AnyplaceCV: Infrastructure-less Localization in Anyplace with Computer Vision

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***Abstract*—In this demonstration paper, we present an innovative indoor localization architecture, coined *Anyplace Computer Vision (AnyplaceCV)*, which provides an infrastructure-free (or "zero" infrastructure) method to localize in indoor spaces that lack any infrastructure whatsoever (e.g., Wi-Fi, BLE, UWB, RFID, Sonar, LED). We have developed a complete functional system of AnyplaceCV around the Anyplace open-source architecture we developed over the years and will make our contributions open-source. We will present AnyplaceCV in two modes: (i) Online Mode, where attendees will be able to collect and analyze real CV fingerprints at the conference venue; and (ii) Offline Mode, where attendees will be able to interact with collected measurements through a smartphone and PC.**

***Index Terms*—Indoor Localization, Computer Vision**

I. Introduction

In our previous work [1], we developed a modular, scalable and efficient IIN architecture, coined Anyplace[1]. Anyplace has traditionally focused on Wi-Fi as the localization method and this lead to several advantages in industrial environments [2]. In this work we focus on *infrastructure-free* localization approaches, which are used in harsh environment where *"zero"* infrastructure is available (e.g., vessels, underground mines, complex industrial environments). For this type of environments, the lack of fixed digital infrastructure (i.e., antennas) usually also denotes the lack of massive human activitity, so privacy issues [3] are also less of a concern.

An obvious technology to use in a zero-infrastructure environment is magnetic localization, which takes advantage of the magnetic field anomalies typical of indoor settings by using them as distinctive place recognition signatures. This sort of technology not only offers very limited accuracy but also magentic signatures work only for stationary steel structures and not for movable objects (like vessels), which are always moving to different places.

Infrastructure-free localization often also refers to solely IMU-based approaches that have been extensively studied in the context of Pedestrian Dead Reckoning (PDR) systems [1]. Particularly, sensory data reported by Inertial Measurement Units (IMU), including accelerometers, gyroscopes, and digital compasses (e.g., CyweeKIOS or WiFiSLAM). Such sensor modules are either integrated into modern consumer electronics, or attached externally on the human body, i.e., head, back, waist or foot mounted while processing occurs by low-power co-processor (e.g., smartphone motion coprocessors). IMU solutions can be used to provide relative location of a mobile but these are known to suffer from drifting (i.e., even the slightest localization or orientation error builds up over short future windows yielding high location errors). As such, IMU solutions are known to require an infrastructure to correct the location signal over time. In Anyplace we traditionally utilize Wi-Fi to correct the IMU signal.

Computer Vision (CV) is an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos. We exploit CV to bring forward a state-of-the-art localization system relying of fingerprints of objects derived from cameras as these are captured by a machine learning model that has been trained in an offline manner on a datacenter equipped with powerful GPU cards. We integrate these developments in the latest release of the Anyplace Indoor Localization architecture and expose through this demonstration system both how the logging and localization system works but also how we developed a complete Smart Alert System, as part of the EU project LASH FIRE.

Currently, there is no other academic or industrial system that brings the location and CV components under the roof of an open-source stack, which will be invaluable to researchers and practitioners at the conference and beyond.

II. Overview of AnyplaceCV

Our proposed method relies on three stages: (i) *Training*, where users supply video recordings of the their interior spaces with a particular focus on static (non-movable) environment objects. The video recordings are analyzed on a deep learning data center to produce a deep learning *model*; (ii) *Logging*, where the model is augmented with spatial coordinates either by the means of crowdsourcing from a smartphone or from a desktop, yielding a *fingerprint database*; (iii) *Localization*, where users utilize a smartphone application using the fingerprint database we constructed to find their location once (i.e., localize) or continuously localize (i.e., tracking).

Our logger and localization subsystems allows selecting between the following three machine learning corpuses:

[COCO] Common Objects in Context[2]: this is a large-scale object detection, segmentation, and captioning dataset

[1]Anyplace. `https://anyplace.cs.ucy.ac.cy/`

[2]COCO dataset. `https://cocodataset.org/`

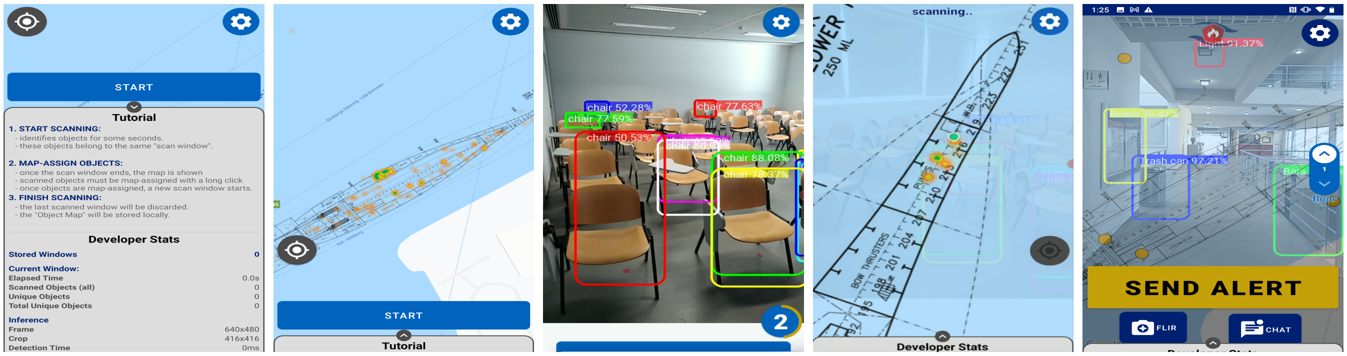

Fig. 1. **AnyplaceCV.** **(i)** *Guidelines:* installers get precise guidelines on how to map the objects of an infrastructure-free environment; **(ii)** *Heat-map:* this helps the installer to know where additional crowdsourcing effort is necessary; **(iii)** *CV Logger:* installers use our AnyplaceCV app to associate (x,y,floor/deck) coordinates to static environment assets (doors, stairs, elevators, signs, etc.) using a smartphone camera; **(iv)** *Localization:* here we run the object recognition software and find the closest fingerpring using state-of-the-art algorithms we developed; and **(v)** *SMAS:* A complete Smart Alert System developed, incorporating AnyplaceCV for first responders on Ro-Ro Vessels as part of the EU LASH-FIRE project [4].

(24MB). COCO has several features, namely: Object segmentation, Recognition in context, Superpixel stuff segmentation, 330K images (200K labeled), 1.5 million object instances, 80 object categories, 91 stuff categories, 5 captions per image, 250,000 people with keypoints. COCO was used for development and for testing the platform for localization accuracy in ordinary spaces, but will also be used for the demonstration at the conference venue.

[UCYCO] University of Cyprus Objects in Context: this is a small-scale object detection, segmentation, and captioning dataset specifically for the University of Cyprus buildings (23MB). This model was particularly useful for the development stage and was constructed with the assistance of Google Colab (i.e., GPU resources in the cloud).

[LASHCO] LASH Objects in Context: this is a mid-scale object detection, segmentation, and captioning dataset specifically for a vessel as part of the EU LASH FIRE project (24MB). LASHCO has approximately 99 classes. The given object detection, segmentation, and captioning dataset will be used for testing the platform and localization accuracy in vessel spaces as part of the LASH FIRE project and has been constructed on a dedicated deep learning server, namely an HP DL380 Gen10 with 80 logical processors and a powerful NVIDIA v100 card. We particularly used the Computer Vision Annotation Tool (CVAT), which is a free, open source, web-based image and video annotation tool which is used for labeling data for computer vision algorithms. The model is loaded along with the AnyplaceCV localization system to the SMAS application [4].

III. Demonstration Scenario

During the demonstration, the attendees will be able to appreciate the functionality, the visualization abstraction and the performance of AnyplaceCV in a real setting.

Demo Artifact: AnyplaceCV has been integrated to our award-winning Anyplace for IoT stack (A4IoT) and will be available to the open public as of release v4.5. Our system has a low setup time because it relies on existing infrastructure available at the conference venue and the COCO . If necessary, our team can quickly deploy additional QR codes to provide adequate CV localization accuracy. Thus, only the floorplan digital map of the demo site is required.

Demo Plan: We will carry our demonstration out in 2 modes: (i) Online Mode, where we will ask conference attendees to collect CV fingerprint data using the Logger and upload them to the Anyplace IIN. We will provide respective Android devices to the attendees. Conference building floor plans will be prepared and uploaded to the Anyplace IIN in advance. After uploading the fingerprints, attendees will be asked to observe and interact with the collected data in order to improve decision making (e.g., where to collect more fingerprints for better localization accuracy). Finally, the audience will be asked to use the AnyplaceCV Navigator to take advantage of the updated indoor models; and (ii) Offline Mode, where we show to attendees how we localize in various indoor spaced with the AnyplaceCV system.

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