Dynamic Maps

Claus Brenner, Leibniz Universität Hannover, Germany
Wolfram Burgard, Albert-Ludwigs-Universität Freiburg, Germany
Marc Pollefeys, ETH Zurich, Switzerland
Christoph Stiller, Universität Karlsruhe, Germany

Motivation for the seminar

In recent years, the advent of car navigation systems has laid the ground for an entirely new industry sector, consisting of map producers, car/ personal/ smart phone navigation manufacturers, and service providers. It has probably gone unnoticed that navigation systems mark a major change in the way we use maps. Partially, they are still just a replacement for traditional maps, providing a means to store and visualize a representation of the environment. In contrast to the traditional use of maps, however, navigation systems perform computations using the map's data structures, such as shortest route, map matching, and route guidance. That is, from an abstract point of view, part of the map is made for machine use only – the user has no direct access to it but rather is only presented the outcome of the computations.

This development will accelerate in the near future, as sensor, processing, and communication capabilities of cars, or in general, robots, increase. Maps will evolve from their traditional meaning towards virtual representations of the environment, containing information specifically tailored to the employed sensors, algorithms, and questions to be solved. For example, a map may contain high-dimensional local descriptors which can be recognized by a given algorithm in the live video stream of a car's camera, allowing solving the positioning problem with unprecedented accuracy and reliability.

Such maps will not only be very different from today's maps, they also will have to be produced by entirely different mechanisms. Since they contain very many details, it is infeasible to use (partially) manual processes to produce them, as is done today. Also, the mapping of details usually implies a high change rate, calling for frequent reacquisition, which is not economically feasible using traditional surveying and mapping techniques. What is required is an approach which is both, inexpensive and accurate, detailed and up to date, using a hierarchy of measurement systems which include the map users themselves.

The purpose of the 'dynamic maps' seminar was to bring together researchers from academia and industry, from several fields of computer science, including computer vision, photogrammetry, robotics, computer graphics, geoinformatics, and driver assistance. Central objectives of the seminar were to alert the different communities to the efforts in the respective other communities, to exchange our ideas about such a future, 'dynamic' map, and to foster future research proposals in this area.

Vision

Future mapping will replace the traditional separation between map making and map usage by a holistic approach, where participants, equipped with sensors, use map data while at the same time

they contribute information, effectively keeping the map up to date at all times. This dynamic map can be viewed as a detailed collective perception of the environment – being as huge as a city, country or continent.

From a technical perspective, this is a very rewarding research goal since many challenging research questions need to be addressed, most of them in the area of or strongly linked to computer science, like robotics, computer vision, computational geometry, photogrammetry, and geoinformatics.

From the perspective of the benefits for the society, dynamic maps are the key to highly reliable autonomous systems, promising to revolutionize individual traffic, robotics in large open spaces, e.g. enabling mobility for elderly people and reducing traffic fatalities by preventing accidents altogether.

The players in this field

Traditionally, *surveying and photogrammetry* have been the key players in mapping. In terms of 3D information, photogrammetry developed automatic image matching algorithms and adopted aerial laser scanning to produce large 3D point clouds. Fully automatic methods to interpret raw data in order to extract roads, buildings, facades and street furniture have been research topics for many years. Regarding very detailed mapping, mobile mapping systems are available today which produce several 100.000 geo-referenced 3D points per second using a moving van, with relative accuracies in the range of a few centimeters.

Similarly, *robotics* has dealt with the problem of building maps of the environment, often relying on laser scanning systems as well. In contrast to the approach in surveying and photogrammetry, it is usually not intended to produce abstract maps (like traditional maps), but rather to obtain environment descriptions which serve a certain purpose, e.g. accurate positioning or the planning of collision-free paths. Nevertheless, many methods are similar, e.g. error handling, setup of observation equations, parameter estimation and tracking. Simultaneous localization and mapping (SLAM) and cooperative mapping using multiple robots are approaches which are very close to the above described vision of a self-sustaining, dynamic map.

Likewise, *computer vision* has worked on the topic of tracking and acquisition of 3D representations of the environment, with special focus on camera sensors (e.g. visual SLAM). Also, the design of high-dimensional feature descriptors which allow the efficient retrieval of images/ objects from huge image data bases is a very active research field. This is an important step towards a scalable environment description allowing efficient global localization. Close links exist to *computer graphics* – e.g. regarding the recognition of spatial patterns and the use of graphics processing units for feature extraction – and to *spatial data structures* and *computational geometry* – e.g. concerning efficient storage and retrieval of very high-dimensional feature vectors.

Also, research in *driver assistance systems* is nowadays concerned with capturing the environment, using camera, RADAR and LiDAR sensors. In contrast to traditional assistance systems, like anti-locking brakes, which strictly relied on measurements from in-car systems, it is now required to interpret much more complex sensor data capturing the environment – moving it closely to approaches in robotics and computer vision. Apart from real sensors, the integration of maps as an 'additional sensor' which can provide important background information has been proposed.

Finally, *geoinformatics* is concerned with processing and storage of spatial phenomena, with strong links to spatial data structures, computational geometry, as well as spatial data bases. During the last years, geographic information systems (GIS) have moved from traditional workplace solutions towards web based data and processing services (e.g. web map/ feature/ coverage/ terrain service), geospatial data infrastructures (GDI), and grid computing. GIS usually provides semantically annotated geospatial information, and integrating this with low and intermediate level information from sensors will be challenging. Thinking of a dynamic map, geoinformatics is an important partner to address the required geospatial infrastructure.

Schedule of the seminar

The seminar program included talks, a break-out session with reports, and an open problems session. See the abstract collection for the contents of the individual talks.

Monday, Sep. 13, 2010			
09:00	Intro of participants, selection of topics for break-out discussions		Chair: Claus Brenner
10:30	Break		
11:00	Claus Brenner	Keynote: Dynamic Maps - a Geodesist's Perspective	Chair: Christoph Stiller
12:15	Lunch		
14:30	Jan Michael Frahm	Keynote: Computer Vision for Dynamic Maps	Chair: Marc Pollefeys
16:00	Break		
16:30	Wolfram Burgard	Keynote: Mapping with Mobile Robots in Dynamic Environments	Chair: Christoph Stiller
	Sören Kammel	Autonomous Driving on the Way to Real-world Traffic	
18:00	Dinner		
Tuesday, Sep. 14, 2010			
09:00	Ruigang Yang	Keynote: Scene Reconstruction and Understanding by Mining	Chair: Sören Kammel
	Uwe Franke	Local Environment Perception and global Maps – a car manufacturer's view	
10:30	Break		
11:00	Maren Bennewitz	Humanoid Navigation in Complex Indoor environments	Chair: Jan Effertz
	Jana Kosecka	Towards Life Long Dynamic Maps	
	Noah Snavely	PhotoCity: Collaborative 3D Reconstruction using Online Games	
12:15	Lunch		
14:30	Christoph Stiller	Maps for Cognitive Automobiles	Chair: Monika Sester
	Konrad Schindler	Some challenges of dynamic cartography - an informal enquiry	
15:30	Break		
16:00	Break-out discussions		Self-organized
18:00	Dinner		

Wednesday, Sep. 15, 2010			
09:00	Report on break-out sessions (plenary)		Chair:
	Bastian Leibe	Towards a Semantic Interpretation of Dynamic Scenes	Claus Brenner
	Davide Scaramuzza	1-Point RANSAC Structure from Motion and Absolute Scale Estimation…	
10:30	Break		
11:00	George Vosselman	Feature extraction from point clouds	Chair:
	Jan-Henrik Haunert	Localization in a map of landmarks: an approach by point pattern matching	Jan-Michael Frahm
	Henrik Stewenius	Why points, 3D models and difficult computation?	
12:15	Lunch		
13:30	Hike/Walk		
18:00	Dinner		
Thursday, Sep. 16, 2010			
09:00	Sven Behnke	Towards Semantic Maps for Domestic Service Robots	Chair:
	Jonathan Warrell	StyP-Boost: A Bilinear Boosting Algorithm for Learning Style-Parameterized...	Volker Paelke
	Simone Frintrop	Visual Attention for Mobile Systems	
10:30	Break		
11:00	Volker Paelke	Making Dynamic Maps Usable for Humans	Chair:
	Dorit Borrmann	Non-Rigid Registration and Rectification of 3D Laser Scans	Konrad Schindler
	Aparna Taneja	Geometry-aligned Image Feature Representations for Matching and Recognition	
12:15	Lunch		
14:30	Monika Sester		Chair:
	Kevin Koeser	Geometry-aligned Image Feature Representations for Matching and Recognition	Jan-Henrik Haunert
	Friedrich Fraundorfer	Visual localization and its need for 3D maps and semantics	
16:00	Break		
16:30	Special session		Self-organized
	Open Problem and Brainstorming		
18:00	Dinner		
Friday, Sep. 17, 2010			
09:00	Olaf Hellwich	Ongoing Work on 3D Surface Reconstruction from Video Sequences	Chair:
	Sudipta Sinha	Visual 3D modeling from unstructured image collections: some recent progress	Friedrich Fraundorfer
	Udo Frese	Towards building a map of a collapsed building with a range camera on an …	
	Giorgio Grisetti	Generalized Least Squares Optimization on Graphs	
11:00	Break		
11:30	Wrap-up session (plenary), next steps		
	Closing		
12:15	Lunch		

Conclusions

The organizers thank all participants for their lively presentations and the fruitful discussions. We think that the seminar was a great success and served its main purpose, namely, making the different communities aware of each other, to a great extent.

It is clear that ‘dynamic maps’ is, and will continue to be, an active research topic for many years to come. Several attendants of the seminar have applied for research grants, as part of a larger German Research Foundation bundle project, in December 2010. It is worth to note that Wolfram Burgard has been granted an ERC advanced grant in 2010 for the topic of ‘LifeNav – Reliable Lifelong Navigation for Mobile Robots’, confirming the importance of the topic.

It is also clear that this area is so wide and complex, involving sensors, vision algorithms, in-car systems, acquisition strategies, data modeling, storage, and serving, that it will require a combined effort of all players to move research forward, and finally develop systems that will ultimately change the lives of all of us. That said, the organizers are looking forward to further seminars on the topic of ‘dynamic maps’.