Multi-Task Recurrent Modular Networks

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PennState

NEC Laboratories America
Relentless passion for innovation

Agenda

- Motivations
- Challenges
- Proposed Model: MT-RMN
- Experiments

Motivations

- Sequence Learning
  - E.g., Sentiment classification, sequence labelling
- Multi-Task Learning
  - Advantages: Computational advantage

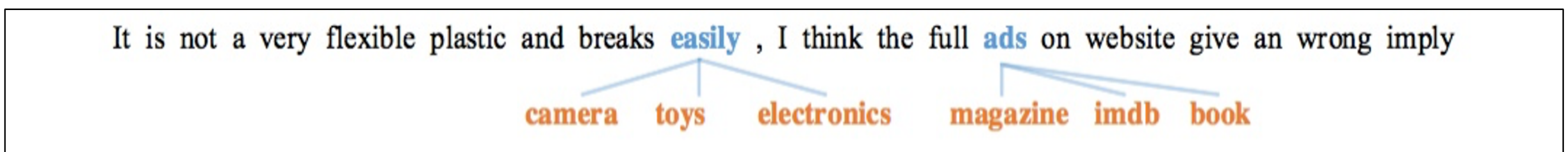
- However, multi-task architectures applicable to recurrent models are underexplored

- Goal: A Recurrent Module
  - Can be integrated into any multi-task learning approach for sequential data
  - To improve model capacity, flexibility, generalization

Challenges

- Dynamics of task relationships
- Limited knowledge of the task relatedness
- Generalization ability [2]

- Example: Dynamic task relatedness in NLP [1]
  - Sentiment prediction of 16 datasets (multi-task learning)



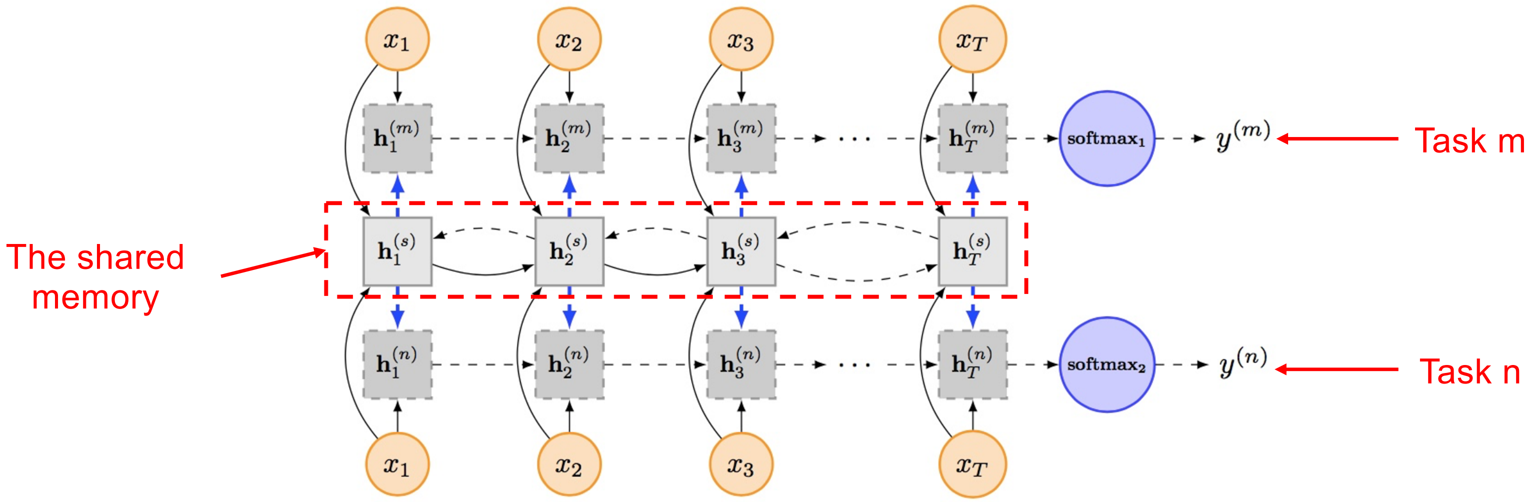
(a) Kitchen Task

Illustrations of the three most relevant tasks for each word in the “Kitchen” task.

[1] Learning Multi-Task Communication with Message Passing for Sequence Learning, AAAI 2019.
[2] Lake, Brenden M. "Compositional generalization through meta sequence-to-sequence learning." NeurIPS 2019.

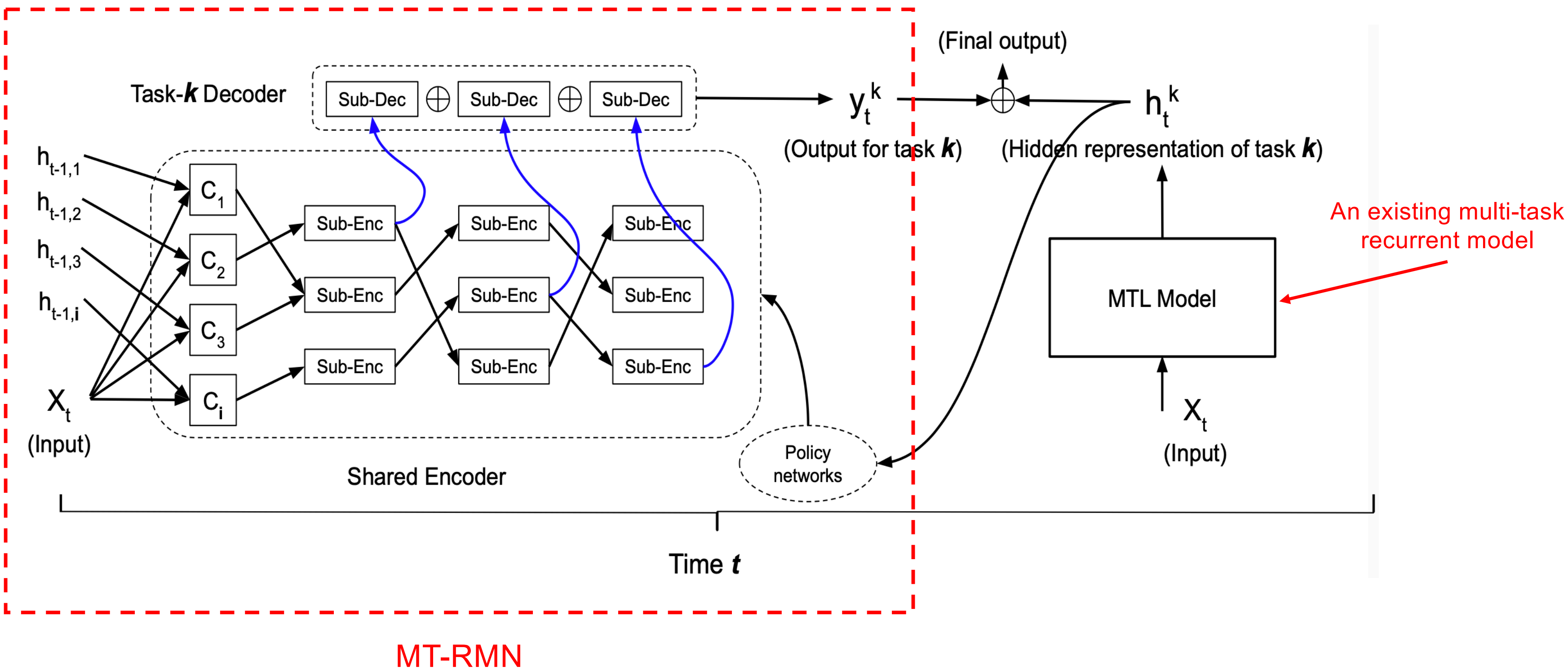
Typical Architecture

- Existing approaches are not flexible enough to learn the dynamic relationship



PSP-MTL (IJCAI'16)

Proposed Model: MT-RMN



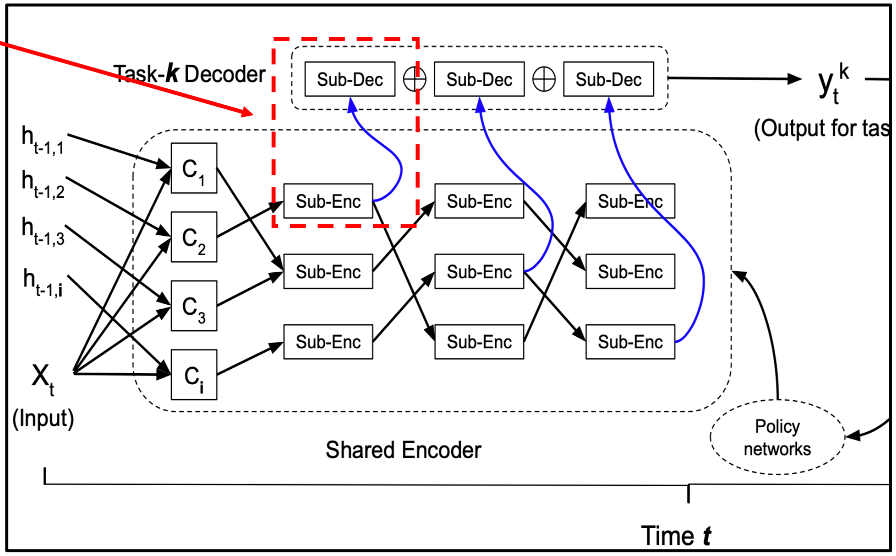
How to Make Connection Decision

- 1) Generate decision vector
  - Using Policy Network

$$\beta^k_{t,j} = \widehat{\mathcal{N}}^k(\boldsymbol{u}_{t,j}) = MLP(\boldsymbol{u}_{t,j} \oplus \boldsymbol{W}_k \boldsymbol{h}^k_t)$$

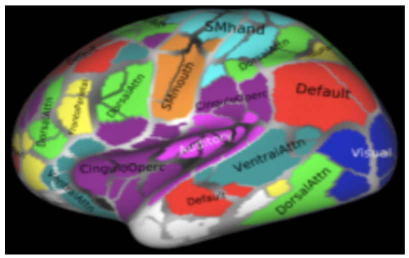
- 2) Estimate the binary decision value
  - Using Straight-Through Router

$$\zeta = \arg\max_i [\alpha_i + g_i], i \in \{0, 1\}$$

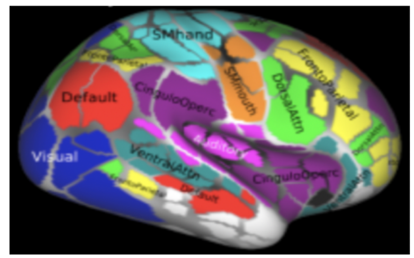


Experiments on Task-fMRI

- Task-Evoked Functional MRI Data[1]
  - To analyze the relationship between brain connectivity and human behavior



The left side of brain



The right side of brain

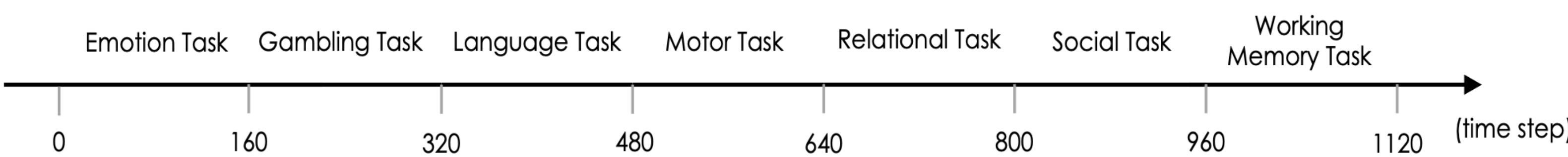


Figure 5: Seven tasks and each task lasts 160 time steps.

[1] Barch, Deanna M., et al. "Function in the human connectome: task-fMRI and individual differences in behavior." Neuroimage80 (2013): 169-189.

Experiments on Task-fMRI

- Construct four tasks

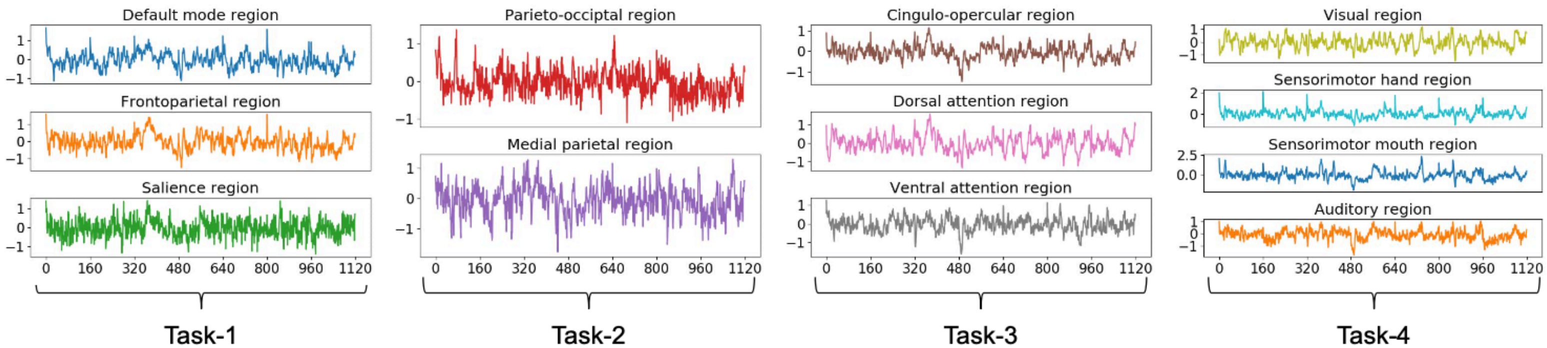


Figure 2: The task-fMRI data of twelve high-order brain regions of a participant. The regions are grouped into four groups based on their functionalities. Each group is used to construct a multi-class classification task of time series. The participant was asked to perform seven tasks successively (Barch, Burgess et al. 2013).

Experiments on Task-fMRI

- Results on the Task-fMRI data

Table 1: Results (accuracy %) on two groups of *tfMRI* tasks.

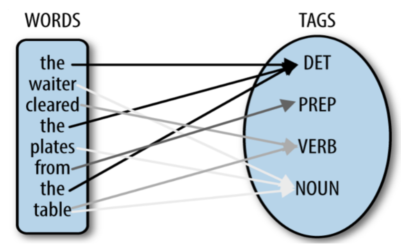
Groups	Group-1			Group-2		
	Task-1	Task-2	Task-3	Task-1	Task-3	Task-4
FS-MTL	89.7±0.6	93.5±1.1	89.1±0.3	73.2±0.5	81.2±0.6	81.3±1.4
SP-MTL	88.7±1.4	94.0±1.9	90.7±2.3	73.7±1.5	78.0±1.5	81.2±2.1
DC-MTL	89.2±0.6	95.6±1.2	90.8±1.0	74.5±0.6	80.0±0.7	80.8±1.3
IC-MTL	89.6±0.4	95.7±1.1	91.3±1.7	74.5±0.4	81.4±1.1	81.8±2.6
RRNs	88.9±3.4	95.4±2.2	90.5±2.8	75.4±2.2	83.2±3.0	82.6±3.8
mtl-RMN	**90.8±2.1**	**96.7±1.6**	**92.9±2.4**	**76.1±1.8**	**84.4±2.4**	**83.5±2.2**

Table 2: Four test-time scenarios to evaluate generalization ability and the results (accuracy%).

Scenario settings					Results of different methods				
Scenarios	Training tasks			Test task	LSTM	RMN$_{un}$	RRNs	IC-MTL	RMN$_{tr}$
A	Task-1	Task-2	Task-3	Task-4	82.6±1.0	82.9±1.2	83.0±2.7	81.2±1.7	**83.3±2.3**
B	Task-1	Task-2	Task-4	Task-3	82.3±0.6	84.5±1.5	84.8±2.5	82.7±1.3	**85.6±1.7**
C	Task-1	Task-3	Task-4	Task-2	93.7±0.6	95.3±0.8	95.6±1.7	95.5±0.7	**97.0±1.8**
D	Task-2	Task-3	Task-4	Task-1	71.7±1.4	73.1±1.7	78.4±4.0	77.3±2.1	**79.3±2.6**

Experiments on POS Tagging

- POS (Part-of-Speech) Tagging of Code-Switched Sentences
  - POS Tagging: To mark up a word in a corpus to a corresponding speech tag
  - Code-Switched Text: Words from multiple languages



POS Tagging

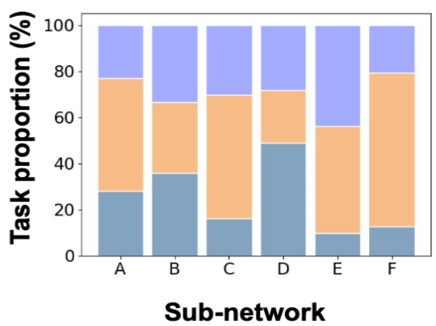
- Data sets [1]
  - Task 1: A Hindi-English code-switch data POS tagging
  - Task 2: Hindi POS tagging
  - Task 3: English POS tagging

[1] "Girnet: Interleaved multi-task recurrent state sequence models." Proceedings of AAAI. Vol. 33. 2019.

Experiments on POS Tagging

- Results on the POS Tagging of Code-Switched Sentences

Methods	Original		DC-MTL		IC-MTL		rrn-RMN		MT-RMN	
	Accuracy	F_1	Accuracy	F_1	Accuracy	F_1	Accuracy	F_1	Accuracy	F_1
NS-MTL	44.3±0.7	38.9±1.6	51.5±0.5	49.4±0.9	51.4±1.4	49.7±0.8	53.5±1.9	52.7±0.8	**55.2±1.2**	**53.4±2.4**
Cross-stitch.	46.0±1.9	12.7±0.8	48.5±0.9	16.1±1.3	47.7±1.7	14.3±0.7	**52.1±1.0**	19.5±0.6	51.7±1.9	**21.4±3.2**
Sluice	58.7±0.7	55.4±2.1	59.2±1.7	56.0±2.3	59.5±1.9	56.2±0.7	60.4±1.2	56.6±0.7	**61.5±1.7**	**57.2±1.8**
GIRNet	62.8±0.6	46.6±0.4	62.5±1.1	57.4±0.5	63.1±1.5	58.6±1.3	63.6±1.7	61.3±1.5	**64.5±2.1**	**62.6±2.4**



1) The proportion of tasks assigned to each sub-network
2) Different colors distinguish different tasks
3) A-F represent the six sub-networks

Thanks!

Q & A