Poster Abstract: UarLogger: Logging Measurements from UWB and AR Sensors on iOS Devices

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ABSTRACT

The multi-user Augmented Reality (AR) is powered by shared mapping and localization obtained from Visual Inertial Odometry (VIO) using AR sensors, including cameras and Inertial Measurement Units (IMU). However, VIO is vulnerable to sparse environment features, low lighting conditions, and dynamic motions. The Ultra-Wideband (UWB) transceiver, as a radio-sensing modality robust to visual and dynamic defects, has been considered as a formfitting patch on VIO to flatter multi-user AR. Nevertheless, like other wireless sensors, UWB suffers from noise and interference. Therefore, how to fuse UWB and VIO for multi-user AR is a promising but challenging research direction. To facilitate this process, we designed and released a tool, UarLogger, to log the relative location measurements from UWB and AR sensors mounted on iOS devices, as well as context-related data. We provide two examples–environmental condition evaluation and sensor fusion–to demonstrate its usefulness and showcase how it can boost the development of new algorithms with daily devices in hand.

KEYWORDS

Ultra-Wideband, Augmented Reality, Localization, Sensor Fusion, iOS Development

1 INTRODUCTION

Collaborative/multi-user Augmented Reality (AR) in co-located scenarios is transforming the collaboration patterns in industry, education, healthcare, entertainment, etc. In shared space, users can view and manipulate virtual objects simultaneously, which creates a more interactive and engaged spatial experience than stand-alone AR. On the other hand, with the rapid development of AR hardware and software, like Apple Vision Pro and iPhone driven by advanced sensors and algorithms, more and more AR applications are taking steps towards daily life. Therefore, it is the appropriate epoch to provide a shared immersive experience using mass-market devices for a wider user base.

The standard AR leverages the measurements from AR sensors, such as cameras and Inertial Measurement Units (IMU), to perform Visual Inertial Odometry (VIO) to track AR devices and map the environment. The relative localization in multi-user AR is determined by sending visual feature maps created by VIO from a device to other devices [4]. However, due to the nature of the AR sensors, VIO is susceptible to degraded environmental conditions like insufficient lighting, the lack of visual textures [5], and user interference such as unstable movement [6], leading to localization errors [1]. In comparison, Ultra-Wideband (UWB) radio localization has the luxury of being able to adapt to various visual and dynamic situations.

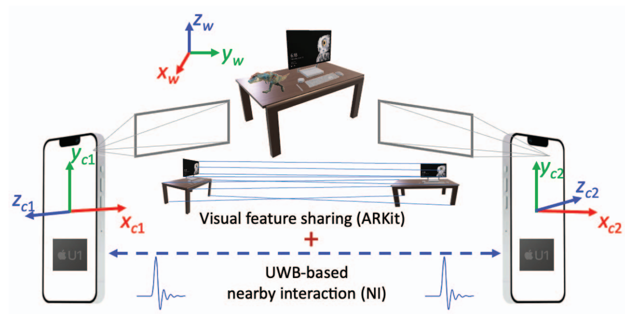

Figure 1: The overview of UWB aided VIO for dual-user AR on iOS devices. The visual measurements are provided by ARKit while the UWB measurements are from Apple's U1 chips via the nearby interaction (NI) interface.

However, the measurements from UWB sensors are much noisier than cameras and IMU. VIO and UWB are, therefore, a perfect combination that lends itself well to relative location estimation in multi-user AR.

A sensor fusion framework of UWB and VIO has been established and proved feasible for the relative positioning in multi-user AR scenarios [3]. This framework is applied to iOS devices with third-party UWB chipsets attached, which is a pioneering work but imposes extra configuration burden upon users. With the prospect of allowing researchers to easily access UWB and VIO measurements using daily devices in hand, we design an iOS tool named *UarLogger*[1] to log the VIO and UWB-based relative location measurements from sensors embedded in iOS devices through Apple's official APIs. We temporarily do not support LiDAR data capturing, as LiDAR scanners are exclusively available on the iPhone Pro series. As shown in Figure 1, the UWB measurements are captured from the onboard U1 chips through the Nearby Interaction (NI) interface. The VIO measurements are collected using the ARKit interface. Besides, UarLogger also captures the data related to the surrounding environment and user movement, including lighting conditions, visual feature numbers, and motion patterns.

2 SOFTWARE DESIGN

Development Flowchart: The application flowchart of UarLogger is illustrated in Figure 2a. During the setup phase, the application initiates a collaborative AR session as well as a UWB session and enters a waiting state to establish multi-user connections while concurrently commencing environmental monitoring. Upon successful connection with another user, the application endeavors to

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[1] https://github.com/Huoyanlifusu/UarLogger

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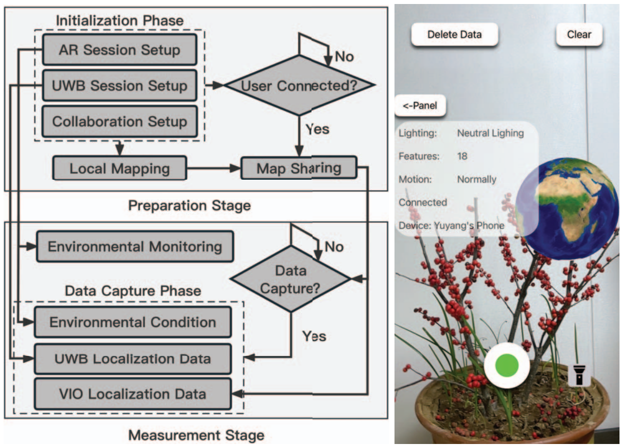

(a) (b)

Figure 2: (a) The development flowchart of UarLogger. (b) UarLogger GUI

create, share, and integrate the collaborative map. Subsequently, users are capable of measuring localization data by activating the capturing function. Following the data collection process, the application systematically stores the acquired measurements in the form of tabular files.

GUI Design: As displayed in Figure 2b, the GUI encompasses several essential components, including an environmental panel, a measuring button, a delete button, and a clear button. The environmental panel serves the function of presenting pertinent environmental conditions and connectivity particulars. Pressing the recording button initiates the measurement function subsequent to the collaborative map-sharing process. The delete button relieves memory pressure by eliminating redundant data, while the clear button is intended for the removal of superfluous AR objects (like the Earth in Figure 2b) generated by users.

Remarks: In case of encountering difficulty in sharing the collaborative visual feature map, potential solutions involve restarting the app or re-conducting a thorough scan of the scene of interest.

3 EXPERIMENTS

Two experiments are provided to show how UarLogger can assist researchers in evolving localization techniques for multi-user AR. In these experiments, a laser measuring tape measures the ground truth of relative locations. An iPhone 12 mini and an iPhone 13 are employed to run dual-user AR sessions.

UarLogger can be used to analyze **the influence of various environmental conditions on relative positioning accuracy**, as displayed in Table 1. It indicates that VIO on iOS devices is virtually unaffected by lighting variations but significantly relies on visual texture. In contrast, the environmental conditions barely impinge on UWB localization. Further exploration in this direction may pave the way for data-driven localization error regression.

UarLogger can capture UWB and VIO measurements to boost **the development of sensor fusion algorithms**. For instance, we've observed that sudden shaking of the phones can introduce localization bias in the VIO measurements, as illustrated by the red lines in Figure 3. Despite this, VIO offers comparatively smoother measurements, allowing for the extraction of velocity information. Conversely, UWB location measurements exhibit noise but are less prone to bias. Therefore, we leverage the Kalman filter based on a low dynamic model to fuse velocity information from VIO measurements with location data from UWB measurements. This integration allows the two sensor types to complement each other effectively. In future developments, UWB and VIO measurements can be fused with more advanced approaches, such as factor graph optimization [7] and moving horizon estimation [2].

Table 1: Relative localization errors (root mean square errors of the relative distance between the two phones) using VIO and UWB under different environmental conditions

Environmental Conditions	Localization Error (m)	
	VIO	UWB
Neutral Lighting	**0.027**	0.103
Dimly Lighting	**0.033**	0.077
White Wall Texture	1.399	**0.031**
Tile Texture	0.175	**0.072**
Wallpaper Texture	**0.020**	0.042

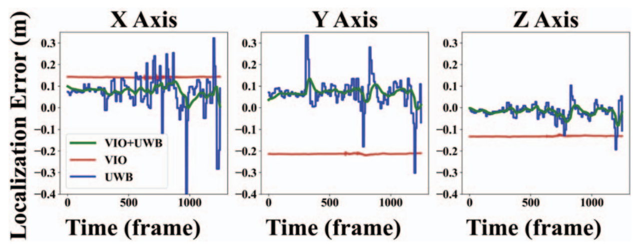

Figure 3: Relative localization errors in dual-user AR

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