C2TAM: A first Approach to a Cloud framework for Cooperative Tracking and Mapping

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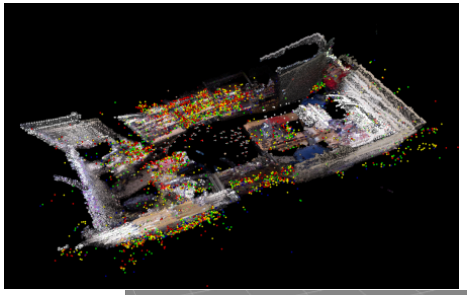
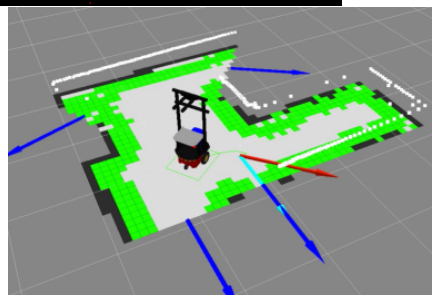




Web-enabled robots and RoboEarth

- RoboEarth: A set of servers, a joint database and a network that allow robots to:
  - Upload information.
  - Download information.
  - Outsource computation.
- EU-funded 4-year project, finishing this year.

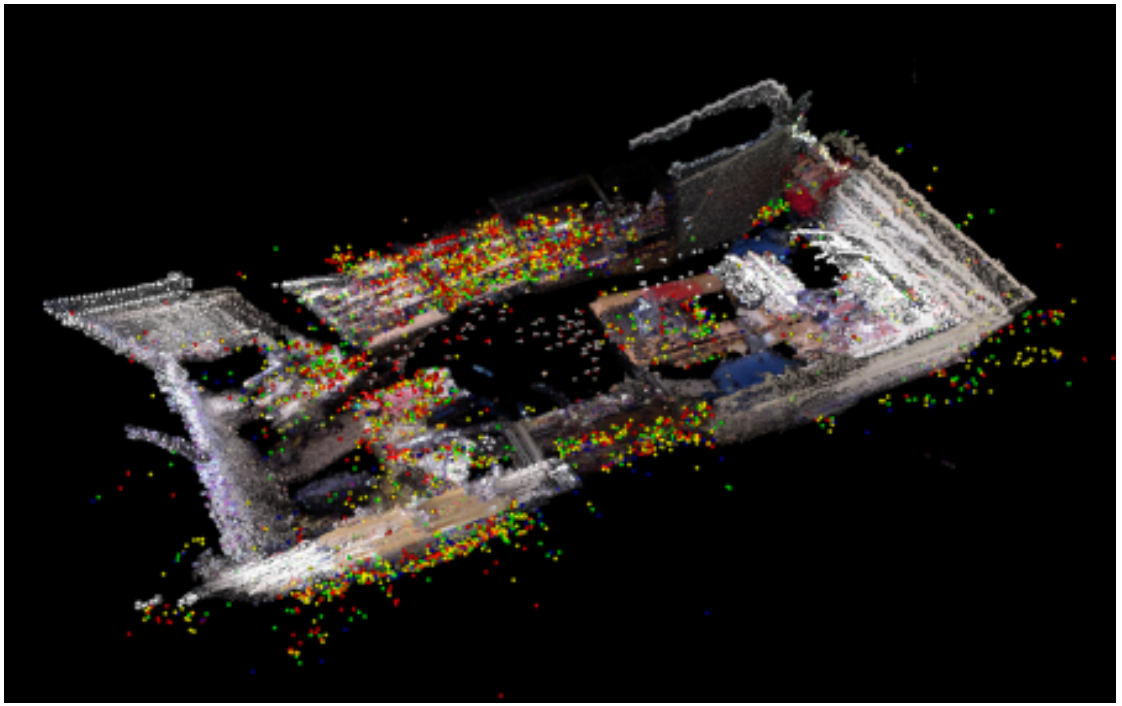
Web-enabled robots and RoboEarth

Web-enabled robots and RoboEarth

- Robotics in general (SLAM in particular) have **hard real-time constraints.**
- The **Cloud Computing has latencies** associated with the net, particularly with raw sensing data.

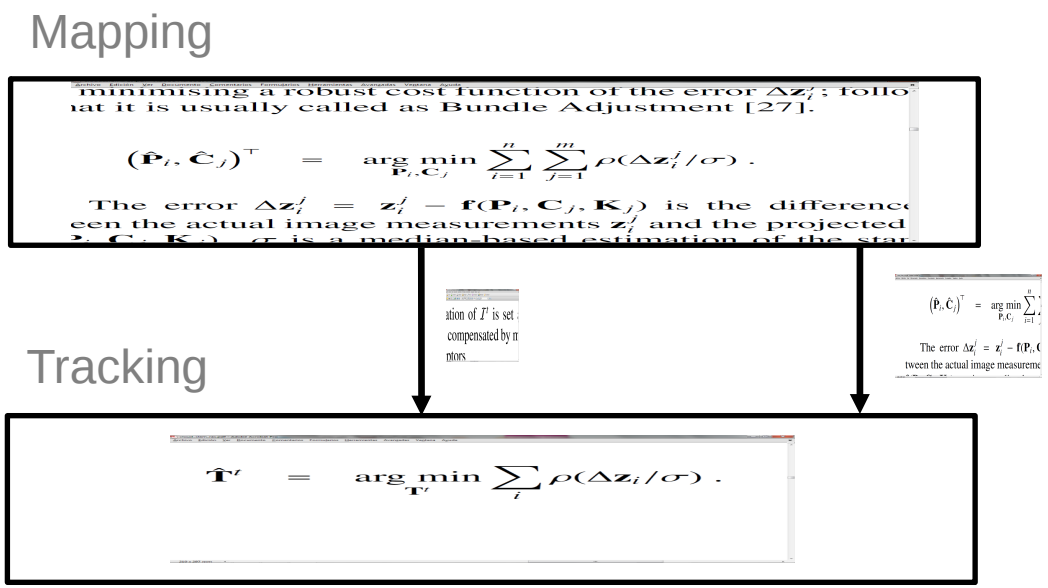
Visual SLAM

- **Several robots**, equipped with sensors (in our case RGB-D cameras), build a map of their environment and estimate their poses sequentially and hopefully in real-time.



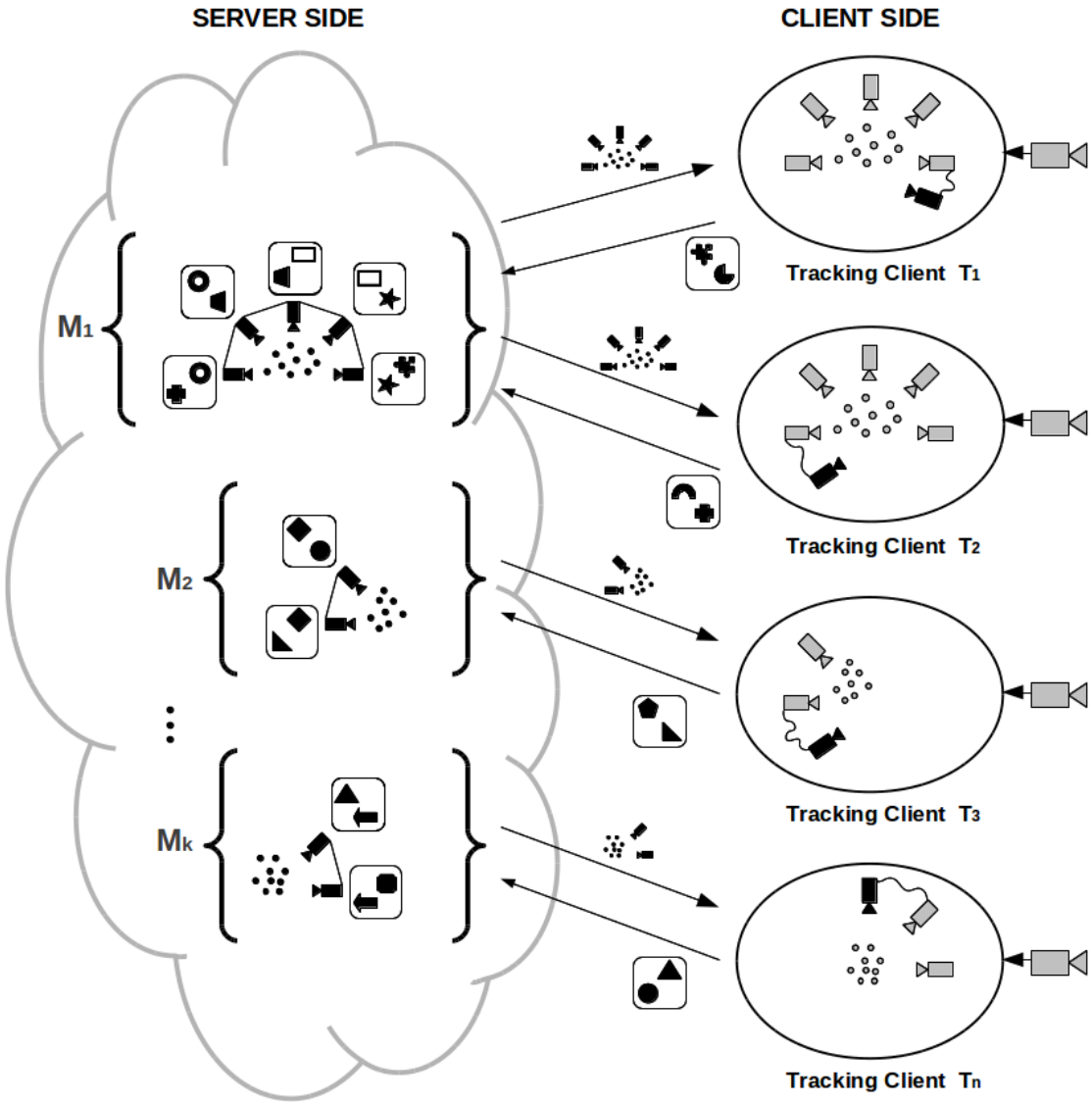
Visual SLAM as Parallel Tracking and Mapping

- Traditionally, joint sequential optimization of pose and map.
- PTAM –Parallel Tracking and Mapping– [Klein & Murray 2007] divides the SLAM problem into 2 threads:
  - Mapping thread: Estimates a map from a set of keyframes.
  - Tracking thread: Estimates the camera pose for every frame assuming a known map.



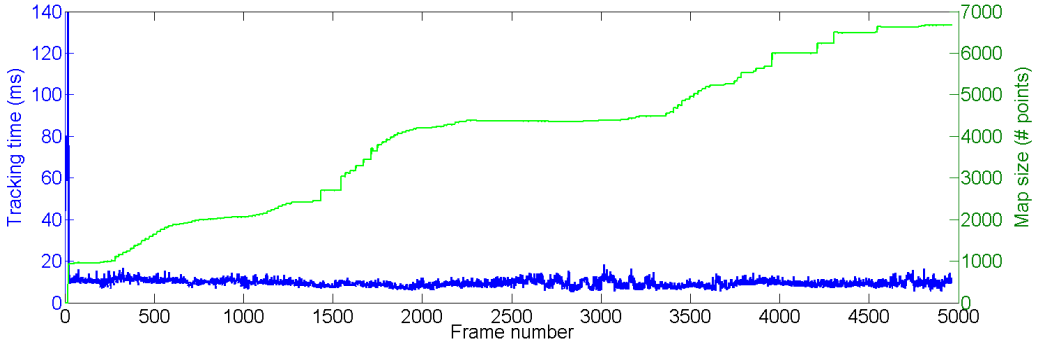
C2TAM scheme

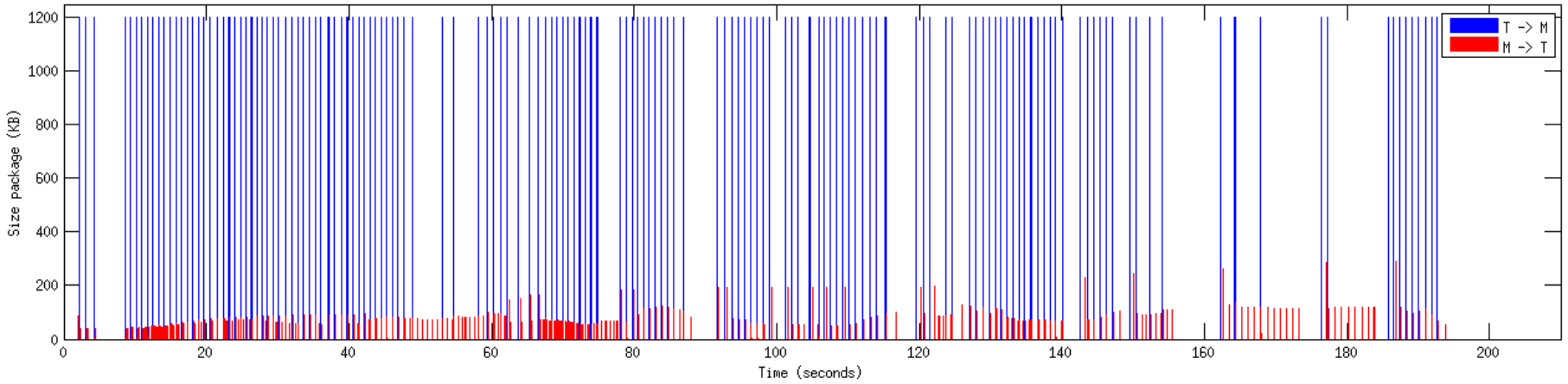
- Data flow:
  - Server->Client: Optimized map and keyframe poses.
  - Client->Server:
  - New keyframes.
- Modes of operation:
  - Map building and storage (single-user single-map)
  - Relocation in a previous map (single-user multi-map). Intensive in computation and data flow.
  - Map extension (single-user multi-map)
  - Concurrent mapping (multi-user multi-map)



Experiment 1: Cloud Tracking and Mapping

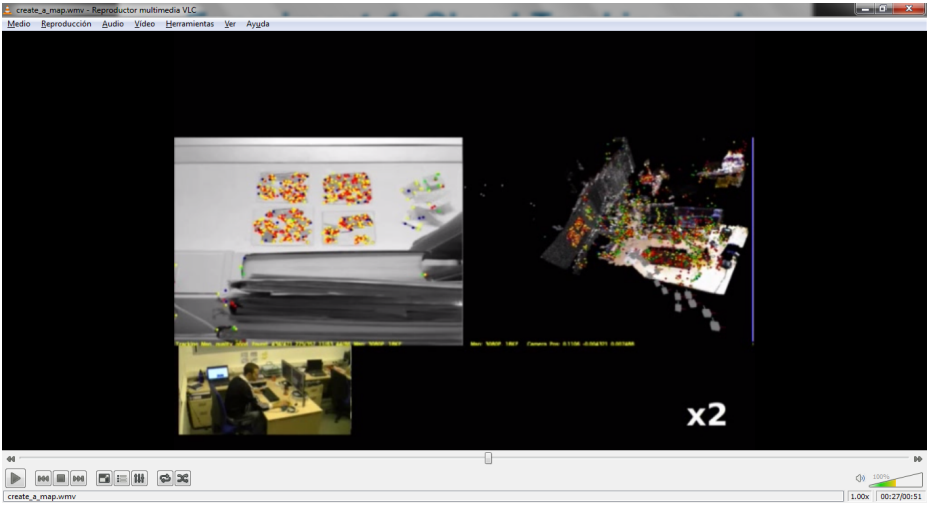
- Experimental setup:
  - 1 [Kinect + laptop].
  - Cloud server (running RoboEarth ROS stack and local copy of RoboEarth).
  - Linked by a standard wireless.
- Results:
  - Map (images + geometry) stored in RoboEarth
  - Data flow ~1MBs; (standard wireless ~3.75MBs).
  - Robust to network delays.



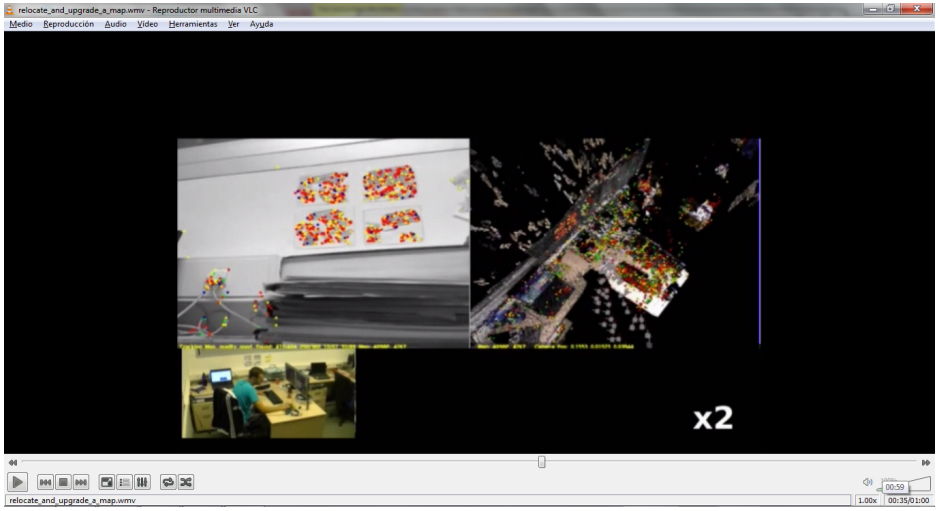


Experiment 1: Cloud Tracking and Mapping

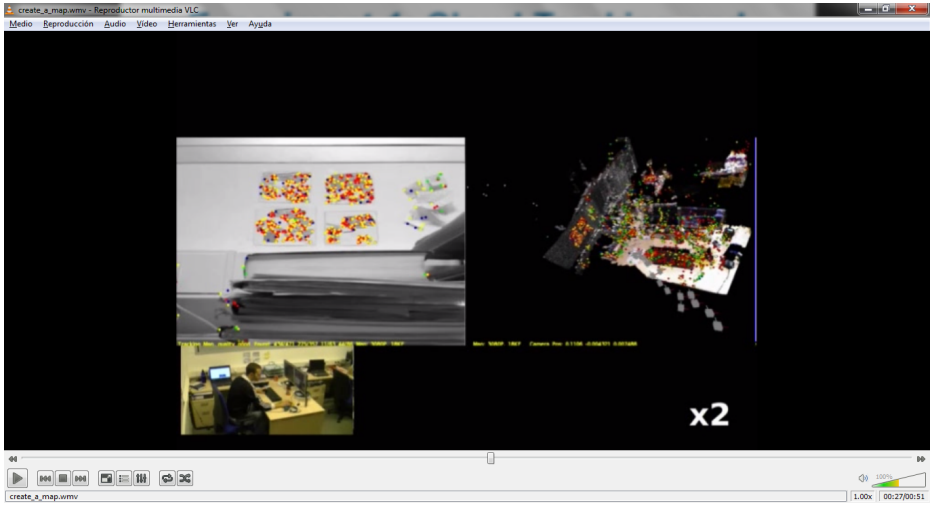
Map creation.



Map relocation and upgrade.

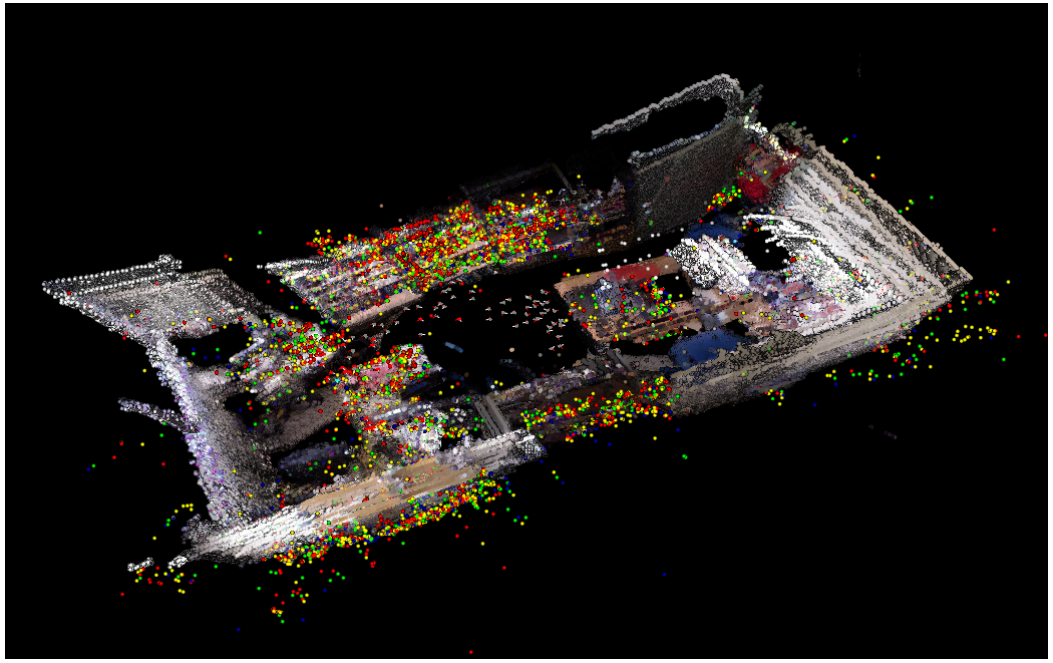


Map creation and map merging.



Experiment 2: Cooperative Tracking and Mapping using C2TAM

- Experimental setup:
  - 2 [Kinect + laptop].
  - Cloud server (running RoboEarth ROS stack and local copy or RoboEarth database).
  - Linked by a standard wireless.
- Results:
  - Data flow ~1MBs; less than the standard wireless bandwith (~3.75MBs).
  - Robust to network delays.
  - Real-Time cooperative mapping of a room (video).
  - Map (images + geometry + tags) stored in RoboEarth



Conclusions

- We propose the partition of a real-time PTAM algorithm that moves part of the computation to the Cloud without loss of performance.
- The bandwith of a standard wireless connection is enough in our experiments.
- The PTAM algorithm is robust to network latencies.
- Experimental demonstration of several modes of operation: single-user single map, single-user multi-map and multi-user multi-map.
- Extended version submitted to RAS (conditionally accepted)
- Open source version coming soon! (mail me at jcivera@unizar.es if you are interested)