**（一）ORB：一种高效的SIFT或SURF的替代方法**

**ORB: an efficient alternative to SIFT or SURF**

Ethan Rublee, Vincent Rabaud, Kurt Konolige, Gary Bradski

（ICCV 2011）

**一、科学问题**

**1.1 本文所涉及科学问题**

计算机视觉；特征匹配。

**1.2 同行专家如何解决**

FAST角点检测、SIFT关键点检测/特征向量描述、SURF、BRIEF特征向量等。

**1.3 本文所解决的问题**

SIFT和SURF算法的精度比较高，但同时它们的速度也相对较慢，且往往要使用GPU。本文提出了一种新的算法，在匹配的精度和实时性上都有了较大的提高。

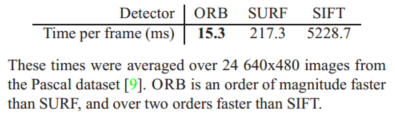
**1.4 本文解决方案效果**

特征匹配的精度和实时性相较于以往的经典算法有了不小的提高，而且还具有尺度不变性。

**二、研究内容**

**2.1 理论与方法介绍**

* Oriented FAST 角点提取——找出图像中的角点，并且计算了特征点的主方向，用于后续的BRIEF（原始的 FAST 没有朝向角的信息）；
* 改进的BRIEF 描述子——对前一步提取出特征点的周围图像区域进行描述 ，并且改进后的 BRIEF 还具有了旋转不变性。

**2.2 验证分析与实验效果**

**三、论文存在问题及后续研究重点**

**3.1 论文存在问题**

ORB特征匹配在某些领域可能会出现特征分布不均、误匹配率较高及匹配精度为整像素级等不足的问题。

**3.2 后续研究重点**

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**四、该问题相关研究成果**

**4.1 相关论文一**

**（1）题目**：ORB-SLAM: a Versatile and Accurate Monocular SLAM System

**（2）作者介绍**：Raul Mur-Artal\*, J. M. M. Montiel

**（3）摘要**: This paper presents ORB-SLAM, a feature-based monocular simultaneous localization and mapping (SLAM) system that operates in real time, in small and large indoor and outdoor environments. The system is robust to severe motion clutter, allows wide baseline loop closing and relocalization, and includes full automatic initialization. Building on excellent algorithms of recent years, we designed from scratch a novel system that uses the same features for all SLAM tasks: tracking, mapping, relocalization, and loop closing. A survival of the fittest strategy that selects the points and keyframes of the reconstruction leads to excellent robustness and generates a compact and trackable map that only grows if the scene content changes, allowing lifelong operation. We present an exhaustive evaluation in 27 sequences from the most popular datasets. ORB-SLAM achieves unprecedented performance with respect to other state-of-the-art monocular SLAM approaches. For the benefit of the community, we make the source code public.

**4.2 相关论文二**

**（1）题目**：ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras

**（2）作者介绍**：Raul Mur-Artal, Juan D. Tard ´ os

**（3）摘要**：We present ORB-SLAM2 a complete SLAM system for monocular, stereo and RGB-D cameras, including map reuse, loop closing and relocalization capabilities. The system works in real-time on standard CPUs in a wide variety of environments from small hand-held indoors sequences, to drones flying in industrial environments and cars driving around a city. Our back-end based on bundle adjustment with monocular and stereo observations allows for accurate trajectory estimation with metric scale. Our system includes a lightweight localization mode that leverages visual odometry tracks for unmapped regions and matches to map points that allow for zero-drift localization. The evaluation on 29 popular public sequences shows that our method achieves state-of-the-art accuracy, being in most cases the most accurate SLAM solution. We publish the source code, not only for the benefit of the SLAM community, but with the aim of being an out-of-the-box SLAM solution for researchers in other fields.

**4.3 相关论文三**

**（1）题目**：基于ORB算法改进的影像匹配方法

**（2）作者介绍**：陈慧颖 刘进 杨洁 向夏芸

**（3）摘要**：在摄影测量学中应用ORB算法时,影像匹配存在特征分布不均、误匹配率较高及匹配精度为整像素级等不足。针对这些问题进行如下改进,控制特征数目及特征分布,增加核线约束及相关系数条件,结合最小二乘匹配算法。此外,为了增强该算法对大角度旋转影像的适应性,将影像间的仿射变换参数作为最小二乘匹配中几何畸变参数的初始值。实验证明,该算法应用于影像匹配时,不仅可以保持ORB算法的高效性,获得均匀分布、高精度的匹配特征,而且对大角度旋转影像具有一定适应性。

阅读笔记

#### 1. ORB 特征

#### 2. FAST 关键点

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#### 3. FAST存在的不足 & ORB做出的改进：

#### 4. BRIEF 描述子

**（二）ORB-SLAM:一个通用的、准确的单目SLAM系统**

**ORB-SLAM: a versatile and accurate monocular SLAM system**

Raúl Mur-Artal\*，Juan D. Tardós

（IEEE TRANSACTIONS ON ROBOTICS）

**一、科学问题**

**1.1 本文所涉及科学问题**

移动机器人；导航及建图

**1.2 同行专家如何解决**

PTAM、LSD-SLAM

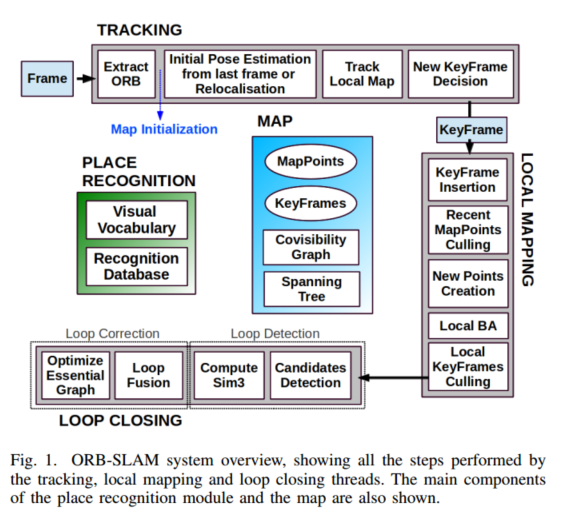
**1.3 本文所解决的问题**

实现了一个基于特征点的单目SLAM系统，可以在狭小的室内环境和宽阔的室外环境中实时运行。

**1.4 本文解决方案效果**

该系统可以处理室内与室外的图像序列，能够用于汽车、机器人和手持设备上。其定位精度在室内小场景中约为1厘米，室外大场景的应用是几米（前提是我们与真实轨迹尺度对齐的情况下）。

**二、研究内容**

**2.1 理论与方法介绍**

系统包含跟踪、局部地图构建和闭环回路检测这三个并行的线程，而且每一个模块都采用同一个特征——ORB特征。

**2.2 验证分析与实验效果**

该系统可以处理室内与室外的图像序列，能够用于汽车、机器人和手持设备上。其定位精度在室内小场景中约为1厘米，室外大场景的应用是几米（前提是我们与真实轨迹尺度对齐的情况下）。

**三、论文存在问题及后续研究重点**

**3.1 论文存在问题**

由于该系统为单目视觉SLAM系统，在物体纹理变化较弱情况下效果不够理想；文章提出的方案在工程上效果较好，关注的人也非常多，其采用的也是当前各种主流的方式来计算slam，但是在创新上并没有很突出。

**3.2 后续研究重点**

增加对双目、RGB-D的支持。

**四、该问题相关研究成果**

**4.1 相关论文一**

**（1）题目**：LSD-SLAM: Large-Scale Direct Monocular SLAM

**（2）作者介绍**：Engel J, Schöps T, Cremers D

**（3）摘要**: We propose a direct (feature-less) monocular SLAM algorithm which, in contrast to current state-of-the-art regarding direct methods, allows to build large-scale, consistent maps of the environment. Along with highly accurate pose estimation based on direct image alignment, the 3D environment is reconstructed in real-time as pose-graph of keyframes with associated semi-dense depth maps. These are obtained by filtering over a large number of pixelwise small-baseline stereo comparisons. The explicitly scale-drift aware formulation allows the approach to operate on challenging sequences including large variations in scene scale. Major enablers are two key novelties: (1) a novel direct tracking method which operates on sim (3), thereby explicitly detecting scale-drift, and (2) an elegant probabilistic solution to include the effect of noisy depth values into tracking. The resulting direct monocular SLAM system runs in real-time on a CPU.

**4.2 相关论文二**

**（1）题目**：ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras

**（2）作者介绍**：Raul Mur-Artal, Juan D. Tard ´ os

**（3）摘要**：We present ORB-SLAM2 a complete SLAM system for monocular, stereo and RGB-D cameras, including map reuse, loop closing and relocalization capabilities. The system works in real-time on standard CPUs in a wide variety of environments from small hand-held indoors sequences, to drones flying in industrial environments and cars driving around a city. Our back-end based on bundle adjustment with monocular and stereo observations allows for accurate trajectory estimation with metric scale. Our system includes a lightweight localization mode that leverages visual odometry tracks for unmapped regions and matches to map points that allow for zero-drift localization. The evaluation on 29 popular public sequences shows that our method achieves state-of-the-art accuracy, being in most cases the most accurate SLAM solution. We publish the source code, not only for the benefit of the SLAM community, but with the aim of being an out-of-the-box SLAM solution for researchers in other fields.

**4.3 相关论文三**

**（1）题目**： Parallel tracking and mapping for small AR workspaces

**（2）作者介绍**：KLEIN,G.

**（3）摘要**： This paper presents a method of estimating camera pose in an unknown scene. While this has previously been attempted by adapting SLAM algorithms developed for robotic exploration, we propose a system specifically designed to track a hand-held camera in a small AR workspace. We propose to split tracking and mapping into two separate tasks, processed in parallel threads on a dual-core computer: one thread deals with the task of robustly tracking erratic hand-held motion, while the other produces a 3D map of point features from previously observed video frames. This allows the use of computationally expensive batch optimisation techniques not usually associated with real-time operation: The result is a system that produces detailed maps with thousands of landmarks which can be tracked at frame-rate, with an accuracy and robustness rivalling that of state-of-the-art model-based systems.

阅读笔记

包括三个并行的线程：跟踪、局部地图构建和闭环回路检测。跟踪线程负责对每帧图像的相机位置进行定位，并决定什么时候插入新的关键帧。局部建图模块负责处理新的关键帧，对周围的相机位姿进行局部BA以优化重构。闭环回路检测模块则是对每个新的关键帧都要进行闭环搜索，以确认是否形成闭环。如果闭环被侦测到，我们就计算相似变换来查看闭环的累积误差。这样闭环的两端就可以对齐，重复的云点就可以被融合。

在跟踪模块中：

* 首先进行**ORB特征提取**（这一部分在前面的ORB文章中详细看过）；
* **通过比较当前帧与前像帧来估计相机的初始位姿：**如果上一帧图像跟踪成功，我们就用运动速率恒定模型来预测当前相机的位置（即认为摄像头处于匀速运动），然后搜索上一帧图像中的特征点在地图中的对应云点与当前帧图像的匹配点，最后利用搜索到的匹配点对当前相机的位姿进一步优化。但是，如果没有找到足够的匹配点（比如，运动模型失效，非匀速运动），我们就加大搜索范围，搜索地图云点附近的点在当前帧图像中是否有匹配点，然后通过寻找到的对应匹配点对来优化当前时刻的相机位姿；
* **通过全局重定位来初始化位姿：**如果扩大了搜索范围还是跟踪不到特征点，（运动模型已经失效），则计算当前帧图像的词袋（BoW）向量,并利用BoW词典选取若干关键帧作为备选匹配帧；
* **跟踪局部地图：**为了降低大地图的复杂性，我们只映射局部地图；
* **新关键帧的判断标准：**距离上一次全局重定位后需要超过20帧图像；处于空闲状态；当前帧跟踪少于50个地图云；跟踪少于参考关键帧K\_ref云点的90%；

在局部地图构建模块中则包括了关键帧插入、地图点云筛选、新地图点云创建、局部的BA、以及最后为了保持重构出来的简洁而添加的局部关键帧筛选步骤。

在闭环检测中，、则经历了选出候选关键帧、计算相似变换、回环融合以及最后的Essential Graph优化。