ATLANTIS – Indoor Planning with Augmented and Diminished Reality

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***Abstract*—The H2020 ATLANTIS project (2020-2022) creates an augmented reality (AR) tool for indoor planning. The tool uses artificial intelligence (AI) services for scene understanding, enabling planning from a single panorama. Diminished reality (DR) is used to conceal real-world objects that would conflict with newly inserted virtual ones.**

***Index Terms*—augmented reality, indoor planning, user-centred design, scene understanding**

I. Introduction

A. Motivation

Visualizing and communicating ideas is a key issue in applications like interior design, furniture retailing or renovation, which involves interaction between professionals (e.g., designers, sales staff) and consumers/future users. Making this communication process effective saves costs, avoids later modifications, and results in providing tailored solutions and higher customer satisfaction. Experts usually express their ideas in traditional 2D drawings produced by computer aided design (CAD) software, making it difficult for the consumers to comprehend them. Emerging technologies such as augmented reality (AR) have the potential to make this process more effective, and put consumers in a better position to review options by experts, or express their ideas, directly in the target environment. Complementing AR with virtual reality (VR) enables visualizing planned scenes both on and off site, i.e., consumers can view overlays over real environments, while the virtual scene can be edited by professionals in the office.

While a number of AR indoor planning apps already exist (for pointers to many of them see [1]), there are two main issues that are not yet satisfactorily addressed: First, creation of the room layout needs to be done manually in most apps, or via importing a CAD model. This requires some IT and technical skills, and may be an obstacle for users. Second, indoor design does in many cases not start from scratch in an empty room, but makes changes to an existing room. When viewing changes on site, the realism of AR is severely degraded when the overlaid 3D objects added to the scene clash with real objects.

B. Concept

The first issue can be addressed by simplifying the capture process, requiring only a single panoramic image. Extracting semantic information about the room from this image is enabled by *automation*. Recent advances in artificial intelligence (AI)-based visual scene understanding enable this automation for constrained environments (such as private or office indoor scenes). These technologies enable detecting the layout of the captured room as well as objects present there, and their boundaries and dimensions. Merging the roles of *user and creator* also blurs the line between authoring and consuming an AR/VR scene, which are currently often done in separate tools. The second issue can be addressed by *diminished reality (DR)* technologies, which enable visually concealing real objects, a functionality not yet widely found in AR apps.

ATLANTIS brings together two SMEs (Roomle, UP), one providing the mobile app and backend and data, the other focusing on UX design and evaluation, and two research organisations (JOANNEUM RESEARCH, CERTH), developing AI services for scene understanding, reconstruction and inpainting.

C. User-centred design approach

ATLANTIS addresses two main target user categories: (1) Professionals working in interior design and (2) consumers improving their homes. Users in category 1 are professionals working with selling home or office furnishings, those working with selling/renting private or commercial properties, and interior designers assisting either professional clients (e.g. architects, estate agents) or consumers (e.g. homeowners/renters). Users in category 2 are those redecorating/renovating their homes and/or looking to buy new furniture.

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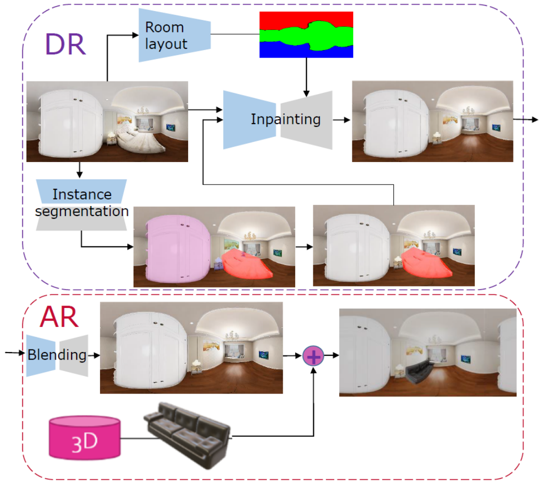

Fig. 1. ATLANTIS tool workflow.

Our user-centred design process is based on [2] and covers the following four phases: (i) Understanding and specifying the context of use, (ii) specifying the user requirements, (iii) producing design solutions, and (iv) evaluating designs against requirements. These phases are carried out in an iterative fashion, with the cycle being repeated until usability objectives have been attained. To this end, we involved users throughout the entire process, starting from interviews with professionals about how they could benefit from such a tool and requirements gathering with consumers, over workshops reviewing and testing mock-ups and early prototypes. A detailed analysis of user requirements can be found in [1]. As technical results from the project became available, two larger rounds of evaluation have been carried out, with smaller and more focused tests in between.

II. System overview

An overview of the proposed processing workflow is shown in Figure 1. Details about the AI-based methods for the components can be found in [3]. For visualization using AR on-site, the augmentation is performed using the AR-toolkit of the target platform to overlay the inpainted region and the rendered 3D objects (currently, implemented for iOS using ARKit). For off-site visualization using VR, the virtual parts of the scene are rendered, with the captured panorama (with inpainted regions for diminished objects, if applicable) as a backdrop of the scene. The app includes functionalities for setting up and editing planning projects, capture 360° images in a guided way, insert furniture objects from catalogues and modify/configure them, and view automated layout proposals. The backend is designed as a distributed, service-oriented and event-driven system, serving a mobile user application. Most AI and processing functionalities are provided as services, each of them performing one clearly specified function on a single or multiple data item(s). *Layout estimation* takes a panorama as input and provides metadata describing the room layout (sparse/planar scene geometry). *Instance segmentation* takes a view or a panorama as input and provides metadata with object bounding polygons and class labels. *Depth estimation* takes a single panorama as input and provides an estimated depth map (dense scene geometry) and the reconstructed 3D model of the scene involved. *Panorama inpainting* takes a view or a panorama, as well as object masks as input and provides a set of image patches or a newly composited panorama for replacing each of the objects. In addition, it provides the dense scene geometry for the non-furnished version of the input panorama. With a generative model and the predicted scene geometry, the inpainting functionality fills in the missing regions while maintaining the reality and geometry of the scene. *Scene localisation* uses a panoramic image and the instance segmentation and depth estimation results to propose a set of image patches in the scene which are suitable as image anchors, which the AR app uses for registering the AR scene. *Scene graph estimation* generates a parametric description of the furniture items in the room and their relative positions, based on results from instance segmentation. This information can be fed into the *layout proposal* service to complement furnishing of a room or suggest alternative layouts. More details about the AI services can be found in a project report [4].

III. Evaluation

The evaluation methodology includes both the objective evaluation of the AI services on appropriate datasets for the respective tasks, as well as subjective evaluation of the app. The evaluation included task-based evaluations on a set of planning tasks, comparing against three baseline apps. The results show that the tool improves efficiency of users in performing refurnishing tasks, and that the user satisfaction (measured using SUS [5]) is higher than for the baseline tools (details can be found in [6]). In addition, evaluation using walkthroughs with professionals are performed. In a separate set of subjective experiments, the benefit of DR-enhanced AR over AR has been assessed, and the results show that users prefer the DR enhancement over placing objects over real ones (despite inpainting artifacts in some of the scenes) [3]. This is more apparent in cases where the removed object differs in size and shape from the existing object.

References

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