PhD Lecture

Cassiopeia
House of Computer Science

In partial fulfillment of the terms for obtaining the PhD degree, Srinivasa Raghavendra Bhuvan Gummidi will give a lecture on the following subject:

Multi-modal Spatial Crowdsourcing for Enriching Spatial Datasets

on Tuesday 11th of May 2021, 13:00,

Abstract:
Despite the advances in technology, many tasks are not effectively resolved by computer-based automated algorithms. These tasks range from image recognition to entity resolution and require the human cognitive ability to improve the algorithms' performance. Crowdsourcing helps resolve such tasks by providing a platform to engage ordinary workers (crowd) to harness their capabilities. Generally, conventional crowdsourcing applications focuses on tasks that workers can resolve via the internet. However, tasks related to real-world scenarios with spatial aspects like traffic information and environmental data collection cannot be resolved virtually and require physical on-location operations. Spatial crowdsourcing (SC), a particular class of crowdsourcing, provides a platform to solve such spatial nature tasks by harnessing the crowd's potential. The widespread availability of location empowered smartphones has boosted SC's application potential ranging from smartphone sensor-based data collection to personal service-based delivery applications. A typical SC application operates on different modes depending on the requirements of the spatial tasks, workers, and task requesters. The different modes can be related to, but not limited to, task complexity, the required number of responses, type of assignment/scheduling problem addressed, type of constraints considered, and task publishing mode. When an SC application operates on multiple modes, this thesis defines such SC application as a Multi-modal SC application.

Given the significance of spatial datasets like OpenStreetMap (OSM) in research, this thesis explores multi-modal SC's potential to address the problems faced by spatial datasets regarding the coverage/ sparsity and quality. The objective is to enrich the spatial datasets like OSM and improve their spatial entities attribute/ tag coverage and quality by utilizing multi-modal SC. This thesis also enhances spatial entities attributes by linking spatial entities across multiple spatial datasets by employing a machine learning-based multi-modal SC application. Furthermore, this thesis encourages worker participation in multi-modal SC by customizing task assignment and scheduling strategies for a potential group of new SC workers, public transportation users, to enrich spatial datasets. The following paragraphs highlight the contributions of this thesis.

Firstly, this thesis provides a comprehensive literature survey of multimodal SC. The survey describes the SC usage workflow and identifies the fundamental difference between spatial and conventional crowdsourcing. The survey introduces a taxonomy to classify the existing SC literature based on the commonalities and differences. Furthermore, the survey elucidates the current literature's issues/challenges and presents some potential research directions for the future. This thesis addresses three challenges of SC highlighted by the survey concerning enrichment of spatial datasets, improvement of worker participation in multi-modal SC campaigns, and improvement of task assignment and scheduling strategies. The survey benefits the researchers in gaining a comprehensive view of the existing research in SC and facilitating the comparison of different task assignment and scheduling algorithms by highlighting their advantages and drawbacks.

Secondly, this thesis addresses the challenge of enriching semantic tag information of spatial entities in the OSM dataset and improving worker participation in OSM. This thesis aims to improve the quantity and quality of the tags associated with the OSM's spatial entities through the multi-modal SC approach in push-based/server-assignment mode. The thesis defines different task assignment problems for maximizing 1) the total number of task assignments, 2) the entities' coverage, 3) the number of verifiable task assignments. Focusing on the use case of road

networks in OSM, this thesis proposes an integrated framework to extract the tasks and assign road segments/ junctions to workers through algorithms based on different constraints in offline and batch-based worker input model scenarios. An experimental evaluation reveals that the proposed junctions-based algorithms result in five times as many unique assignments and seven times as many verifiable assignments as the baseline max-flow based algorithm and around half the average distance travelled per task than the baseline algorithm.

Thirdly, this thesis addresses the challenge of enriching spatial datasets by linking spatial entities across multiple spatial datasets like Google Places, Flickr, and Krak. Linking spatial entities has a vast potential to offer rich attribute information regarding the spatial entities. However, linking the spatial entities from different sources involves finding out whether they represent the same physical entity or not, leading to a spatial entity linkage (SEL) problem. This thesis aims to resolve the SEL problem by exploiting the wisdom of SC workers. Given the reward budget limitations, this thesis proposes a hybrid Skycrowd solution incorporating machine learning-based SC and automatic labeling (AL) techniques. The proposed Skycrowd solution performs 30% better than the automatic labeling of the entire SEL tasks set with respect to F-measure. It achieves an F-measure value of 0.91 by spending a fraction (7%) of the reward budget required for crowdsourcing the entire set of SEL tasks.

Finally, this thesis addresses the challenge of improving worker participation and improving the task assignment and scheduling algorithms by considering the worker movement information. This thesis considers a new group of workers travelling via public transportation to improve online task assignment and task scheduling strategies by incorporating transit route information. This thesis assumes that the new group of workers can perform assigned tasks at transits stops on their route while waiting to change for the next bus/ train. This thesis defines the Transit-based Task Assignment (TTA) problem to maximize the average worker rewards considering different constraints like worker transit route (WTR) adherence and task deadlines. Furthermore, this thesis defines a credibility-based TTA problem to ensure quality crowdsourced responses. Moreover, this thesis also defines a flexible-TTA problem assuming a threshold reward to convince a worker to stay longer at a transit stop for a high reward task, thereby relaxing the WTR model's rigid nature. This thesis proposes algorithms to solve the three different problems and performed an extensive evaluation of the implemented algorithms. The FlexibleTTA problem algorithm outperforms other algorithms by 55% regarding the number of assigned tasks and at least 35% regarding the worker's average reward.

In conclusion, this thesis performs a comprehensive survey of the existing SC literature and proposes a framework comprising novel multi-modal SC applications for enriching spatial datasets. In addition to addressing the spatial dataset enrichment issue, the proposed applications address other SC issues by suggesting strategies to improve worker participation and improving task assignment/ scheduling algorithms. As part of future work, this thesis suggests implementing a comprehensive multi-modal SC solution to enrich the OSM dataset, integrating the proposed individual multi-modal SC applications regarding OSM tag enrichment, spatial entity linkage, and transit-based task assignment.

Members of the assessment committee are Associate Professor Chenjuan Guo, Aalborg University, Denmark, Associate Professor Michela Bertolotto, University College Dublin, Ireland, and Professor Xiaofeng Gao, Shanghai Jiao Tong University, China. Professor Torben Bach Pedersen, Professor Xike Xie, and Professor Esteban Zimányi are Srinivasa Raghavendra Bhuvan Gummidi's supervisors. The moderator is Associate Professor Peter Dolog.

All interested parties are welcome.