# SCALABLE MULTI-ROBOT 3D MAPPING WITH REAL-TIME COLLABORATIVE VISUALIZATION

Ilya Nalivaiko[1], Mark Fiala[1], Martin Jägersand[1]
[1] Department of Computing Science, University of Alberta, Edmonton, Canada.
Email: nalivaik@ualberta.ca

## INTRODUCTION

Teleoperation of mobile robots using a live video feed is bandwidth-heavy and prone to significant latency when deployed in practice under suboptimal network conditions, which leads to poor transparency, making the system difficult to operate precisely. One approach to mitigate this is to build a 3D textured model of the environment using the video input, which allows the viewer and camera to move independently. To achieve practical real-time performance, the algorithm of D. Lovi et al. [1] constructs the model coarsely with free space carving (CARV), where view-based texturing is key for detail. However, existing implementations were limited to taking one source of video (robot) and presenting the resulting model to one viewer (the operator), with all computation and rendering running on the same device. The goal of this work is to develop a viable real-time, remote, networked, collaborative solution that supports several instances of CARV and several viewers. This would enable several operators and robots to construct and view the same virtual representation of the world.

## MATERIALS AND METHODS

This is a real time, scalable, networked collaborative framework that allows multiple sources of geometry and textures from several CARV instances to be efficiently transmitted and combined into a single world, which can then be viewed from several clients. The existing CARV code created a 3D model of the environment and saved relevant keyframes; this was then modified to encode the geometry into a form based on glTF geometry format, and use an SVD decomposition of the relevant keyframes to enable view-dependent texturing and reduce bandwidth. A central server running on the Unity game engine is then notified via ZMQ when one of the CARV sources has an update. The geometry and corresponding SVD textures are downloaded on the server side, then sent to connected clients using existing videogame protocols, preserving quality and reliability with minimal latency.

## RESULTS AND DISCUSSION

Running the core server and one client on a laptop with an Intel 12700H and 16 GB RAM, and an average home Wi-Fi network, was enough to support a total of 4 CARV instances and 4 viewers (Fig 1) on separate devices on the same network without hitting the limits of the system. The results are promising, as even moderate consumer hardware maintains usable performance, and suggests that if more devices are available to run clients and CARV instances, this can be scaled further. Due to the locally stored and decoupled nature of the geometry rendering, the system is resilient to slowdowns and dropouts due to network or hardware limitations. Even during a seconds-long interruption, the operators are free to move and look around the previously delivered world, with only the millisecond-level render latency typical of any 3D rendering engine. The updates are then processed as soon as network conditions permit. The result is a comfortable user experience compared to traditional video-based teleoperation, where any camera movement has visible latency dependent on network quality.

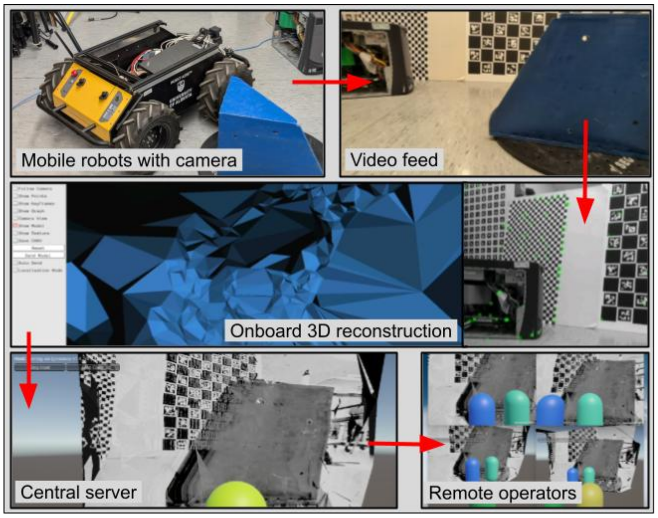


**Fig 1** System overview: mobile robots use CARV onboard. The central server aggregates geometry and textures, enabling simultaneous visualization by multiple remote clients.

## CONCLUSIONS

This technology demonstrates how networked free space carving can enable a team to create a single model of the environment while being aware of others' locations. A key application of this is disaster recovery, where time constraints require a real-time solution, and collaboration between rescue operators is required. Future work will investigate deployment in the field and determine whether a second source of position data like GPS can augment SLAM trajectories for more precise geometry mapping when the robots' relative positions are difficult to determine.

## REFERENCES

[1] Lovi D, Birkbeck N, Cobzas D, Jägersand M. Incremental Free-Space Carving for Real-Time 3D Reconstruction. 2011.