

The first end user is the Researcher, who is not necessarily a creator or developer, but someone who is invested in the evaluation of the work, either informally or formally. Based on the user's limitations and the form of the medium, we can separate them in:

- 360º VR Researcher – This stakeholder deals with immersive video and does not have lot of experience with coding, therefore needs to have an abstraction layer for the evaluation. He is not as interested in the technical details of the VR experience, but more on overall knowledge of what the participants experienced.
- Model-based VR Researcher – This stakeholder deals with immersive 3D content (therefore with coding experience) and wants more detailed control over the evaluation process, being able to choose what parts of the scene he wants to track. He is interested in technical details of the VR experience, and how he can optimize the experience (both in terms of usability and performance of users).

The second end user is the Participant, the person that experiences the VR event. Based on their knowledge of the system capturing the information and the basis of the study (chosen by the Researcher), can be split into:

- Known participant – This participant has willingly agreed to be a participant in the study by providing the researcher with the participant's information (including identifying elements).
- Unknown participant – This participant has no knowledge that information about his experience is being recorded, and personal information about him is limited to non-identifying elements.

3. Conceptual Design

To identify the problem that we are addressing in the field, we:

- Reviewed existing platforms for evaluating VR experiences (CognitiveVR, Ghostline, Fishbowl VR, Unity, Retinad, EaseVR, Wistia, Youtube, Facebook, JauntVR, InstaVR, Focalhub, Thrillbox, and OmniVirt). These platforms present analytics features for 360º VR or model-based VR. Please refer to Survey Paper for a more detailed description.
- Reviewed literature to determine metrics used in evaluating VR experiences. Please refer to Survey Paper for a more detailed description.
- User Centered Design by analyzing users and users' tasks. This was done with semi-structured interviews with M-ITI researchers working in the VR field and 360º video creators at the "Immersive Media" Summer course, covering both subtypes of the Researcher stakeholder. Additionally, we looked at technical reports on the barriers affecting journalists from adopting Immersive Media[1,3].

Based on the previous topics, we have identified several issues to address:

- Existing analytics platforms do not offer flexibility to their features, compelling researchers to choose a specific layout, being forced to a specific type of medium/study and evaluation mode.
- Existing analytics platforms either cater to researchers without technical experience (making platforms that are inflexible and that cannot grow to the user's expectations), or for researchers with a lot of technical experience (making platforms that are overly technical, and that ignore more artistic aspects like storytelling).
- Existing analytics platforms are normally specific to content of a specific field (e.g. gaming, advertising, etc.).
- Existing analytics platforms are not suited for academic studies, since they don't collect demographical information on the participants. Furthermore, they rely on showing the analytics in visualizations requiring human interpretation (qualitative information), failing to deliver hard data (quantitative information).

- 360º video creators don't have the technical experience (e.g. coding skills) to use and/or personalize the "drag & drop" plugins offered by some analytics platforms. They require a skilled collaborator to incorporate the plugin. Furthermore, they prefer platforms that package their content for distribution, not dealing directly with the technical implementation of a distribution system.
- Existing analytics platforms don't use the content of the video (e.g. the narrative structure) as a factor impacting the user experience.
- Existing analytics platforms don't deal with the possibility of branching stories as they segment the study to just one scene.

Based on these issues, we have conceptually modelled the platform to be as flexible as the researcher's experience:

- For a researcher in 360º video, this means that the platform needs to help with the distribution of the content.
- For a researcher in model-based VR, this means that the platform needs to be extendable in the way that it captures participant's data.
- For both researchers, the platform needs to help with process on analyzing captured data, by offering multiple tools for analysis and automatizing the process of gathering insights and relevant data.

4. USE CASES

To put the user's needs in context, we wrote the following User stories (representing the 2 subtypes of the Researcher stakeholder).

USER STORY #1

Catarina is a digital artist that just recorded a 360º video in an almost-empty subway station with the train arriving, and she has questions whether she should color correct the video to make the train's color brighter and draw attention away from the commuters. She makes 2 versions of the video, with and without color correction, and uploads it to her server. She logins into IVRUX, and makes a study for 5 participants, and chooses the color corrected video. She makes another 5-person study with the video without color correction. She invites five people to one study, and five to the other.

Mary receives an invite to participate in a study. She installs the IVRUX app and after creating the account, she starts the study, where she views a 360º video of a subway station.

Two days later, Catarina comes back to find that both studies are finished. Before analyzing, she decides to annotate the video. She chooses one and makes a marker that follows the main interest point (the train), saves the annotation, exports the annotation, and uploads it to the other video since they have the same main interest point. She then decides to analyze. From the analysis, she finds out that in the color corrected video people spent 54% of their time looking at the interest point, while in the uncorrected version, they only spent 30%.

USER STORY #2

Tomas is making a VR puzzle game for the Gear VR. In one scene, there are several objects in a table (a helmet, a candle, a lipstick, an axe, a block of ice) and you need to combine them to make a new object (use the axe to carve the block of ice and make a sculpture). Tomas is wondering which object people will pick up first, and how they will use the axe. He logins to IVRUX and makes a new study with an unlimited number of users, and chooses to track dynamic objects, and controllers. Using the id supplied by the study, Tomas goes to the Unity game engine, and inputs the id. He then chooses what elements in the scene he wants to keep track. He adds the table as a static mesh and all the objects on it as dynamic. He uploads all the meshes and makes a build of the game scene, uploads the link to the platform and sends an invite to his friends. The day after, he logins to the dashboard to see the results, where it the analytics feature he can see the 3D scene with an indication of where the user was looking, where the controllers were and what he did with the objects. By analyzing each player, he sees that no one has picked up the lipstick and candle, and that as soon as they picked up the axe, most players tried to chop down the table. His friends must really love destroying stuff.

USE CASE DIAGRAM & DESCRIPTIONS

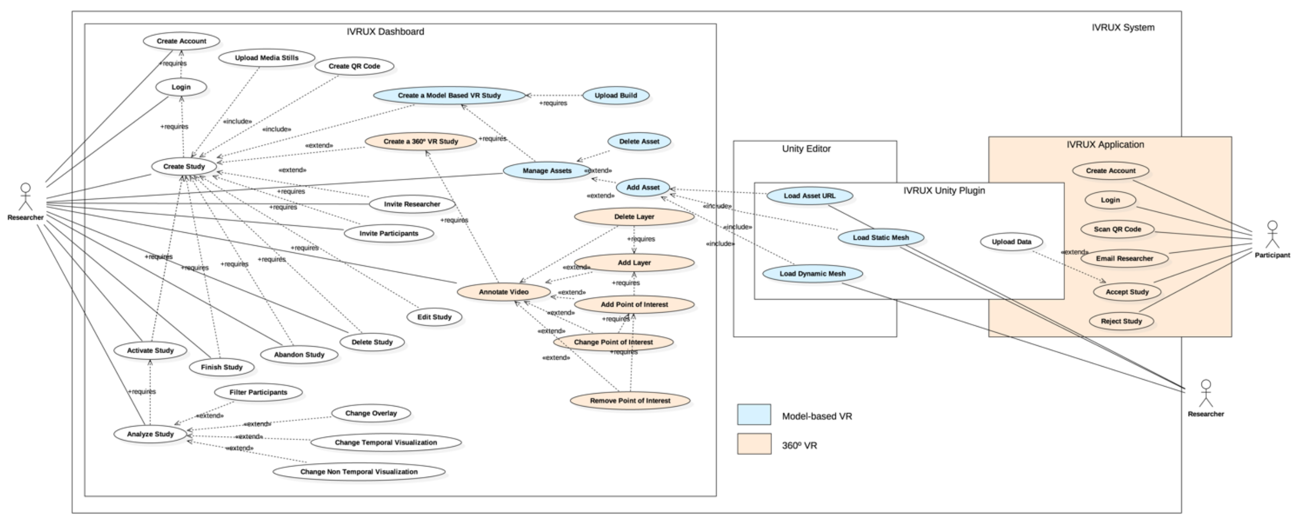

FIGURE 1 USE CASES FOR THE IVRUX SYSTEM. BLUE USE CASES REPRESENT USE CASES FOR MODEL-BASED VR, WHILE ORANGE USE CASES REPRESENT USE-CASES FOR 360º VR

Based on the user stories, we document the following use case (see Fig 1; for a higher resolution image, please refer to document UseCases.pdf) according to their subsystem:

- IVRUX Dashboard
    - UC1 Login – The researcher can login by entering his email and password. The system verifies if there is an account and if it matches the password, before allowing the login. If not, an error message is presented.

- UC2 Create account – If the researcher is a new user, he can request to create a new account, and must fill information about his email, password, first and last name. The system verifies if there is already an account and if the remaining information is valid, before creating the account. If not, an error message is presented.
- UC3 Create Study – The researcher can create a study by filling out the required and optional fields, and choose between a 360 VR Study or a Model-based VR Study. The system prompts the user with error messages, if so required.
- UC4 Create 360º VR Study – The researcher can create a 360 VR Study and fill out the link to the immersive video and audio, and then choose what type of metrics he wants to record. After creating the study, the study is considered inactive.
- UC5 Create Model-based VR Study – The researcher can create a model-based VR study, by choosing the type of metrics he wants to record. After creating the study, the study is considered inactive.
- UC6 Upload Media Stills – The research uploads images that represent the study and that can be viewed by the participants before accepting to join the study.
- UC7 Create a QR Code – The system creates a QR code that identifies the study that was created.
- UC8 Activate Study – The researcher chooses to activate the study and start allowing participants into the study.
- UC9 Finish Study – The researcher chooses to finish the study and block new participants from joining the study.
- UC10 Invite Researcher – The researcher can invite researchers to collaborate on the study. The invited researcher if invited will have access to study, including most of its features, but cannot delete a study.
- UC11 Abandon Study – An invited researcher can abandon a study, meaning that he will no longer have access to the study's information. The researcher that created the study cannot abandon a study.
- UC12 Delete Study – The researcher that created the study can choose to delete all information associated with the study. After prompting for confirmation, the system proceeds to delete all content associated with the study including uploaded assets.
- UC13 Annotate Video – In a study with immersive video assets associated, the researcher can annotate the video in a special interface.
- UC14 Upload Build – In a Model-based VR study, the researcher can upload a link to a build to be distributed to the invited participants.
- UC15 Invite Participant – The researcher enters the emails of participants and the system emails them an invite for the study
- UC16 Manage Asset – In a Model-based VR study, the researcher can view which assets have been associated with the study.
- UC17 Add Asset – The system associates an asset to the study
- UC18 Delete Asset – The system disassociates an asset to the study
- UC19 Add Layer – In the annotation interface, the researcher can add a layer to the annotation structure of the video.

- UC20 Delete Layer – In the annotation interface, the researcher can remove a layer of the video's annotation structure.
  - UC21 Add Point of Interest – In the annotation interface, the researcher can add a point of interest to a layer in the annotation structure of the video.
  - UC22 Change Point of Interest – In the annotation interface, the researcher can change the values of point of interest in a layer.
  - UC23 Delete Point of Interest – In the annotation interface, the researcher can delete a point of interest of a layer.
- IVRUX Unity Plugin
  - UC24 Load Static Mesh – The system associates the system with a loaded mesh and its static properties.
  - UC25 Load Dynamic Mesh – The system associates the system with a loaded mesh.
  - UC26 Load Asset URL – The system associates the system with a link for an asset
  - UC27 Upload Data – The system uploads the document structure that represents all the recorded information during a user's study session.
- IVRUX Application
  - UC28 Login – The participant can login by entering his email and password or alternatively, login without entering any information. In the first case, the system verifies if there is an account and if it matches the password, before allowing the login. If not, an error message is presented.
  - UC29 Create account – If the participant is a new user, he can request to create a new account, and must fill information about his email, password, first name, last name, gender and date of birth. The system verifies if there is already an account and if the remaining information is valid, before creating the account. If not, an error message is presented.
  - UC30 Scan QR code – The participant can access the phone's camera and scan a QR code, to gain access to a study.
  - UC31 Email Researcher – The participant can email the main researcher of a study, opening the external email client.
  - UC32 Accept Study – If the participant has been invited to a study or has scanned a QR code, he can start the study, showing the study's protocol followed by the immersive video.
  - UC33 Reject Study – If the participant has been invited to a study or has scanned a QR code, he can choose to reject participating in the study.

5. System Composition

As seen in the use cases, the system can be subdivided in four subsystems or components:

- IVRUX Dashboard – This component is used by the Researcher to start new studies, as well as, analyze the results of the study. The study can be a 360º VR study (in which case, the researcher indicates the audio and video to be tested) or a model-based VR study (in which case, the researcher must use a Unity plugin to indicate the content to be tested).
- IVRUX Application – This component is used by the Participant to take part of 360º VR studies.
- IVRUX Unity package plugin – This component is used by the Researcher to establish a connection between the model-based scene and the study he created. The IVRUX application also uses this plugin to record information about the user experience. Additionally, the applications created by a Researcher for a model-based study, also use this plugin.
- IVRUX API – This component is responsible for connecting different components and the database where all relevant information is stored. It is not used directly by the users, relying on an abstraction layer.

6. Requirements

Based on the description of use cases and architecture subsystems, we have documented the following functional and non functional requirements (divided by subsystems)

Functional Requirements

- IVRUX Dashboard
    - FR1 The dashboard supports the creation of new accounts for Researchers.
    - FR2 The dashboard supports the creation and editing of VR studies.
    - FR3 The dashboard should support studies where the content being tested is in 360º video.
    - FR4 The dashboard should support studies where the content being tested is a 3D scene.
    - FR5 The researcher can invite participants for a specific study.
    - FR6 The researcher can invite researchers to have access to a specific study.
    - FR7 The researcher can abandon a study if he was not the creator of the study.
    - FR8 The researcher can delete a study if he was the creator of the study.
    - FR9 The dashboard should support the creation of QR codes to publicize a study.
    - FR10 The dashboard should support the annotation of a 360º video.
    - FR11 The dashboard should support the analysis of data captured in the VR study.
    - FR12 The researcher should be able to filter participants during the analysis.
    - FR13 The dashboard should support the reproduction of 360 video or 3D scenes in the analysis of a VR study.

- FR14 The dashboard should support a modular layout for the analysis, where the researcher can choose different visualizations to serve the task better.
- FR15 The researcher should be able to see the assets that are linked to a study.
- FR16 The researcher should upload a link to the build of a study to share with invited participants.

- IVRUX Application
  - FR17 The application should support the creation of new accounts for Participants.
  - FR18 The application should allow for Participants who do not wish to make an account, to still use the application.
  - FR19 The application should support the scanning of QR codes to gain access to a study.
  - FR20 The application should support the screening of 360 video content.
  - FR21 The application should record relevant information about the device and the user's interaction with the shown content.
  - FR22 After the VR experience, the application should forward participants to a form if so stated in the study's settings.
  - FR23 The application should allow the participant to contact the researcher for further clarification about a study.
- IVRUX plugin
  - FR24 The plugin should support the authentication of the Researcher in the editor.
  - FR25 The plugin should support the identification of the study in the editor.
  - FR26 The plugin should use information stated by the researcher in the study creation, to setup the study in the game engine.
  - FR27 The plugin should support the loading of assets (meshes, etc.) to an external database for use in the study analysis, in the editor.
  - FR28 The plugin should support the recording record relevant information about the device and the user's interaction with VR content.

Non-Functional Requirements

- IVRUX Dashboard
  - NFR1 The dashboard should be web-based, and a single page application (to reduce client server cycles).
  - NFR2 The dashboard needs to allow for the playback of video, audio and 3D scene content.
  - NFR3 The systems needs to allow for storage of external files such as meshes.
- IVRUX Application
  - NFR4 The application should be compatible with Android systems.
  - NFR5 The application needs HMD's support for Google Cardboard, Google Daydream and Gear VR, with possibly other devices in the future.
  - NFR6 The application needs to be built in the Unity game engine.

7. CONCEPTUAL CLASS DIAGRAM

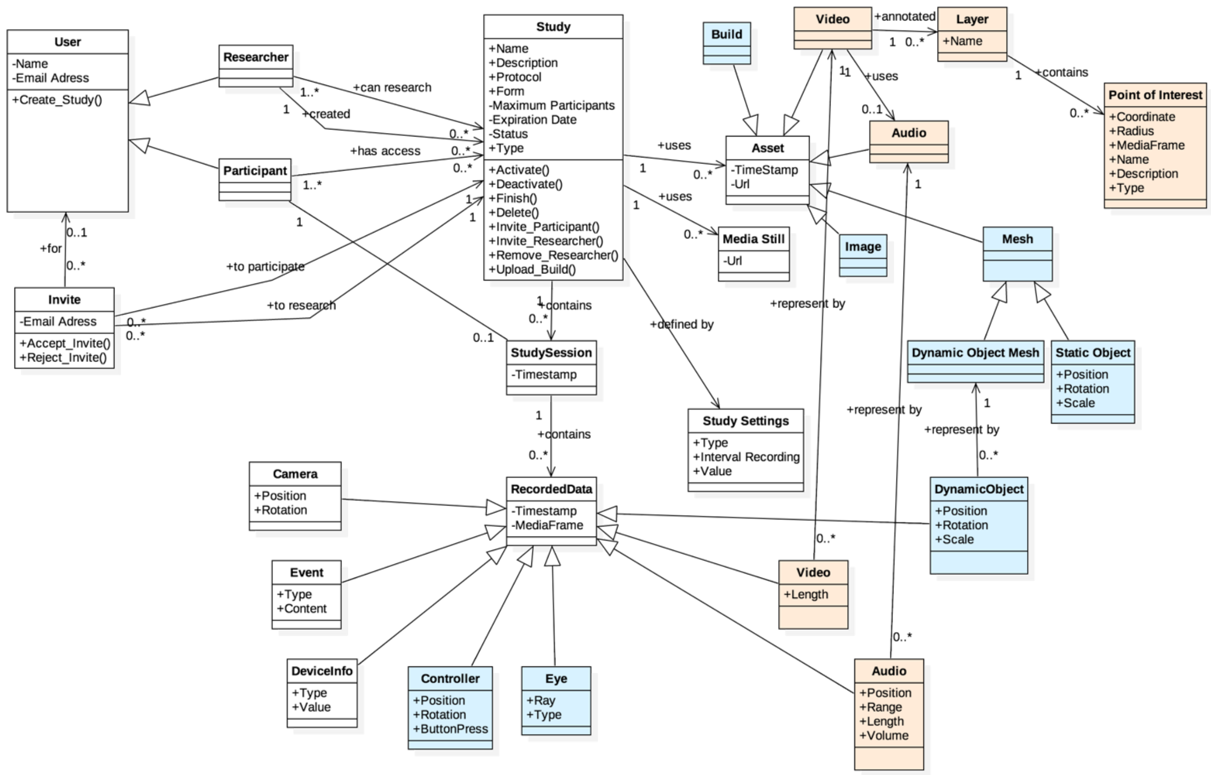

FIGURE 2 CONCEPTUAL CLASS DIAGRAM FOR IVRUX SYSTEM. BLUE CLASSES REPRESENT CLASSES FOR MODEL-BASED VR, WHILE ORANGE CLASSES REPRESENT CLASSES FOR 360º VR

Based on use cases and functional requirements, we created a conceptual class diagram with the main classes/concepts (see Fig.2). A conceptual class diagram differs from a detailed class diagram, since the first is aimed at modelling the concepts of the system, while the latter is aimed at modelling the technical implementation of system's objects (including properties and methods). For a higher resolution image, please refer to document ConceptualClassDiagram.pdf.

8. PROTOTYPES

LOW QUALITY PROTOTYPES

For the purpose of the assignment, we conceptualize some of the user interfaces for IVRUX (namely those corresponding to the 1st phase). They were tested informally with researchers from M-ITI, who emphasized desire to have a free alternative for monitoring users in model-based VR. People understood the interfaces, but highlighted the need for tooltip explanations to features or a tutorial to guide new users. For the low quality interfaces, please refer to document LowQualityPrototypes.pdf.

High Quality Prototypes

For the purpose of the assignment, we iterated over the low quality prototypes, taking in feedback from colleagues, and integrated the use cases for the second phase of development. These high quality prototypes are meant to be detailed and used to test usability, since they are close to the final product. Due to time constraints, we were unable to carry on another round of user evaluations. For the high quality interfaces, please refer to documents HighQualityPrototypes_IVRUXApplication.pdf and HighQualityPrototypes_IVRUXDashboard.pdf. Using these interfaces (I1 to I10 and IA1 to IA10), we constructed user flow maps for IVRUX Dashboard (see Fig.3) and IVRUX Application (see Fig.4). For higher resolution images of the user flows, please refer to documents UserFlow_IVRUXApplication.pdf and UserFlow_IVRUXDashboard.pdf

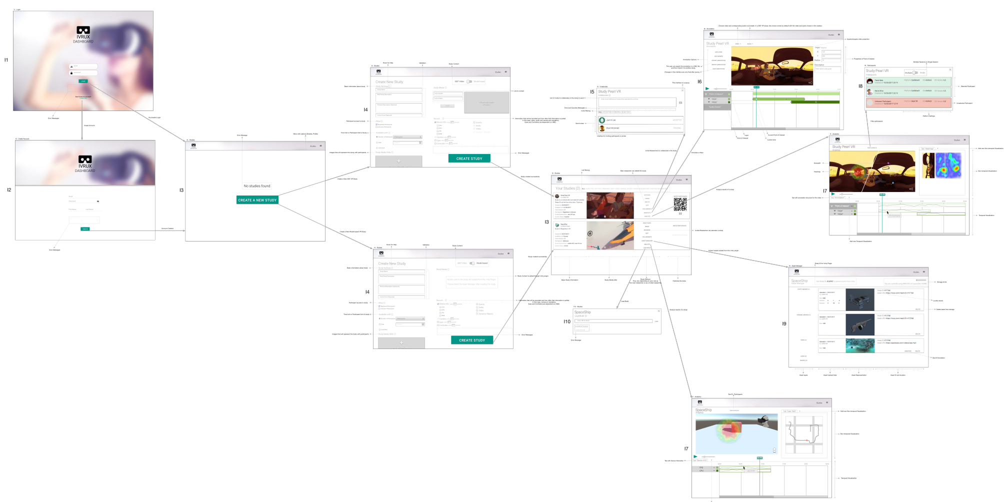

FIGURE 3 USER FLOW FOR IVRUX DASHBOARD

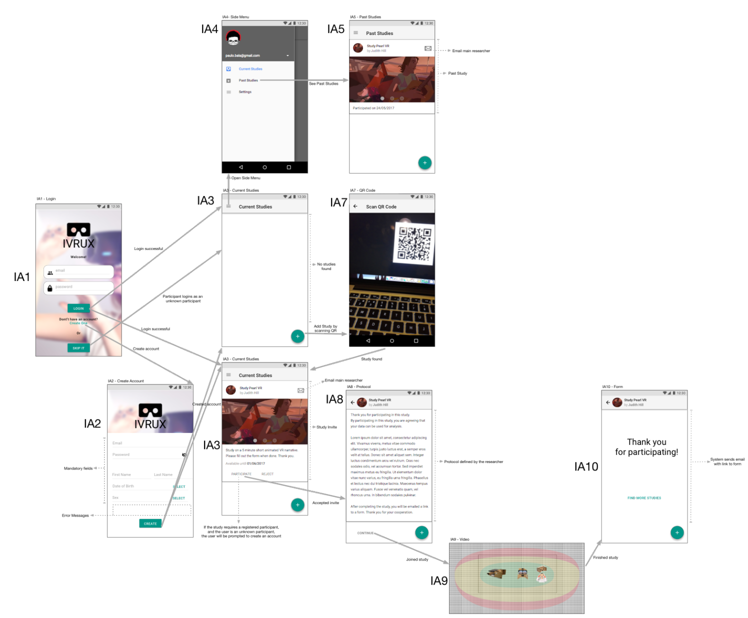

FIGURE 4 USER FLOW FOR IVRUX APPLICATION

9. HIGH LEVEL ARCHITECTURE & IMPLEMENTATION

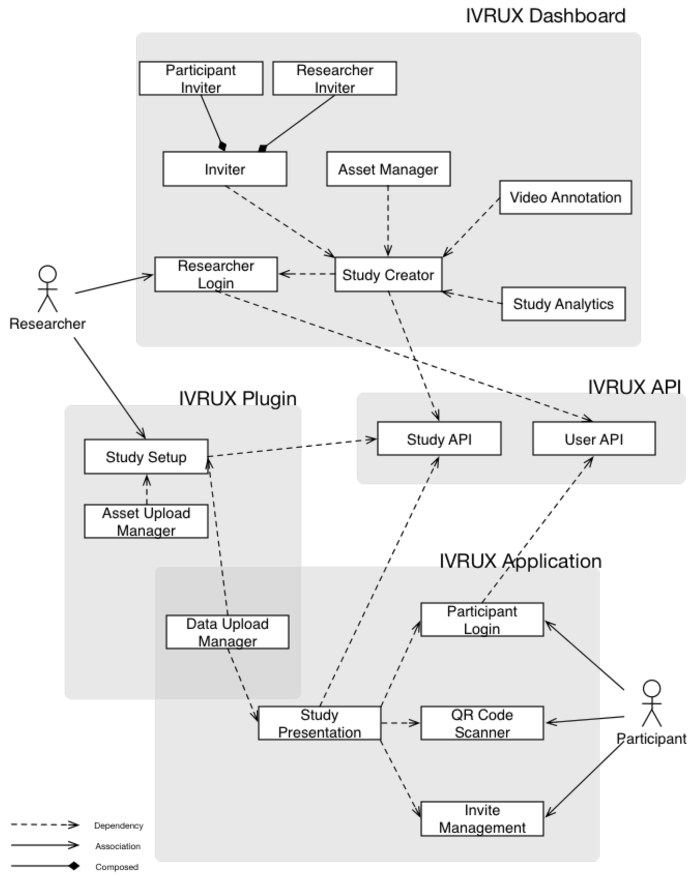

FIGURE 5 HIGH LEVEL ARCHITURE OF IVRUX SYSTEM

The image above (see Fig.5) showcases the high level architecture of the system, including the separation in subsystems (and components). For a higher resolution image, please refer to document HighLevelArchitecture.pdf

The IVRUX Dashboard prototype will be developed in Angular (formerly Angular JS). Angular is a structural MVC framework for dynamic web applications. In the past, web pages followed client server cycles, but these took too many requests and dragged performances. With single page applications, data that is needed is loaded once, and the client is responsible for formatting the data. This allows for fast rich web applications especially for pages with lots of data (such is the case of the analytics page). Angular is also compatible with external libraries needed for UI elements of the interface, such as heatmaps [6], Video Playback [7], VR support [8], 3D scenes [9], graphs [2,10–12] and timelines[12].

The IVRUX Application and the IVRUX plugin will be developed in Unity, due to the game engine's support for HMD platforms. This choice opens the door for the inclusion of other HMDs for the platform, and future iterations of the current supported HMDs (Cardboard, Daydream and Gear VR).

The IVRUX API will be developed using Express.js, a Node.js web application framework, to make a RESTful web service. As a database, we will use MongoDB, a document-oriented NoSQL database, which uses JSON structures allowing for dynamic schemes and is appropriate for applications with high write loads and fast querying needs. The dynamic schemes allow for the structure of the database to evolve over time and to save in space. For example, if a dynamic object changes position, the recorded data can just be the new position, ignoring the scale and rotation fields. The following schema (see Fig. 6) is a physical representation of the working database; however due to the nature of the document structure, it is very volatile and merely destined to use for conceptually modelling the web services. For a higher resolution image, please refer to document DBScheme_Diagram.pdf and for a more detailed description, please refer to document DBScheme_FullSpecification.pdf

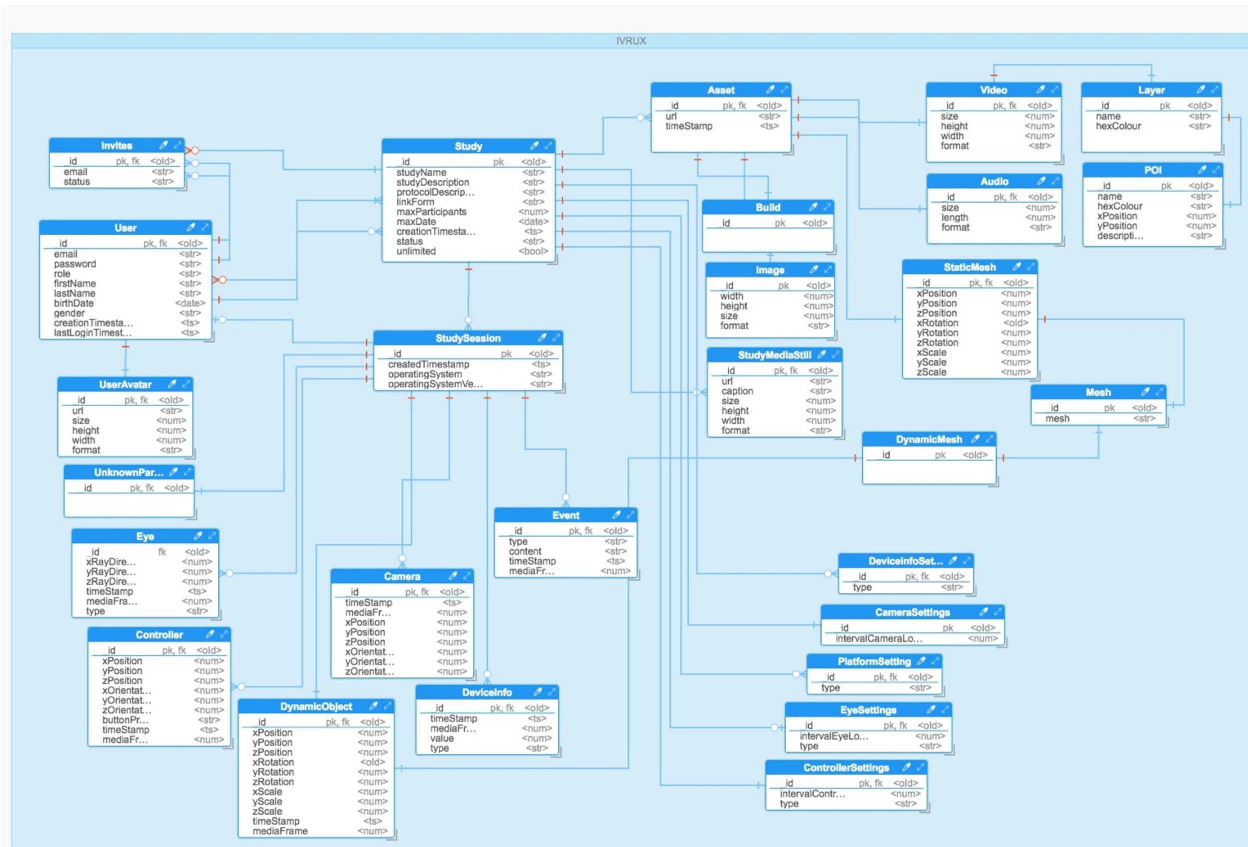

FIGURE 6 DATABASE SCHEME

10. FUTURE WORK

The documentation here provided focuses on the support system of setting up studies, with more work being needed on the specification of the analytics features, namely the temporal and non temporal visualizations. Furthermore, there is a need for deeper specification on the functions of the Unity plugin dealing with multiple scenes and with other asset elements (lights, particle systems, world UI, etc.). Although, the complexity of the scenes in Unity doesn't allow for full transposition to the IVRUX Dashboard, there needs to be a reasonable abstraction that allows for researchers to gain insight on model-based VR. However, the architecture chosen (namely, the document based database) is one that allows for growth of the application and a degree of flexibility dealing with unexpected problems in development.

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