10.20378/irb-58474

Requirements Elicitation for New Video Game Development Tools: A Case Study

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Abstract. This paper presents a case study involving requirements elicitation for new tools in video games development. Eight video game developer companies from three different countries and a variety of stakeholders (N=17) participated in a user study that was based on a tailor-made requirements elicitation framework. During the process, interesting issues emerged related to the applied method but as well concerning the presentation of innovative tools, as disruptive technology, the different stakeholders' points of view and roles in the process, the role of technology providers and the organizational challenges towards this new game development pipeline. This case study provides interesting insights in applying a user-centered approach for requirements elicitation in the video game application domain and discusses lessons learned which can be of value for UX researchers and practitioners in video game research.

1 Introduction

In requirements engineering, requirements elicitation is the practice of collecting the requirements of a system from users, customers and other stakeholders. The practice is also sometimes referred to as "requirement gathering" [1]. During the last decade there has been a growing interest in the adaptation and customization of requirements elicitation methods and techniques to the unique characteristics to each individual application domain (e.g. mobile learning, serious games, banking systems) [2-4]. The attempt to bootstrap requirements elicitation techniques to each application domain is based on the promise to optimize validity of results by taking into consideration intrinsic characteristics of each application domain, expectations and goals among various stakeholders and diverse requirements prioritizations [5-7].

From this perspective, in this paper we reflect on our experiences in user requirements elicitation of an innovative mixed pipeline for assets creation within the video game application domain. Video game development has become over the years a collaboration activity which embraces complex communication and collaboration processes among several stakeholders who

share different roles within the video game development pipeline [8,9]. As such, it represents a unique domain in which requirements elicitation embraces challenges like: (a) creating and sharing a common understanding among technology developers and UX experts related to the underlying technology and its effect on current workflows and procedures; (b) define a custom requirements validation framework bootstrapped on this particular case study; (c) recruit representative end-users in order to perform the requirements elicitation study; (d) communicate in an efficient way the vision to end-users aiming to elicit their views, opinions, motivation, concerns and requirements related to the envisioned approach; and (e) consolidate results of the requirements elicitation with technology partners aiming to find the best trade-off solution between user wishes and feasibility.

In the aforementioned context, a three phase requirements elicitation method was adopted, as depicted in Figure 1:

- *Phase A-Preparation,* aimed to transform the vision statement of the new approach into a set of presentable usage scenarios;
- *Phase B-Requirements Elicitation*, verified the view against the perceptions and opinions of real game developers; and
- *Phase C-Analysis and Consolidation*, analyzed findings of the previous step, consolidated and prioritized results with partners and finally documented the final end-user requirements.

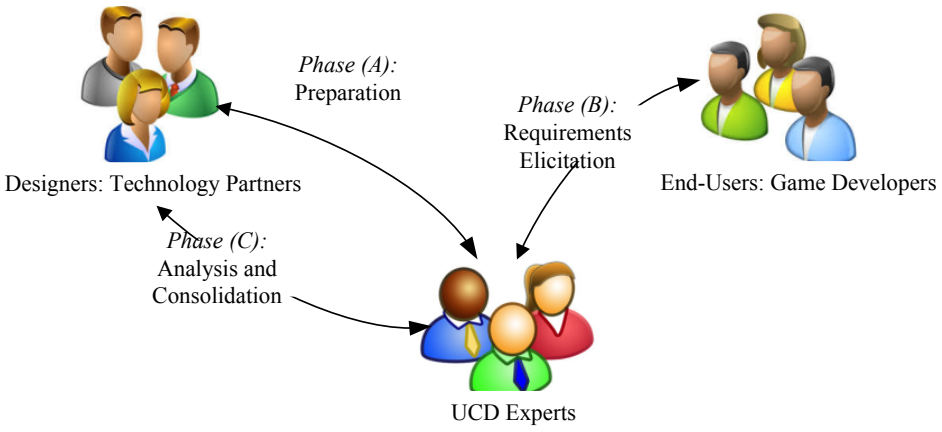

Figure 1. Overall requirements elicitation methodology.

The adopted method aimed at addressing the aforementioned challenges and reaching an optimized trade-off solution among end-users requirements and constraints related to feasibility, available time frames and resources. The rest of this paper is structured as follows. We first provide background information related to the context of the study and present the rational and

motivation behind the vision to design an innovative pipeline for assets creation in video games. Consequently we present each step of the method that was adopted with the aim to identify and validate the user requirements in the aforementioned context. Finally, we present lessons learned and summarize our findings and conclude the paper.

2 Context of the Study

According to [10], art, design and programming accounted for nearly half of the total retail cost of a next generation video game, while the remainder went to marketing, distribution and retail mark-up. In this realm, there is profound need to propose an innovative development pipeline for the creation of video game assets in order to drastically reduce both time and expenses involved in their creation, and make high quality realistic contents accessible even to small game developers [20]. From a technology point of view, this will be achieved by means of new image-and video-based technologies [11, 12] that will be developed and optimized and smoothly integrated into most dominant video game development engines (e.g. Unity3D, Unreal). From a procedural point of view, game developers will be able to capture and reconstruct real life objects by simply taking a few sequences of photos and videos to be processed by a semi-automatic software using image based rendering techniques integrated with traditional assets made of polygons and textures. As mentioned in [20]: "*It is anticipated that the new approach will significantly affect the content creation pipeline in video game development with new tools which will allow a much faster turnaround time from the idea to the prototype implementation of video games*".

The envisioned pipeline is comprised of the following major steps as depicted in Figure 2: a) the capturing step; b) the reconstruction; and c) the edit and play step. In particular, with regards to the capture step, the idea is to allow representative users to take images and videos of real life elements (e.g. buildings, houses, streets, cars, moving trees) and reconstruct them through innovative image and video based rendering algorithms and subsequently use them within a video game engine with the aim to create video games.

Figure 2. Major steps in the proposed pipeline (*source: www.cr-play.eu*).

3 Phase (A) – Preparing the user requirements study

The main objectives were: a) to perform a stakeholder analysis with the aim to understand stakeholder values, motivation and concerns in adopting the new pipeline (i.e. anticipated impact that the system would have within their current working context); b) to elaborate representative usage scenarios and to identify primary and secondary users for the tools and c) to define a tailor made requirements elicitation method based on the aforementioned tasks.

For achieving the aforementioned goals several known techniques were applied like stakeholder analysis, current workflow analysis and user scenarios. In Table 1 we summarize the scope, the method and main results of each applied technique.

Technique	Main contribution to the requirements elicitation framework
Stakeholder analysis	*Scope:* To identify stakeholder categories and understand their values, motivation and concerns in adopting the new pipeline. Finally, to define the anticipated impact of the new pipeline in their current working context and activities. *Method:* Literature review, interviews, group discussions and consolidation with consortium partners. *Results:* Stakeholders were group in two major categories, direct and indirect involved stakeholders (Appendix A). The analysis of the anticipated impact revealed several UX dimensions which were considered as important investigating within the subsequent study.

	With regards to its indirectly affected stakeholders, following dimensions were identified: a) the intention of adopting the mixed pipeline for video game development with an emphasis on validating the usefulness in current and future projects; and b) the impact on achieving the business goals and the possible effect in internal organizational or operational structures. With regards to directly affected stakeholders, following dimensions were identified: a) the perceived ease of use of the tools; b) the completeness of gathered end-user requirements with respect to the identified tools, functionalities and workflows; and c) the perceived usefulness.
Current workflow analysis for assets creation in video games	*Scope:* To identify, based on the aforementioned stakeholder analysis, primary and secondary users of the proposed pipeline. Furthermore, to specify in detail how this new approach will affect the traditional workflow of assets creation in video games. In particular, questions that were investigated were related to: a) where and when the interaction takes place; b) who is interacting with the technology; c) how the user is interacting in terms user input, what does the system do, what results does the system provide to the user; and finally d) when the user will be satisfied with the obtained results. *Method:* Literature review, interviews and consolidation with consortium partners. *Results:* The traditional workflow analysis contributed significantly in identifying the primary and secondary users of the envisioned tools (Appendix B). The technical specialists group, mainly artists and programmers, represent the primary user category which will directly interact with the interactive tools. However, there are also secondary users (the art directors, game designers, game producers, publishers and video game players) who are implicitly related to the results of the proposed pipeline. It also revealed several layers of abstractions related to the pipeline which were: system implementation layers (*system layer*), the available tools (*tool layer*) aligned to specific user category, user goals (*user layer*) and business objectives (*business layer*).

Usage Scenario Description	*Scope:* To elaborate a representative use case scenario with the aim to present it to end-users in the subsequent step. The objective of the usage scenario description was to highlight user interaction aspects of the new pipeline in terms of workflows, information architecture, presentation, functionalities and data formats. *Method:* Interviews, group discussion and consolidation with consortium partners. *Results:* The scenario description that has been elaborated consisted of several layers namely: a) the user layer; b) the tool/goal layer; and c) the activity layer (Appendix C). Based on this approach, we elaborated a representative usage scenario for each step of the pipeline (i.e. capture, reconstruct and play) along with the pre-requisites related to human and technology factors (e.g. which software or hardware would be necessary, specific human skills, knowledge or previous experience) aiming to achieve a certain goal.

Table 1. Applied techniques during phase (A).

4 Phase (B) – Requirements Elicitation Study

The objective of this phase was to capture requirements for the pipeline with the involvement of end-users, i.e., video game developers. For this purpose, we recruited (8) game developing companies, all of small medium size, from (3) different countries in the EU: Italy, Finland and Greece, and we conducted (N=17) semi-structured interviews with different stakeholders. Prior the interview the participants followed a detailed presentation related to the usage scenario that has been elaborated in the previous phase of the applied methodology.

As shown in Table 2, the participants shared different roles within the game content creation pipeline and stated that they were experienced professionals. It should be mentioned that 15 participants are usually enough to provide a solid ground for analysis [13,14], while some suggest that even smaller number is enough in case of experts [15,16].

Role	Total Number	Average Years of Professional Experience	Average Age

Producer	2	14	37
Game Designer	6	4.4	31.1
3D Artist	5	6.4	28.6
Game Programmer	4	9.7	40

Table 2. Participants' information.

Furthermore, based on findings of the previous phase, we created a tailor made requirements elicitation framework. A high level presentation of this framework is shown in Figure 3, which aligned specific dimensions with stakeholder groups.

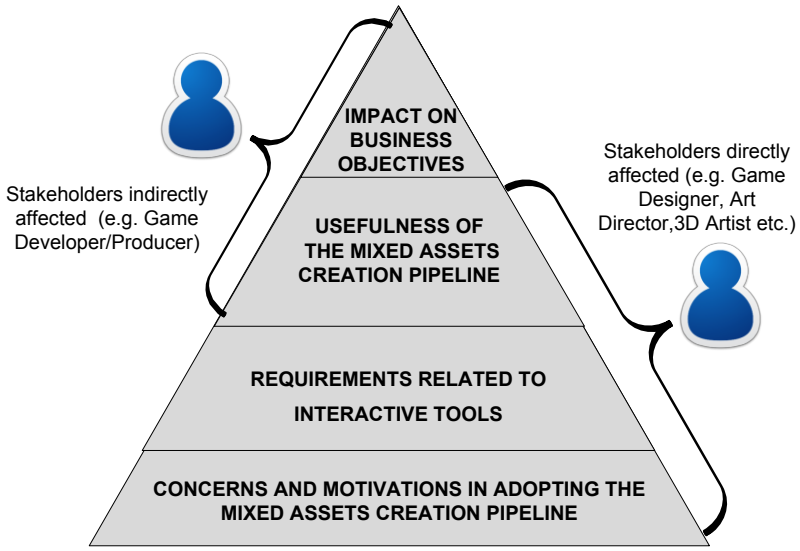

Figure 3. Requirements analysis perspectives.

The framework embraced the identified major stakeholder categories and investigated following perspectives: the adoption of such new perspectives focusing on values, motivations and intentions of end-users, the completeness of requirements with regards to the new tools focusing on scenarios as expressed in the usage scenario description, and the impact of the pipeline in business objectives. Based on the aforementioned framework, semi-structured interviews were prepared in order to determine the perceived values and difficulties on creating intentions, actual using the system and measuring the CR-PLAY impact in current processes and workflows with regards to video games content creation. In particular, the interviews were applied in order to determine the perceived values and difficulties on creating intentions, actually using the system and measuring the impact in current processes and workflows with regards to video games content creation. The interview questions were open ended aiming to allow the interviewee to express freely

her/his opinion related to several issues that were investigated during the study (e.g. *Please describe your main concerns with regards to the capturing activity as described (initializing, capturing, guidance, post processing steps, preferred output etc.)*

As shown in Figure 4, the method followed in the requirements elicitation phase was split into three steps: i) to capture the game developers' current content creation pipeline, workflows and procedures; ii) to present the proposed mixed pipeline to game developers, and iii) to analyze their views and perceptions through semi-structured interviews.

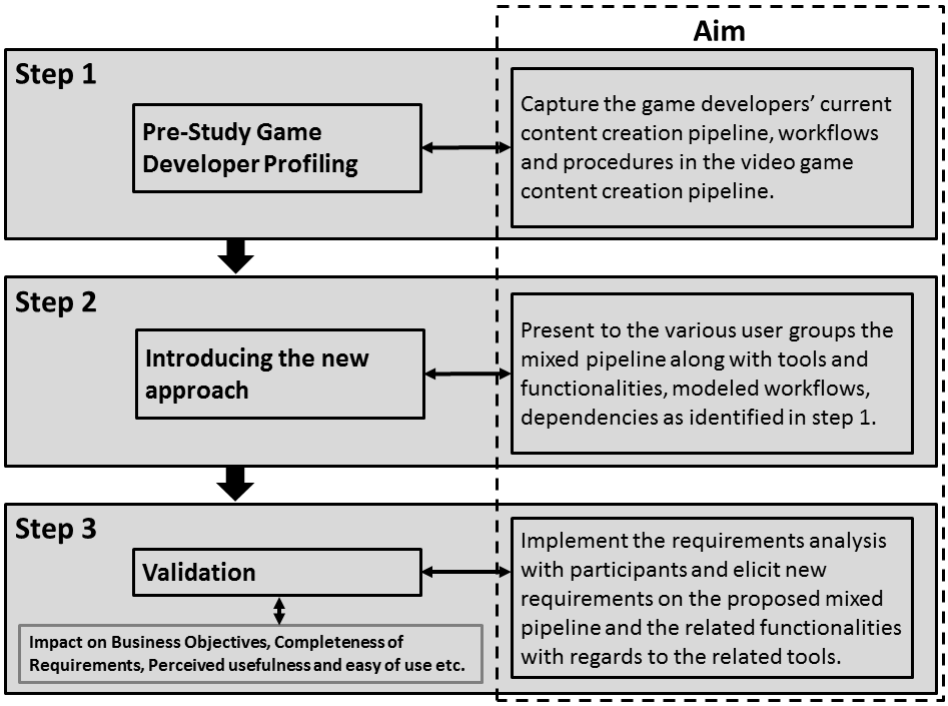

Figure 4. Requirements analysis implementation method.

5 Phase (C) – Analysis of Results

The data analysis phase of the requirement elicitation study followed sequential steps. First, the answers from all semi-structured interviews were transcribed by the UX team. For the transcription we adopted a coding schema based on the identified validation dimensions: a) impact on business objectives; b) perceived usefulness of the pipeline; c) requirements completeness focusing on functional and non-functional requirements and d) intentions, concerns and motivations in adopting the proposed pipeline.

We coded the participants' responses by reflecting the validation goals and annotated the participant responses according to the discussion theme, the

game developer company, the participants' role and the unique identifier of the interview. Following this approach we created a common template that was used by the analysts group. An example of the interviews' transcriptions is shown in Figure 4 where (A) indicates the validation goal, (B) indicates the participants' transcript label (*indicated the time of the audio recorded interview the participant expressed his opinion followed by his companies abbreviation, his role within the company and the interview unique identifier*), (C) indicates the interviewee's response and finally (D) correlates the participants response with the validation question.

A	Perceived usefulness	Motivation	C
B	[18:25] {TL_3DARTIST_ID:1}	*"Main thing is to have QUICK, PHOTOREALISTIC ENVIRONMENTS FOR OUR GAMES"*	D

Figure 5. Semi structured interviews transcript example.

The transcriptions were added on a common template and were discussed with the analysis team. Subsequently, the results were analyzed by summarizing the prevalence of categories and identifying further groupings or relationships through brainstorming sessions which were conducted by the analysis team. In addition, various content analysis techniques, such as frequencies or counts of events/mentions were performed along with narrative and correspondence analysis that aimed to create user role profiles in accordance to their responses to the semi-structured interviews.

The interviewed data were analyzed by a team that consisted of 5 UX experts. Initially, each team analyzed the data separately according to the aforementioned coding. Then, the teams arranged a round table discussion aiming to discuss findings derived from the conducted interviews and plan further activities. Next, the end-user requirements were grouped according to the requirements framework. Finally, a draft end-users requirements analysis report was consolidated with the technology partners. This task was necessary since that the requirements elicitation embraced several requirements as expressed by end-users which are from a technological point of view difficult to implement or even out of scope of the project.

6 Discussion and Lessons Learned

We summarize below our main experiences and lessons learned towards achieving the main goals of the requirements elicitation process.

Phase (A)- Preparation. Objectives: Creating and sharing a common understanding among technology developers and UX experts with regards to

the underlying technology and its effect on current workflows and procedures. Define representative usage scenarios for end-users. Define a custom requirements validation framework bootstrapped on this particular case study. Recruit representative end-users in order to perform the requirements analysis study (2 months time).

The elaboration of a representative usage scenario derived from the need to present to end-users a good real life example on how this new approach would affect their everyday activities with the utter aim to elicit requirements. We underpin that several iterations among UX experts and technology partners were required for achieving this task. This iterative cycle was primarily necessary in order to create and share a common understanding among different technology partners and UX experts within the consortium related to user interaction perspectives. We also stress, that the active and collaborative involvement of technology partners in various techniques during phase (A) facilitated reaching a common ground and mutual understanding related to the involved steps of the pipeline aligned with stakeholder categories, user roles and activities.

In particular, the stakeholder analysis contributed in the identification of the effects of the envisioned approach to each stakeholder category and separated the impact of the envisioned technology to multiple levels of abstraction per stakeholder group (e.g. business, operational, organizational and procedural). Subsequently, the traditional workflow analysis related to video games assets development contributed significantly in further identifying the primary and secondary users of the envisioned tools. It also, revealed the main procedural impact of the new pipeline and analyzed interactions in several levels like system procedures (system layer), functionalities as exposed by the tools of the new pipeline (tool layer), user goals (user layer) and high level objectives (business, organization, operational layer).

Finally, the usage scenario elaboration schema (Appendix C) was perceived as very helpful by the technology partners in order to formalize the user interaction activities. The schema inquired specific information related to the pre-requisites of representative related to human and technology factors and details for the anticipated human computer interaction in each step of the pipeline like where and when the interaction takes place, who is interacting with the technology, how the user is interacting in terms user input, what does the system do, what results does the system provide to the user, and finally when the user will be satisfied with the obtained results.

It is also important to mention that the aforementioned approach revealed the need to identify a specific requirements elicitation framework with the aim to focus not only in user interaction tasks but also to take into considerations

other aspects which also affects stakeholder groups. Accordingly, specific instruments were developed (questionnaires, semi-structured interviews and focus group studies discussion topics) aiming to address specific functional, non-functional requirements, intentions of use and end-users motivation and concerns.

One more important aspect was related to recruiting representative end-users. Given that the involvement of real end-users is a very critical aspect with respect of the internal validity of a study (since it determines in a high percentage the accuracy of delivered results) it is important to consider the user recruitment, even at a project proposal stage, as one of the most critical tasks and contain contingency plans aiming to resist in last minute cancelations of end-users.

Phase (B) – Implementation. Objectives: Communicating in an efficient way the vision to real end-users the new approach aiming to understand their views, opinions, motivation, concerns and requirements related to the envisioned approach. (1 month time)

The implementation of the study was performed smoothly, despite that the requirements elicitation needed to be implemented within a multinational context and that innovative aspects needed to be presented in a clear and understandable way to end-users. From a procedural point of view we decided to translate the initial presentation for end-users and semi-structured interviews in the local language of each game developer aiming to present the pipeline in a more efficient way as well to non-proficient English speakers. Based on the same rational, the interviews were performed by consortium partners in their local language and were afterwards translated to English. The participants followed an initial presentation prior the conducted interviews. Furthermore, the interview structures with the representative scenario were sent to the interviewees before the interview appointments. In each requirement validation session conducted, audio was recorded (with the consent of the participants) and took on average 1 to 1 and 1/2 hours.

The new technology along with its vision was presented in different levels of abstraction based on the adopted framework (e.g. technical, procedural, conceptual and business level) to seventeen (17) persons who had different roles in the video game production pipeline and were end-users. Participants were asked to express their thoughts and were encouraged to be as precise as possible and were asked not to hesitate to provide positive or negative feedback on the themes of discussion. Focus group studies were also organized, after the semi-interviews, in order to triangulate results and

facilitate the exchange of ideas and enhance discussions among participants who shared different role within the video game development pipeline.

Phase (C) – Analysis and Consolidation. Objectives: Consolidate results of the requirements analysis aiming to find the best trade-off solution between user wishes and feasibility. (1 month time)

The participants of the requirements validation study share a positive attitude towards adopting the proposed mixed development pipeline of contents creation. They perceived the approach as very useful and innovative with the potential of solving an outstanding issue. However, besides the positive predisposition expressed by the game developer companies in adopting the proposed approach, the requirements validation study revealed concerns. The critical concerns of the participants are related to the quality of the representations, the degree in which the representations can be modified, the capability of controlling the quality of the assets as well as support for team member communication during the capture phase, the guidance during the capture that must be related with the desired quality of an asset and the overall management of the captured and reconstructed assets within a certain game design. Several functional and non-functional requirements were identified which are further presented in [19].

One important aspect from the analysis phase is that some of the end-users resisted to change and maintained a bias towards their current way of thinking and acting, in terms of methods, tools used. So in case of disruptive new technologies, like the proposed one, they may fail to envisage the new potential and capabilities offered, that may change dramatically the way they conduct their work. However, the same attitude was recognized, in some cases, by technology partners since they resisted in adopting end-users views, opinions and expressed requirements. In addition, some end-users often felt threatened by the new approach, as their skills (e.g. in the case of 3D artists and modelers who will be affected by this new approach in several ways) may become useless and obsolete. In particular, some participants noticed: "*Adopting the proposed approach means that we will not do any modeling or we will model the basic structure. Seems that we are not needed. [3D artist]*".

7 Conclusions

The work presented in this paper describes a case study for requirements elicitation. In particular, the aim was to identify and prioritize requirements for an innovative assets creation pipeline for video games development. As such, the main contribution of this paper is to present a body of knowledge, based

on our experience, which may be of interest by UX researchers and practitioners who are facing similar challenges. From this perspective, the paper presents a case study during which stakeholders perceptions, goals and needs have been captured with regards to an envisioned new approach for assets creation during video games development. These requirements are an essential first step of the innovative tools development cycle and were gathered by adopting an iterative process. In the context of the reported study, this process involved the active participation of the technology providers, who developed the capturing tools and the image - video based rendering technology. The tensions between the technology affordances and the users' requirements were identified and discussed in successive stakeholders' analysis meetings, an important part of the requirements analysis framework.

This research could be also of importance for the video game industry and game players' experience since it discusses the introduction of advanced technologies in the form of tools to be used by the game designers and developers themselves. Study of the process of designing these tools, and the way these are introduced affecting the way new generations of games are designed in the future, is also important for the game industry.

Acknowledgements

This work is supported by the European Seventh Framework Program under grant ICT-611089-CR-PLAY.

Appendix A. Stakeholder Analysis

Stakeholder Category	**Role in the video game creation pipeline**	**Anticipated Impact in current activities**
Game Producer / Game Developer	Handle all development costs set and maintain deadlines and the overall budget. Overview the progress of the video game development tasks to assure quality and timely delivered outcomes.	A **significant competitive edge** to the European SME's in the game sector.
Game Publisher	Handles all publishing costs (materials production, advertising, etc.) Coordinates with press, plans events at	An important **positive impact** on time-to-market.

	gaming conventions (etc.).	
Game Designer	Game designers originate ideas for new games, determining the game mechanics, the users motivation etc.. They create a detailed design document to guide the various art and technical teams executing the game. Usually a design document specifies story, game play, settings, characters, environments etc.	More creative games can be produced within shorter time. An important **positive impact** on **development costs** and **time-to-market**.
Art Director, Concept Artists, 3D Animators, Engineers	Run the entire creative process, providing direction and feedback to the various teams of artists in the content creation pipeline.	A **major shift** in the content creation pipeline in terms of **simplicity, speed** and **quality**.
Capture Expert	Capture real life assets according to a certain game design and review the quality of the proposed result according to a specific game design	*Not applicable since this is a currently non-existing stakeholder category*
Video Game Player	This category represents the final users of the video game development pipeline. The players are the final "customers" the video game industry is targeting to.	Through the proposed approach more **creative** video games will be available for game players faster and cheaper.

Appendix B. Current Workflow Analysis

The figure below depicts the main human roles and summarizes associates workflows in the video game asset creation pipeline [17, 18]:

(a) The *game designer* in collaboration with others (*i.e. the game producer, the art director, etc.*) envisions the entire game and creates a detailed design document.

(b) The *concept artist* is usually prototyping according to the game design document various characters, environments and objects.

(c) The *modeler* responsibility is to take a two dimensional piece of concept art and translate it into a 3D model that can be given to animators. There are a variety of 3D modelers depending on the specific role: environmental, character or objects modelers.
(d) The *technical engineers* ensure that the game assets are easily integrated into the game engine and are behaving as stated in the game design document. They are also responsible for balancing the quality according to technical limits of the chosen platform (*e.g. depending on the platform, mobile or web, the technical engineers decide about high or low rendering etc.*). The technical team tasks include among others to implement the game mechanics and to proceed with texturing and lighting tasks etc.
(e) – (f) Several iterations among the art director and aforementioned team members are important in order to assure high quality results.

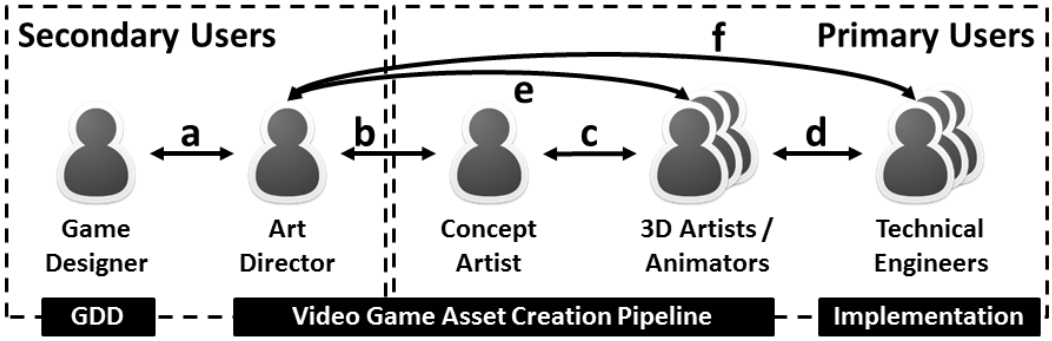

Figure 6. Current workflow analysis.

Appendix C. Detailed Usage Scenario Description

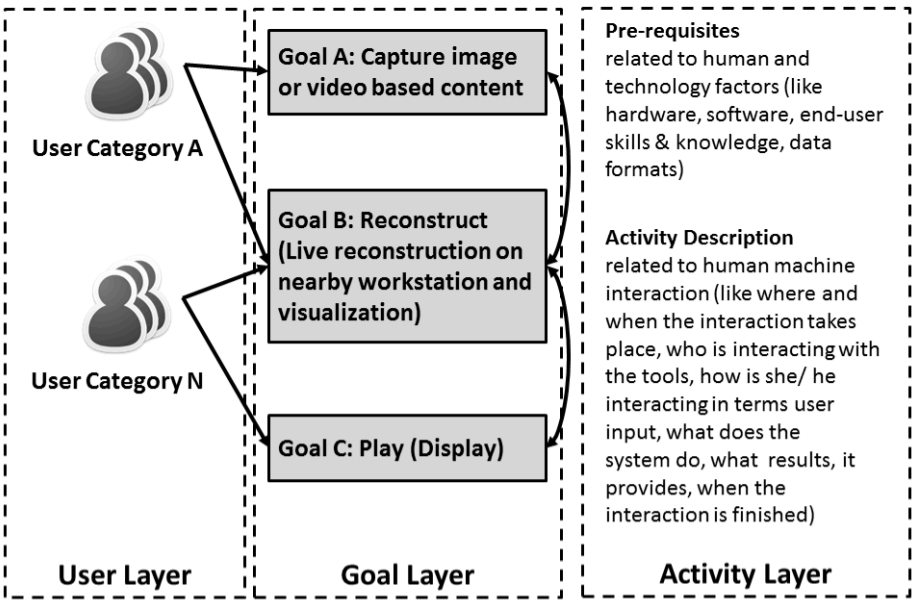

Figure 7. Usage scenario elaboration schema.

Usage Scenario:
Paolo wants to make use of a mixed pipeline for content creation to create a prototype of the game set in his hometown. He urges the team's programmers and game designers to familiarize themselves with the tools and technologies developed. The production of the game prototype is organized so as to re-use animations, tricks and features of the game together with photorealistic environments and objects captured and displayed within the mixed pipeline. In particular there is great interest in having ***high quality environments and animated elements (fountains, moving trees, flags, moving cars etc.)****, captured from the real world and mixed with characters already created with a traditional approach. Another important feature for the game is the possibility to* ***represent different moments of the day*** *thanks to the* ***dynamic lighting model*** *supported by system*."

Paolo has several goals when using the pipeline:
User Activity (a): Capture image or video based content

Pre-requisites: Paolo is using the capturing tool on his new Smartphone device (iPhone 5). He downloaded the app from the apple store. The mobile device has a high resolution camera and contains gyroscopes and inertial sensors which help estimate small camera-phone pose changes. To capturing details of surface normals especially for single objects (which is a very demanding task) he knows that a specialized setup is required (e.g. the mobile camera would sit in a lightweight cradle and it would capture image sequences while triggering LED lights, attached to the four sides of the cradle, i.e. above, below, left, and right of the camera).

Goal - Initializing: Paolo activates the capture tool. The tool provides Paolo with several functionalities. Paolo gives some basic information about the scene structure (e.g. indoor / outdoor, single object / complete street) the system will decide how many images are needed, and it will provide guidance on the positions they have to be taken from. Furthermore, the capture tool allows user-based annotations and extends them to the complete scene for a better segmentation/separation of objects.
Goal - Capture: The system will decide automatically if enough data has been captured or will guide the user towards new camera positions that support a more complete reconstruction. The user is then guided towards the new view, and the image is captured automatically at the right position. In order to actually capture a computed view, the user needs to move the device into the correct position. The feature matching and pose estimation of the next best view (NBV) is done constantly in about 1 second but the global optimization gets more expensive when the number of images and 3D points increases.
Goal - Guidance: The capture tool uses the phone display to provide guiding to Paolo in two ways: First, it presents an estimate of how the new image has to look like, in order to give a global impression of the camera position and viewing angle. Second, it shows an approximation of the direction towards the exact 3D position. Visual aids will be provided, such as arrows guiding the user to the NBV.
Goal - Iterations: The next iteration starts after the internal reconstruction has been updated. The capture application registers all captured images, creates a sparse reconstruction, and uses this data to estimate new views and to guide the capture process.
Goal - Post processing: Paolo has finished capture the desired scene. For the quality of a final reconstruction it can also be important to exclude captured data if it introduces too much uncertainty. As a consequence Paolo is using on a nearby workstation a system that post-processes data and removes unnecessary or outlier data before a complex reconstruction. It can also be important to separate a dataset into several smaller parts. In fact this activity develops confidence measures as a post processing step, and improved reconstruction, which, in contrast to previous techniques will concentrate on providing the 3D information useful for IBR and VBR, rather than an accurate-as-possible geometric model.
Results: Paolo has finished the post-processing step. He can now proceed with the following actions aiming to manage captured indoor or outdoor scenes. The available options are: a) Review which provides him a real time feedback about the captured scenes, he actually can move to different viewpoints of the captured scene, b) Delete one or all images/videos takes in this activity, c) Save the capture activity, d) Share/Send to other members in the content creation pipeline, e) Edit and finally f) export as external files. The export functionality allows Paolo to move the captured content to the reconstruction stage.

User Activity (b): Reconstruct (Live reconstruction on nearby workstation and visualization of the resolution)

Pre-requisites: Paolo has finished the capture activity of a scene and he has exported in a pre-defined IBR/VBR format the following data: a) multiple photos of a scene, b) calibrated cameras for each photo (i.e. the position and orientation of each photo), c) 3D point cloud with normals (*usually sparse and often inaccurate*), d) a mesh, usually approximate, can contain holes and inaccuracies. Other data may also be included. All this information is saved in an IBR/VBR format aiming to be integrated to the reconstruction tool.

Goal - Import files: Paolo uses the reconstruction tool to import the captured data. It is a stand alone application that is used for reconstructing the captured scene. As seen in the figure below tools provide a coarse (sometimes inaccurate) 3D version "point cloud" or mesh.

Goal - Specifying preferred resolution: Through the reconstruction tool offered functionalities the user can choose among high or low resolution representation of the captured scene, Depending on the produced quality the end-user can decide whether the capture step has been accomplished successfully or whether he needs to re-engage in the capture activity.

Results: The output of the reconstruction tool is 3D information (point cloud, normals, mesh), which can be incomplete and inaccurate as they are comprised from a collection of images/videos taken from known camera viewpoints. Paolo uses his laptop aiming to review – evaluate the produced outcome and eventually start over with the capture process or re-capture certain view positions. This will be done by viewing the result with the renderer / play stage. The additional cost to see the result with IBR is minimal. The functionalities provided by the PLAY tool allow Paolo to navigate through the produced model aiming to examine continuity and diverse points of view with regards to the produced 3D model of the captured backdrop. Given that Paolo has the game design in mind he can evaluate whether the produced results are appropriate

User Activity (c): Play (Display)

Pre-requisites: The reconstruction step has finished and now it is the time that the resulting IBR/VBR representations are displayed in a game engine environment (e.g. Unity 3D).

Goal - Display the 3D model: The captured and reconstructed environment is displayed through an IBR/VBR format for display within the game engine.

Goal - Play: The usability dimension in this approach relies on the fact that Paolo can use, as he did, all the available functionalities of his favorite game engine in a unified manner with regards the virtual and real world captured objects. Among others the editing tools which will be embedded within a standard game engine will support dynamic lighting / delighting

modeling, will allow high quality rendering of the imported assets, high-quality real-time in-painting (*allowing users to move around more freely in captured environments, even when part of the output image includes regions not seen in the input photographs*) and will allow class-specific surface synthesis. With regards to imported 3D video based data, artists will be able to encode, as a view-dependent Video Sprite, effects such as sand or snow being kicked up with foot-falls, or dirt being sprayed by spinning wheels. During play, the data will be rendered to match the environment and new viewing angle, and when the action calls for it. Here, the game designers will be able to specify which of the recorded dust-clouds is triggered by a big vs. a little impact.

Goal - Rendering: Through the IBR / VBR plug-ins the rendering contains many photo-realistic features such as shading, texture, reflection, shadowing, motion blur, transparency and depth of field -- depending on the type of capture – creating a lifelike perception.

Results: Paolo can use the photorealistic environments and objects captured together with characters and assets already created with a traditional approach. The game engine handles both types of content in a unified manner therefore Paolo can continue to develop the game mechanics of the game etc.

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