A Deep Actor-Critic Reinforcement Learning Framework for Persistent Keypoint Detection under Challenging vSLAM Conditions

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***Abstract*—Existing visual Simultaneous Localization and Mapping (vSLAM) methods heavily rely on visual feature detection algorithms, which become unreliable or indistinguishable under poor illumination conditions. When visual perception does not meet the requirements of each specific environment, effective navigation should not rely on higher resolution sensing, but on smarter learning algorithms and predictive models. In this paper, we present a novel approach by introducing a Reinforcement Learning framework, utilizing an Actor-Critic scheme, which can be used by any type of deep feature detector. Our proposal prioritizes the extraction of fewer, more robust, and reliable subsets of keypoints that are trackable over time, leading to improved matching and, in turn, more accurate localization. The goal is quality over quantity by assigning to the RL the task of objectively deciding which keypoints are considered important for vSLAM. Our experimental results demonstrate that our method outperforms the original state-of-the-art models in a variety of publicly available challenging datasets for localization.**

***Index Terms*—vSLAM, Localization, Keypoint Detection, Deep Learning, Reinforcement Learning**

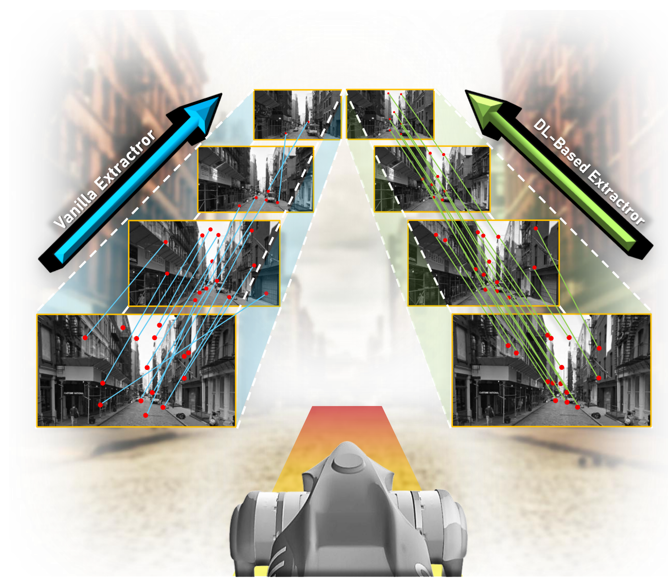

Fig. 1. An overview of the proposed system. The core idea includes the deployment of a Reinforcement Learning (RL) pipeline to train a deep feature extractor on detecting robust visual keypoints that would "survive" within visual Simultaneous Localization and Mapping (vSLAM) [4] architecture.

I. Introduction

WHETHER guiding robots successfully through crowded cities with Autonomous Navigation Systems or interacting with digital objects in the real-world through Augmented Reality [1], [2], [3], the core functionality relies on accurate and efficient visual Simultaneous Localization and Mapping (vSLAM) [4] solutions, where robust, low-cost, and passive sensing is essential. The general SLAM [5], [6], [7] algorithms in autonomous systems aim to estimate an agent's pose, while concurrently building a map of the environment by fusing sensory data. On the contrary, vSLAM has gained attention for its simplicity, by solely utilizing camera-derived measurements as input to leverage rich visual information. However, it comes with unique challenges since it depends on the environment's scene appearance, which can degrade feature tracking and subsequently lead to trajectory and mapping failures.

While conventional vSLAM approaches have proven themselves effective in controlled environments, their strict dependence on carefully designed hand-crafted visual features, in combination with their demanding geometric modeling makes them fragile in challenging real-world tasks with weak textures, varied and harsh illumination conditions or unpredictable structures. In such cases, classic feature extraction methods produce short-lived or weak keypoints, leading to deficient vSLAM performance. Based on the above interpretation, it becomes necessary to revisit the keypoints selection and exploitation strategies, in order to address feature stability and improve long-term localization.

Inspired by the necessity to fill this gap, our proposed solution comes as an addition in visual feature extractor techniques specifically targeting vSLAM architectures. Our guiding principle is to maximize long-term feature trackability, rather than raw feature count, as seen in Fig. 1. To achieve this, we developed a learning-based feature selection pipeline [8], making use of the well-established SuperPoint [9] architecture

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