Joint point process models and recurrent neural networks for sequential recommendations and time prediction

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Introduction

Recurrent Neural Network (RNN):

- **Feedback loops** allows model to retain information of previous input.
- Typically fed **sequence data** with inter-item dependencies.
- Used to achieve state of the art results in many **NLP and audio** related problems.
- Recently shown promise in the field of **session-based recommendation** [1].

Point Process:

- Well established concept from statistical theory.
- Probabilistic distribution of point in underlying mathematical space.
- Distributed according to probability distribution.

Our proposal:

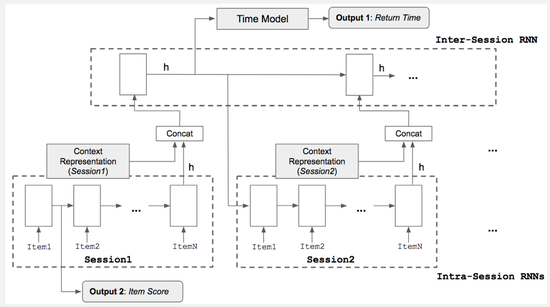
- **Joint model** based on RNN and point process that performs recommendation and return time prediction.
- RNN is used to **recommend** next item based on previous choices.
- **Time** until next session is modeled with a **point process**.
- RNN is also used for **inter-session modeling**, which is used to assist both recommendation and time prediction.

Model

We propose a **Temporal Hierarchical RNN** (**THRNN**) based on the work done in [2]. The hierarchical RNN is extended with a point process and **shares factors** with one of the RNN layers. The point process is inspired by [3], and used to model **time between sessions** as opposed to choices.

Hierarchical RNN:

- **Two highly coupled RNN layers.**
- **Intra-session RNN:**
  - Fed with user choices and **outputs item scores** for recommendation.
  - The final output of full session is stored as a **session representation**.
- **Inter-session RNN:**
  - Fed with **session representations** along with **session contexts**.
  - Used to supply recommendation and time prediction with **inter-session information**.
  - Final output is used as **initial hidden state** in Intra-session RNN **and** is used in the **intensity function** of the point process.



Temporal modeling

The **parameterization** of the **intensity function** of the **point process** is shown in Equation 1

$$\lambda^*(t) = \exp(v_t^\top \cdot h_j + w_t \cdot (t - t_j) + b_t) \tag{1}$$

- h_j is the **final output/hidden state** of the **inter-session RNN**.
- v_t, w_t and b_t are **temporal modeling** specific **trained parameters**.
- t_j is the time of the **last session** and t is the **time variable**.

The full **conditional density distribution** of the point process is shown in Equation 2.

$$f^*(t) = \lambda^*(t) \exp\left(- \int_{t_j}^{t} \lambda^*(\tau) d\tau \right) \tag{2}$$

Temporal tuning parameter

We introduced a **tuning parameter** in the **temporal loss** for controlling the **long-/short-term** focus of the model. The parameter appears as an **exponent** in every **time term** in the **negative likelihood loss** using the conditional density distribution (Equation 2).

$$(t - t_j)^\alpha$$

Results: Recommendation

	R@20	MRR@20
GRU4REC	0.2474 ± 0.0002	0.0969 ± 0.0002
HRNN	0.2751 ± 0.0006	0.1004 ± 0.0004
	(+11.2%)	(+3.7%)
THRNN	0.2795 ± 0.0006	0.102 ± 0.0003
	(+13.0%)	(+5.3%)

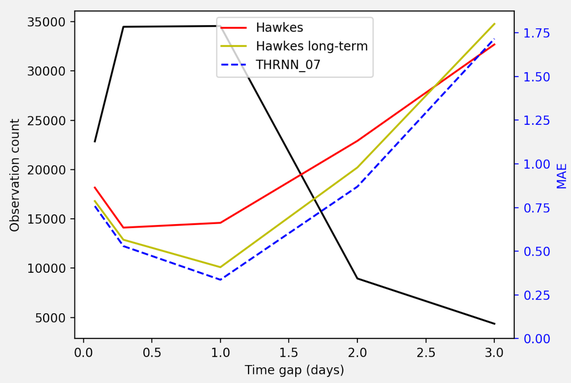
Table: Recall and MRR results on the LastFM dataset.

	R@20	MRR@20
GRU4REC	0.475 ± 0.0003	0.25 ± 0.0006
HRNN	0.616 ± 0.0012	0.3347 ± 0.0015
	(+29.7%)	(+33.9%)
THRNN	0.6228 ± 0.0009	0.3371 ± 0.0014
	(+31.1%)	(+34.8%)

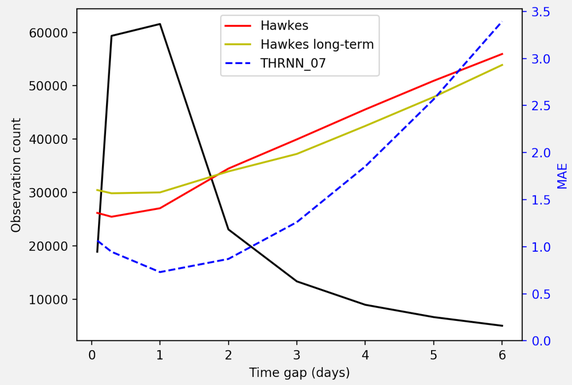
Table: Table with the recall and MRR on the Reddit dataset.

- **GRU4REC:** Model based on the single layer RNN model proposed in [1].
- **HRNN:** The hierarchical RNN model from [2].
- **THRNN:** Our model, Temporal Hierarchical RNN.

Results: Time prediction



(a) Plot of time prediction results on the LastFM dataset.



(b) Plot of time prediction results on the Reddit dataset.

Time Prediction Plot Info:

- **x-axis:** Length of return-time to predict in days
- **Left y-axis:** Number of of observed return-times of x days length
  - **Black curve:** Observation count
- **Right y-axis:** Mean Absolute Error in days
  - **Colored curves:** Return-time MAE of the proposed model and baselines

Results: Tuning parameter settings

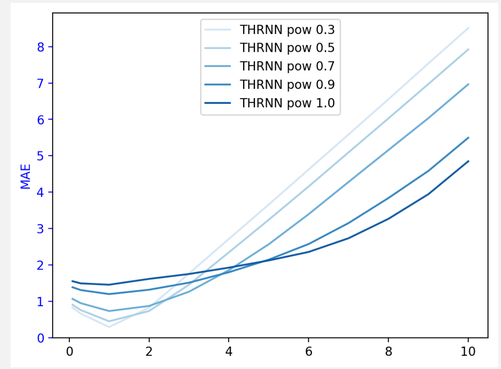


Figure: Plot showing the effect of different setting of the tuning parameter α on the Reddit dataset.

References

[1] Balázs Hidasi, Alexandros Karatzoglou, Linas Baltrunas, and Domonkos Tikk. Session-based recommendations with recurrent neural networks. *CoRR*, abs/1511.06939, 2015.

[2] Massimiliano Ruocco, Ole Steinar Lillestøl Skrede, and Helge Langseth. Inter-session modeling for session-based recommendation. In *Proceedings of the 2nd Workshop on Deep Learning for Recommender Systems, DLRS@RecSys 2017, Como, Italy, August 27, 2017*, pages 24–31, 2017.

[3] Nan Du, Hanjun Dai, Rakshit Trivedi, Utkarsh Upadhyay, Manuel Gomez-Rodriguez, and Le Song. Recurrent marked temporal point processes: Embedding event history to vector. In *Proceedings of the 22Nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, KDD '16, pages 1555–1564, New York, NY, USA, 2016. ACM.

[4] Bjørnar Vassøy, Massimiliano Ruocco, Eliezer de Souza da Silva, and Erlend Aune. Time is of the essence: A joint hierarchical rnn and point process model for time and item predictions. In *Proceedings of the Twelfth ACM International Conference on Web Search and Data Mining*, WSDM '19, pages 591–599, New York, NY, USA, 2019. Association for Computing Machinery.

Additional Information

- **Code repo:** https://github.com/BjornarVass/Recsys/
- This research project led to the publication [4].
- Authors with * are presenters at NorwAI Innovate 2021.

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