Representation, Analysis and Visualization of Moving Objects

Summary report of Dagstuhl Seminar No 10491 (05.12. – 10.12.2010)

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1 Executive summary

This seminar is a successor to the Representation, Analysis and Visualization of Moving Objects seminar in 2008 (seminar 08451). The major goal has been to bring together the diverse and fast growing, research community that is involved in developing better computational techniques for spatio-temporal object representation, data mining, and visualization of massive amounts of moving object data. The participants included experts from fields such as computational geometry, data mining, visual analytics, GIS science, transportation science, urban planning and movement ecology. Most of the participants came from academic institutions, some from government agencies and industry. The seminar has led to a fruitful exchange of ideas between different disciplines, to the creation of new interdisciplinary collaborations, concrete plans for a data challenge in an upcoming conference, and to recommendations for future research directions (see Section 4)

2 Challenges

People, wildlife, material, food, data and even ideas move in increasing volumes at increasing speeds over increasing distances, hence mobility and movement are key processes in our present world. Understanding of mobility patterns is essential to substantiate decision making in public and private sectors, in application domains such as fleet management, transportation modeling, urban planning, tourism, wildlife ecology, spatial epidemiology, location-based services, flight safety, and marine safety. It is needed, for instance, for the prediction and monitoring of individual and group behaviors in response to and mitigation of security threats over short and long time scales. Traffic management can greatly benefit from the analysis of movement data, for example through better movement simulation (leading to better road network designs) but also by incorporating advanced detection sensors in vehicles. As a final example, mobility patterns of endangered species are prerequisites to devising protective measures in nature conservation and successfully managing interactions between tourism and conservation.

Moving object data typically include trajectories of concrete spatial objects (e.g. humans, vehicles, animals, and goods), as well as trajectories of abstract concepts (e.g. spreading diseases, gaze points in eye movement tracking). Technologies for object tracking have recently become affordable and reliable and hence movement records are nowadays generated in huge volumes on a routine basis, using diverse technologies such as radio telemetry, GPS, analysis of video sequences, Doppler radar, or infrared eye tracking. Despite this plethora of readily available tracking data, methods for extracting useful information are still immature, due to fragmentation of research and lack of comprehensiveness from monodisciplinary approaches. Overcoming these limitations calls for improved networking of the type that can be facilitated by Dagstuhl seminars.

The main obstacle in movement research is that it is still a young field, facing problems of a predominantly interdisciplinary nature. The fact that the field is still young is illustrated by the fast development of new analysis algorithms and the ever increasing data avail-

Dagstuhl Seminar Proceedings 10491
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http://drops.dagstuhl.de/opus/volltexte/2011/3086

ability (in terms of diversity as well as quantity). At the preceding seminar 08451, many interesting research results were presented, demonstrating the progress in this field, and an agenda for future research was compiled. While the participants were highly satisfied with that seminar, it was also felt that future meetings should involve an increased representation of domain specialists from relevant application domains. This need has been addressed by inviting representatives from diverse applications domains, including animal ecology, transportation, urbanism, tourism, and mobile information systems.

Interdisciplinary collaboration requires a long-term investment from the different disciplinary experts to learn about the problems at hand and the terminology used by their counterparts from other disciplines. Bringing together computing scientists with domain experts at this seminar helped to develop concrete case studies, identify suitable example data sets, and sketch out guidelines for benchmarking. The availability of example data, as well as concrete case studies help to speed up the process of bridge-building between different disciplines. This seminar has served as a catalyst in this respect, and has stimulated research on interdisciplinary topics. Nevertheless, continuity over a sufficiently long period is still important to achieve real progress. The establishment of sustainable and long-term projects (and project funding) for this type of research remains a challenge and deserves utmost attention. This seminar thus also paid specific attention to informing the participants about potential funding opportunities, and to stimulating joint grant proposals. A long-term perspective is also provided by the recently established network of the COST action IC0903 MOVE (http://www.move-cost.info/), which was joined by many of the participants, owing to the open participation framework of COST actions.

3 Program Overview

The seminar program was made up of two types of sessions, **regular sessions** that featured talks delivered to a plenary audience, and **special sessions** with a high degree of interaction (breakout sessions, research funding session). When designing the program, it was especially attempted to reserve ample time for detailed and in-depth discussions — this time even more so than in the preceding seminar 08451. As it turned out, this was also greatly appreciated by the participants.

In the following, we will give an overview of the program structure, explaining why we chose to set up the program in this way, and providing a summary of the content. The detailed program structure and the titles of the talks are provided in Section 5.

In the **starting session** of the seminar, every participant had the opportunity to deliver a brief 5' statement about his/her research interests. This gave, on the one hand, the possibility for everybody to introduce himself/herself to the group. On the other hand, it also helped to prepare for the selection of possible topics for small-group discussion in the **breakout sessions**. These topics were ordered into two sets, methods-oriented topics and data-centric (or application-centric) topics:

Methods-oriented topics:
- Benchmarking data and procedures
- Visualisation of movement
- Temporal scale
- Aggregation of trajectories
- Similarity measures

Data-centric topics:
- Supermarket customers
- Gulls Behaviour Classification
- Context, Visualisation
- Pedestrians

These topics were then discussed in two sets of breakout sessions, whereby each participant chose one topic and hence one group per session. The first session was scheduled on Tuesday afternoon, the second on Thursday morning. Each break-out group was given the task to nominate a rapporteur, responsible for reporting back the results of the

discussion to the plenary. Thus, it was guaranteed that despite the discussion in parallel groups, everybody was at least able to hear a summary of the discussion. In addition, a record of the discussion was kept that was made available via the seminar proceedings.

Besides breakout sessions, a **session on funding opportunities** was held on Wednesday night. This special type of plenary session was used to communicate information about the various funding opportunities that exist to support joint research on the international level. Using this input, the plenary then discussed possible avenues for pursuing joint grant proposals. The “Initial Training Network” opportunity in FP7 seemed particularly interesting, as well as the participation in the existing COST Action IC0903 MOVE.

There were two types of **regular sessions.** First, keynote talks of 30 minutes duration, which had the purpose of providing equal foundations to an interdisciplinary audience, reviewing the state of the art, and giving hints on key problems and challenges. These keynote presentations were all scheduled at the beginning of the week, on Monday afternoon and Tuesday morning, respectively. The second type of presentations consisted of short talks of 15 minutes duration that were scheduled on Wednesday morning and Thursday morning. These sessions were deliberately limited to few presentations, in order to make more room for break-out sessions and long breaks that could be used for further discussion and work in small groups.

The seminar benefitted particularly from several participants who brought life data to the seminar, including data on seagull flights, vervet monkeys in the wild, pedestrians in a city, and visitors of a town fair. One of the participants brought a number of GPS devices to the seminar, with which hands-on data collection exercises and processing could be practiced. On Wednesday, a small data-collection trial was organized by a group of seminar participants who took GPS devices on a walking and on a biking trip, respectively. The data were post-processed, visualized, partially analyzed and discussed on Thursday.

Due to the efforts of both the presenters and the audience, the disciplinary boundaries were crossed many times and this resulted in stimulating discussions, immediately after the presentations, during break-out sessions, but also during the breaks in the pleasant environment of Schloss Dagstuhl.

4 Outcomes

Outcomes of the seminar include a collection of presentation abstracts, presentation slides, reflections and summaries of the various discussions that took place, and the movement data tracks that were collected during the workshop, made available on the Dagstuhl website (http://www.dagstuhl.de/Materials/index.en.phtml?10491).

Similar to the previous seminar of this series, new partnerships and collaborations between multi-disciplinary groups did arise, further advancing this field with the inclusion of emerging topics. As a first initiatives in this direction, a data challenge activity was prepared during this seminar that will use seagull data from the University of Amsterdam, as well as a set of research questions defined at the seminar. It will be used as part of an upcoming workshop at the Lorentz Centre at Leiden University (NL) (http://www.lorentzcenter.nl/lc/web/2011/453/program.php3?wsid=453) that is organized by some of the seminar participants. Also, initial plans were made to set-up a European Integrated Training Network (FP7 Marie-Curie) of doctoral students and postdocs, to educate the future researchers in the analysis of movement data. Most of the Europeans among the participants of Dagstuhl seminar 10491 are also expected to participate in this ITN, which will be submitted in 2012.

Besides the above future activities that will involve a large part of the seminar participants, several smaller multilateral initiatives were started at the seminar. For instance, two research visits of 2-3 weeks were organized between groups that ‘found’ each other at the seminar. These visits were funded by the COST Action IC0903 MOVE through the instrument of so-called Short-Term Scientific Missions (STSMs). Also, several concrete initiatives seem to be under way for submission of STREP and FET Young Explorers proposals within the FP7 Programme, again made possible by the fact that the right people met in Dagstuhl seminar 10491.

5 Detailed Program

Dagstuhl Seminar 10491 on		
Representation, Analysis and Visualization of Moving Objects		
		Talks
		Special sessions: Intro, Open Problems, Break-out groups
		Breaks and leisure
Monday, 6 December 2010		
9:00	Intro of participants, open problems (5 min slots)	
10:30	Break	
11:00	Intro of participants, open problems (5 min slots)	
12:00	Lunch	
14:30	van Loon, E.	An Introduction to the Research on Bird Movement at UvA
	Miller, H.	Mobility Analytics in Geospaces
16:00	Break	
16:30	Gudmundsson, J.	Algorithms for Movement Patterns
	Laube, P.	Scale and Granularity in Movement Analysis
18:00	Dinner	
Tuesday, 7 December 2010		
9:00	van der Spek, S.	Activities in Public Space
	Willems, E.	A Conceptual Model of Animal Movement Ecology: A Primatological Case Study
10:30	Break	
11:00	Discussion on topics for break-out sessions	
12:00	Lunch	
14:30	First break-out session	
16:00	Break	
16:30	First break-out session continued	
18:00	Dinner	
Wednesday, 8 December 2010		
9:00	Snoeyink, J.	Motion Models and Kalman Filters (Short)
	Laube, P.	Report from MPA'10 workshop (Short)
	Silveira, R.	Median Trajectories (Short)
10:30	Break	
	Buchin, M.	Clustering Subtrajectories (Short)
	Fekete, S.	Improving Traffic Flow by Local Methods (Short)
	Weibel, R.	Funding Opportunities: MOVE Cost Actions
12:00	Lunch	
13:30	Hike/Walk or	
	Visit of Trier	
18:00	Dinner	
21:00	Special session on funding opportunities for joint research projects	
Thursday, 9 December 2010		
9:00	Sester, M.	Incremental Acquisition of Information from GPS-Tracks (Short)
	van Loon, E.	Model Based Movement Analysis (Short)
	Slingsby, A.	Browsing Storm Tracks (Short)
10:30	Break	
	Versicherle, M.	Bluetooth-Tracking @ Ghent Festivities 2010 (Short)
	Timpf, S.	Geospatial Actions as Context Info (Short)
12:00	Lunch	
14:30	**Reports of first break-out session:**	
	Purves, R.	Benchmarking
	Demsar, U.	Visualisation
	Mountain, D.	Temporal scale
	de Berg, M.	Aggregation
	Gudmundsson, J.	Similarity
16:00	Break	
16:30	Second break-out session	
18:00	Dinner	
Friday, 10 December 2010		
9:00	**Reports of second break-out session:**	
	Dias, E.	Supermarket customers
	Mountain, D.	Gulls Behaviour Classification
	Willems/Demsar/Buchin	Context, Visualisation
	Silveira/Spek/Snoeyink	Pedestrians
10:30	Break	
11:00	Closing plenary	
12:00	Lunch	