Student:	..
Supervisor/s:	Luca Reeb, Tobias Feigl
Client:	..
Thesis:	Masters Thesis

Generalization of Channel Charting

Keywords: Siamese Networks (SN), Sammon's Mapping (SM), Autoencoder (AE), Dimension Reduction, QUADRIGA, SiMoNe, Transfer Learning, Continual Learning, Trustworthiness, Continuity, Kruskal's Stress.

Motivation. The demand for increased traffic volume and number of terminals in future wireless communication systems requires the use of new technologies, e.g., massive multi-input and multi-output, millimeter-wave bands, that rely on knowledge of transmitter locations to solve the challenges encountered in their practical application [1]. In contrast to supervised wireless location frameworks such as fingerprinting, Channel Charting (CC) is system-level unsupervised and operates directly on Channel State Information (CSI) that are passively collected at multi-antenna base stations (BS). As such, it avoids the expensive data collection phase of their supervised counterparts.

While promising results in simulated, static environments have demonstrated the potential feasibility of the method [1, 2, 4], generalization and robustness in complex, dynamic environments with potentially sparse UE coverage is still an open question. Another unresolved challenge is the existing evaluation criteria of CC techniques, which essentially rely on qualitative inspection and thus suffer from a lack of well-calibrated and understood performance metrics. For example, trustworthiness (TW) and continuity (CT) impede the automatic comparison required for hyperparameter optimization. With the addition of side information, CC can be generated or mapped to reflect absolute receiver positions [3, 5].

Idea to address these challenges. Approaching the generalizability of CC should be used when evaluating state-of-the-art methods w.r.t. performance sensitivity to variations in parameters such as UE density, dynamic UEs, and LoS/NLoS components, ideally over a wide range of scenarios. Integrating time and velocity information from CC, as well as better CSI distance metrics, may help address generalization issues, so should be investigated. In addition, the extension of CC for absolute positioning with additional information should be observed. A user study should be conducted to calibrate the TW and CT metrics to better capture the quality of the resulting charts and competitors based on e.g. rank correlation can be proposed and compared.

Overall goals. Three main goals are addressed in qualification theses: (1) Channel Charting using representation-constrained DL models, (2) Lifelong Learning for Channel Charts, and (3) Channel Chart Assisted Localization. These are defined in the following sub-goals:

- (1) Transfer between different propagation environments and channels;
- (2) Robustness of the novel CC framework to sparse data, data gaps, and delays;
- (3) Implementation and evaluation of state-of-the-art methods;
- (4) Benchmarking of the robustness of distance metrics learned to reconstruct geometric structured channel charts;
- (5) Definition of efficient application-specific metrics (beyond TW, CT, KST, and similarity metrics: euclidean distance vs triplet loss);
- (6) Adaption of the CC framework to a simulation interface, such as QUADRIGA;
- (7) Lifelong learning: updating CC to changing environments (dynamic objects, receivers and transmitters);
- (8) An academic paper will be written.

Student:	..
Supervisor/s:	Luca Reeb, Tobias Feigl
Client:	..
Thesis:	Masters Thesis

Timetable (6 months, in person weeks [PW]).

4 PW Literature and patent research; Familiarization with relevant work on the subject areas;

10 PW Methodological work: adaptation of the individual components to the state-of-the-art methods and advances to the state-of-the-art based on recent deep learning methods;

4 PW Evaluation;

6 PW Transcript.

Expected results and scientific contributions.

- A novel CC framework that generalizes to changing environments.
- An appropriate metric will be defined to enable public benchmarks and comparison.

References

[1] Studer, C., Medjkouh, S., Gonultaş, E., Goldstein, T., & Tirkkonen, O. (2018). Channel charting: Locating users within the radio environment using channel state information. IEEE Access, 6(?), pp. 47682-47698.

[2] Deng, J., Medjkouh, S., Malm, N., Tirkkonen, O., & Studer, C. (2018, October). Multipoint channel charting for wireless networks. In: Asilomar Conf. on Signals, Systems, and Computers (Asilomar), pp. 286-290.

[3] Lei, E., Castañeda, O., Tirkkonen, O., Goldstein, T., & Studer, C. (2019, September). Siamese neural networks for wireless positioning and channel charting. In: Annual Allerton Conf. on Communication, Control, and Computing (Allerton), pp. 200-207.

[4] Agostini, P., Utkovski, Z., & Stańczak, S. (2020, May). Channel charting: an Euclidean distance matrix completion perspective. In: Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP), pp. 5010-5014.

[5] Pihlajasalo, J., Koivisto, M., Talvitie, J., Ali-Loeytty, S., & Valkama, M. (2020). Absolute Positioning with Unsupervised Multipoint Channel Charting for 5G Networks. In 2020 IEEE 92nd Vehicular Technology Conference (VTC2020-Fall) (pp. 1-5). IEEE.