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Attention-based Neural Networks for Multi-modal Trajectory Prediction

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Motivation

Trajectory prediction is of great importance in wireless and intelligent networks. Accurate forecast of users' trajectories can provide efficient handover management, continuous network connection, and generally a better network quality of service.

Contributions

- A trajectory predictor based on Transformers Neural Networks acquiring the self-attention mechanism [3].
- A social-aware mobility model where agents are not acting in isolation and the interaction between agents is considered [1].
- A reinforcement learning approach to design the highest-performance neural architecture based on the multi-modal trajectory scenario.
- INteractive TRAnsformers ReinFORCEd (INTRAFORCE), a framework that achieves high prediction accuracy while reducing training and architecture design time, and computational complexity.

Transformers Trajectory Prediction

- A trajectory is defined as the sequence of location tags over time as a 2D signal: $T(Loc, t) = [(Loc_1, t_1), (Loc_2, t_2), \ldots, (Loc_n t_n)]$.
- A trajectory predictor forecasts mobile user's future location based on his historical data: $p(Loc_{t+1} | Loc_t, Loc_{t-1}, \ldots Loc_{t-n})$.
- Transformers consist of attention-based encoder and decoder blocks.
- An attention layer can focus more on some parts of input data based on their measured relevance weights, similar to human brains.

Reinforcement Learning Optimization

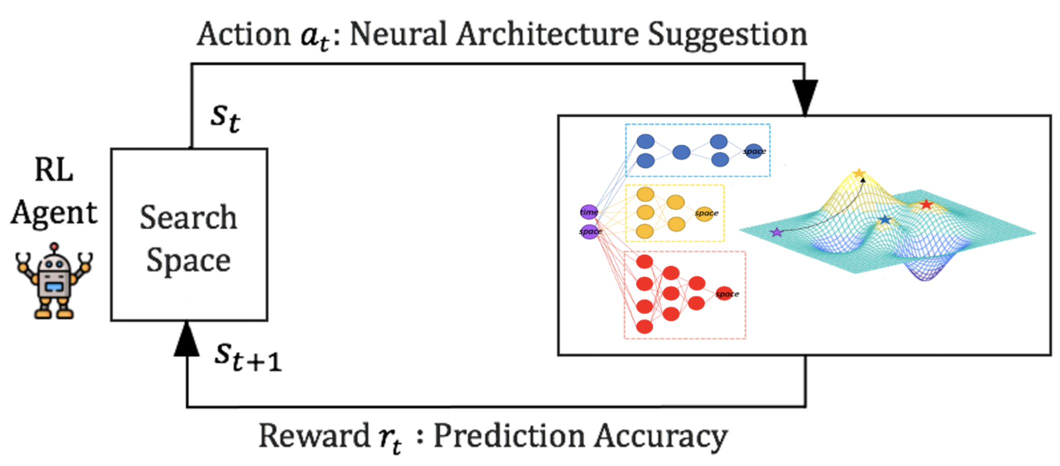

Figure 1:Personalizing transformers neural architecture design through a RL approach.

- The agent after taking an action and receiving the reward, updates state-action value $Q(s, a)$ on each iteration through Bellman's Equation:

$$Q_{t+1}(s, a) = (1 - \alpha) Q_t(s, a) + \alpha \left(r_t + \gamma \max_{a' \in \mathcal{R}(s')} Q_t(s', a') \right).$$

- The Q values helps the agent to narrow down the search space toward high-performance neural architectures.

Social Awareness

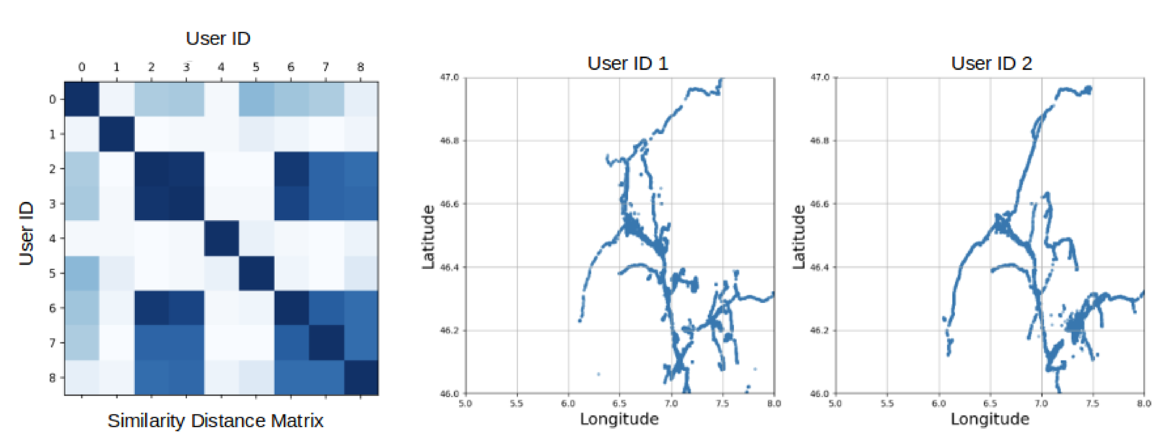

Figure 2:Measuring similarity and clustering adjacent trajectories.

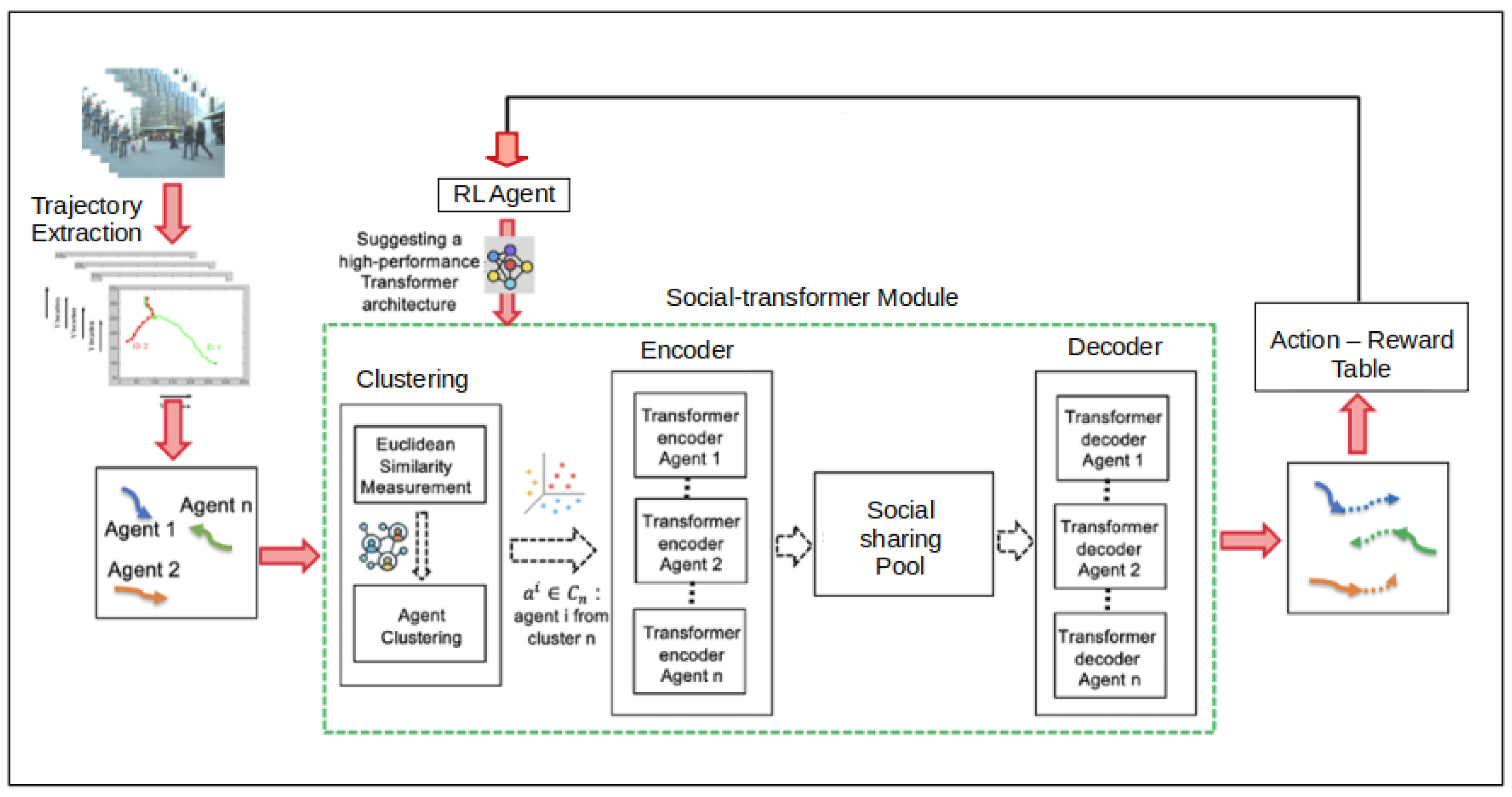

Figure 3:INTRAFORCE architecture.

- Clustering neighbor trajectory users to extract spatio-temporal dependencies of neighbor trajectories.
- Feeding co-cluster users to Intraforce.
- Pooling knowledge of adjacent users to capture the interactions.
- Feeding back the model's output to RL for a better decision making.
- Objective function: $\min \sum_i \frac{1}{m_i} \|y_i - x_i W_i\| + \lambda \sum_{i,j} A_{i,j} \|w_i - w_j\|$.

Evaluations and Conclusions

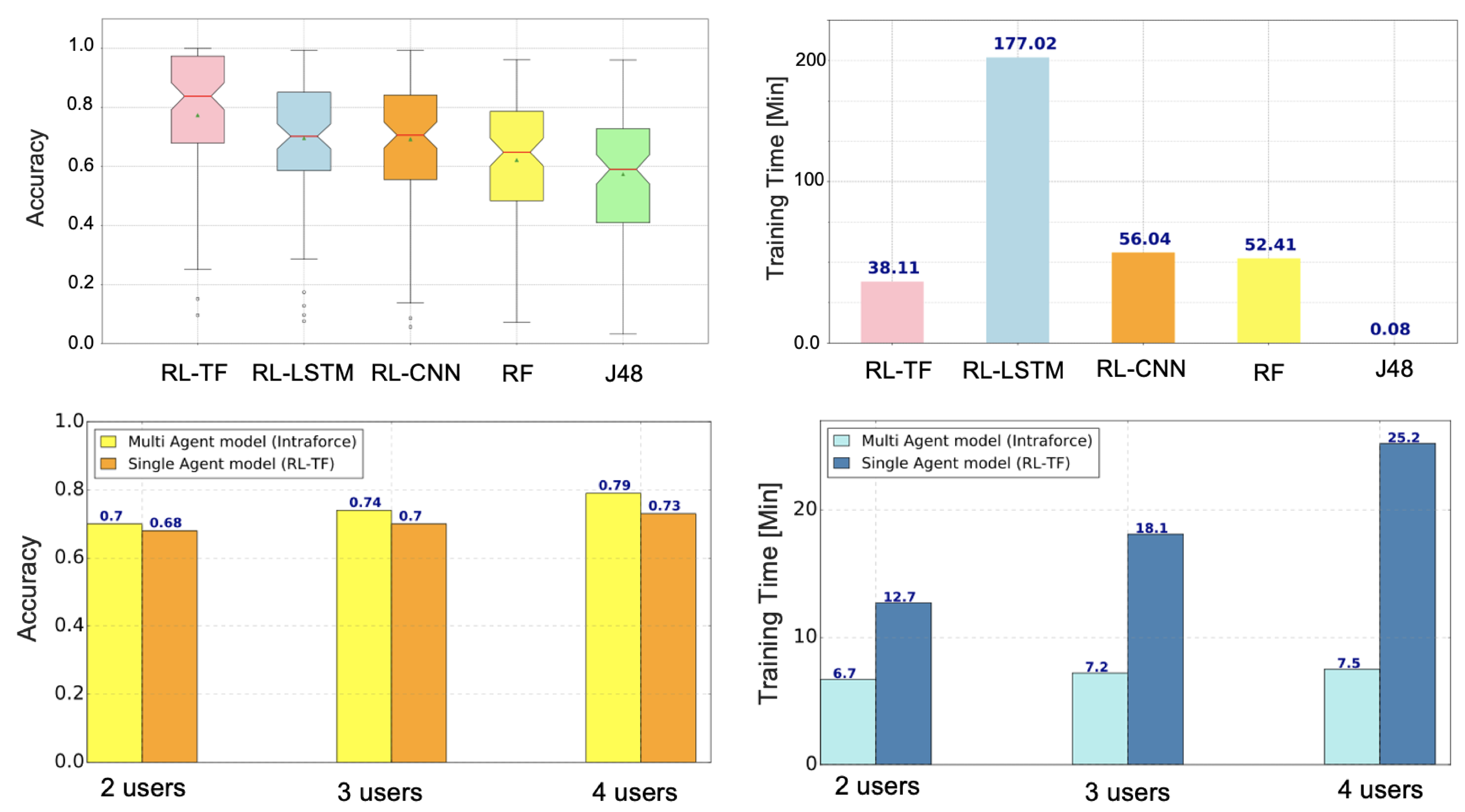

Figure 4:Accuracy and training time comparison of different mobility predictors.

- We evaluate our proposed model on Orange dataset [4].
- We observe that RL-TF remarkably outperforms the state-of-the-art trajectory predictors in terms of prediction accuracy and training time [2].
- We observe that the social-aware INTRAFORCE predictor brings a noticeable efficiency into the trade-off between accuracy, training time, and computational complexity.

References

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[2] N. Emami, L. de Sousa Pacheco, A. Di Maio, and T. Braun. Rc-tl: Reinforcement convolutional transfer learning for large-scale trajectory prediction. 2022.

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