

# Supplemental Material

## Mem2Seq: Effectively Incorporating Knowledge Bases into End-to-End Task-Oriented Dialog Systems

Andrea Madotto\*, Chien-Sheng Wu\*, Pascale Fung  
Human Language Technology Center  
Center for Artificial Intelligence Research (CAiRE)  
Department of Electronic and Computer Engineering  
The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong  
[eeandreamad,cwuak,pascale]@ust.hk

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\*\* These two authors contributed equally.

# 1 Tables

## 1.1 Time per Epoch

|                          | <b>T1</b> | <b>T2</b> | <b>T3</b> | <b>T4</b> | <b>T5</b> | <b>DSTC2</b> | <b>In-Car</b> |
|--------------------------|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| <i>Seq2Seq</i>           | 0.7       | 1.22      | 0.85      | 0.15      | 1.57      | 9.36         | 2.00          |
| <i>+Attn</i>             | 1.18      | 2.38      | 2.2       | 0.32      | 6.04      | 22.07        | 6.18          |
| <i>Ptr-Unk</i>           | 1.28      | 2.5       | 2.21      | 0.38      | 6.10      | 20.39        | 6.48          |
| <b><i>Mem2Seq H1</i></b> | 0.73      | 1.10      | 0.55      | 0.15      | 1.05      | 1.49         | 0.68          |
| <b><i>Mem2Seq H3</i></b> | 0.97      | 1.48      | 0.77      | 0.21      | 1.33      | 2.36         | 1.02          |
| <b><i>Mem2Seq H6</i></b> | 1.23      | 2.14      | 1.11      | 0.33      | 2.20      | 4.22         | 1.43          |

Table 1: Minutes per-epoch. Mem2Seq is faster compared to others especially for longer inputs.

## 1.2 Hyper-parameters

|                       | <b>T1</b> | <b>T2</b> | <b>T3</b> | <b>T4</b> | <b>T5</b> | <b>DSTC2</b> | <b>In-Car</b> | <i>lr</i> |
|-----------------------|-----------|-----------|-----------|-----------|-----------|--------------|---------------|-----------|
| <i>Seq2Seq</i>        | 256 (0.1) | 256 (0.1) | 128(0.1)  | 256 (0.1) | 256 (0.1) | -            | 512 (0.3)     | 0.0001    |
| <i>+Attn</i>          | 256 (0.1) | 256 (0.1) | 256 (0.1) | 256 (0.1) | 128 (0.1) | -            | 512 (0.0)     |           |
| <i>Ptr-Unk</i>        | 256 (0.1) | 256 (0.1) | 256 (0.1) | 256 (0.1) | 128 (0.1) | -            | 512 (0.0)     |           |
| <i>Mem2Seq GRU L1</i> | 256 (0.3) | 256 (0.2) | 128 (0.2) | 256 (0.2) | 256 (0.1) | 256 (0.1)    | 256 (0.2)     | 0.001     |
| <i>Mem2Seq GRU L3</i> | 256 (0.1) | 256 (0.3) | 128 (0.2) | 256 (0.3) | 128 (0.1) | 128 (0.2)    | 256 (0.1)     |           |
| <i>Mem2Seq GRU L6</i> | 256 (0.2) | 128 (0.3) | 256 (0.1) | 128 (0.3) | 256 (0.2) | 256 (0.1)    | 256 (0.2)     |           |

Table 2: Selected hyper-parameters in each datasets for different hops. The values is the embedding dimension and the GRU hidden size, and the values between parenthesis is the dropout rate. For all the models we used learning rate equal to 0.001, with a decay rate of 0.5.

## 2 Visualization

### 2.1 Multiple Hops Attention



Figure 1: 3-hop memory attention visualization from bAbI dialog task 3. In the generation step 8, the attention at hop 1 is shallow and divided equally over the 5 possible choice, and becomes very sharp at hop 3.



2.2 Last Hop Attention

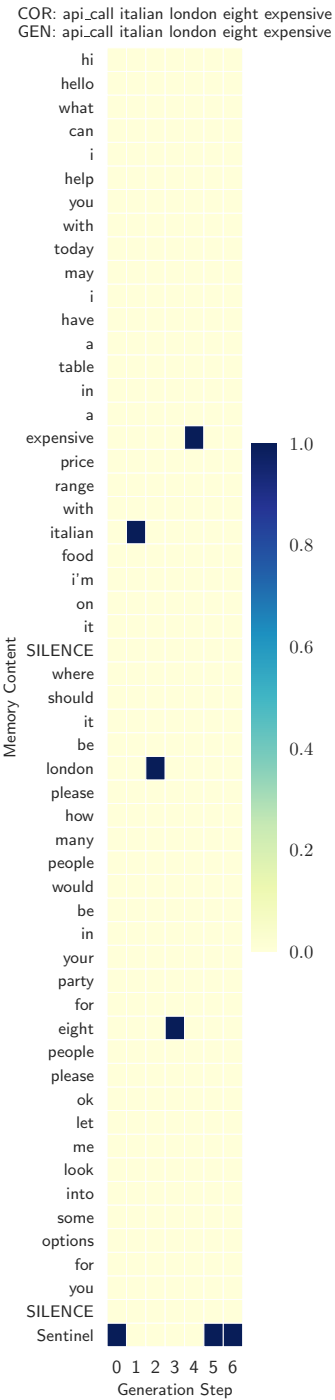


Figure 3: Last hop memory attention visualization from the bAbI dataset. COR and GEN on the top are the correct response and our generated one.



Figure 4: Last hop memory attention visualization from the In-Car dataset. COR and GEN on the top are the correct response and our generated one.

### 3 InCar Assistant Dataset Examples

Table 3: Example of generated responses for the In-Car Assistant on the weather domain.

| location                             | monday  | tuesday                               | wednesday                          |
|--------------------------------------|---|---------------------------------------|------------------------------------|
| grand rapids                         | hot, low of 50F, high of 70F                              | raining, low of 60F, high of 80F      | rain, low of 20F, high of 30F      |
| new york                             | misty, low of 30F, high of 50F                            | snow, low of 70F, high of 80F         | cloudy, low of 20F, high of 30F    |
| boston                               | hail, low of 90F, high of 100F                            | overcast, low of 60F, high of 70F     | rain, low of 50F, high of 60F      |
| durham                               | hot, low of 90F, high of 100F                             | dry, low of 60F, high of 80F          | misty, low of 60F, high of 80F     |
| san francisco                        | rain, low of 60F, high of 70F                             | cloudy, low of 30F, high of 40F       | overcast, low of 90F, high of 100F |
| carson                               | raining, low of 70F, high of 80F                          | humid, low of 90F, high of 100F       | frost, low of 40F, high of 60F     |
| san jose                             | blizzard, low of 40F, high of 50F                         | snow, low of 90F, high of 100F        | overcast, low of 60F, high of 80F  |
| thursday                             | friday  | saturday                              | sunday                             |
| clear skies, low of 60F, high of 70F | warm, low of 70F, high of 90F                             | foggy, low of 50F, high of 60F        | overcast, low of 50F, high of 60F  |
| rain, low of 80F, high of 100F       | rain, low of 40F, high of 60F                             | cloudy, low of 30F, high of 50F       | snow, low of 20F, high of 40F      |
| dew, low of 20F, high of 30F         | cloudy, low of 90F, high of 100F                          | overcast, low of 50F, high of 70F     | overcast, low of 80F, high of 90F  |
| misty, low of 90F, high of 100F      | hot, low of 70F, high of 90F                              | hail, low of 30F, high of 40F         | rain, low of 60F, high of 80F      |
| stormy, low of 90F, high of 100F     | cloudy, low of 90F, high of 100F                          | clear skies, low of 90F, high of 100F | foggy, low of 30F, high of 50F     |
| dry, low of 50F, high of 60F         | foggy, low of 80F, high of 100F                           | overcast, low of 50F, high of 70F     | overcast, low of 60F, high of 70F  |
| rain, low of 30F, high of 50F        | rain, low of 80F, high of 100F                            | dry, low of 50F, high of 60F          | dry, low of 90F, high of 100F      |
| <b>DRIVER</b>                        | Is it gonna snow in Durham during the week?               |                                       |                                    |
| <i>Seq2seq</i>                       | there is no snow in the forecast for this week            |                                       |                                    |
| <i>+Att</i>                          | there is no snow in the forecast for durham for durham    |                                       |                                    |
| <i>Ptr-Unk</i>                       | yes there is no snow in durham on week                    |                                       |                                    |
| <i>Mem2Seq</i>                       | no snow, the forecast does not predict any snow on Durham |                                       |                                    |
| <b>GOLD</b>                          | Durham does not have any snow predicted this week         |                                       |                                    |

Table 4: Example of generated answers for the In-Car dataset on the Weather Domain.

| monday                               | tuesday  | friday                               | wednesday                            |
|--------------------------------------|--|--------------------------------------|--------------------------------------|
| windy, low of 40F, high of 50F       | snow, low of 40F, high of 50F                      | frost, low of 30F, high of 40F       | hail, low of 70F, high of 80F        |
| rain, low of 30F, high of 40F        | foggy, low of 60F, high of 70F                     | stormy, low of 50F, high of 60F      | snow, low of 80F, high of 90F        |
| cloudy, low of 20F, high of 40F      | clear skies, low of 70F, high of 90F               | clear skies, low of 60F, high of 70F | dry, low of 40F, high of 60F         |
| warm, low of 90F, high of 100F       | windy, low of 50F, high of 60F                     | blizzard, low of 20F, high of 30F    | rain, low of 60F, high of 70F        |
| snow, low of 60F, high of 80F        | clear skies, low of 30F, high of 50F               | clear skies, low of 30F, high of 40F | dry, low of 30F, high of 50F         |
| windy, low of 50F, high of 60F       | drizzle, low of 80F, high of 100F                  | windy, low of 80F, high of 100F      | clear skies, low of 50F, high of 70F |
| clear skies, low of 60F, high of 70F | rain, low of 90F, high of 100F                     | foggy, low of 20F, high of 40F       | hail, low of 20F, high of 30F        |
| thursday                             | sunday   | location                             | saturday                             |
| raining, low of 80F, high of 90F     | foggy, low of 40F, high of 50F                     | san francisco                        | snow, low of 40F, high of 50F        |
| drizzle, low of 50F, high of 60F     | clear skies, low of 90F, high of 100F              | manhattan                            | dry, low of 70F, high of 90F         |
| stormy, low of 40F, high of 50F      | hail, low of 40F, high of 60F                      | seattle                              | windy, low of 60F, high of 70F       |
| overcast, low of 80F, high of 90F    | blizzard, low of 20F, high of 40F                  | oakland                              | clear skies, low of 50F, high of 70F |
| raining, low of 50F, high of 60F     | windy, low of 30F, high of 50F                     | exeter                               | overcast, low of 60F, high of 70F    |
| frost, low of 40F, high of 50F       | drizzle, low of 40F, high of 60F                   | menlo park                           | foggy, low of 50F, high of 70F       |
| dry, low of 20F, high of 30F         | cloudy, low of 20F, high of 40F                    | carson                               | windy, low of 80F, high of 100F      |
| <b>DRIVER</b>                        | Is it going to snow today?                         |                                      |                                      |
| <b>CAR</b>                           | What city do you wanna know if it will snow today? |                                      |                                      |
| <b>DRIVER</b>                        | Please check for Oakland                           |                                      |                                      |
| <b>GOLD</b>                          | Today is gonna be warm in Oakland                  |                                      |                                      |
| <i>Seq2seq</i>                       | It is not snow in today in                         |                                      |                                      |
| <i>+att</i>                          | No there will be snow in Oakland today             |                                      |                                      |
| <i>Ptr-Unk</i>                       | Today is gonna be PAD in                           |                                      |                                      |
| <i>Mem2Seq</i>                       | it will not snow in oakland today                  |                                      |                                      |

Table 5: Example of generated responses for the In-Car Assistant on the navigation domain.

| poi                   | distance  | traffic_info     | poi_type            | address               |
|-----------------------|---|------------------|---------------------|-----------------------|
| Stanford Express Care | 3 miles   | no traffic       | hospital            | 214 El Camino Real    |
| home                  | 4 miles   | heavy traffic    | home                | 5671 barringer street |
| Whole Foods           | 2 miles   | heavy traffic    | grocery store       | 819 Alma St           |
| P.F. Changs           | 6 miles   | moderate traffic | chinese restaurant  | 669 El Camino Real    |
| Jing Jing             | 5 miles   | heavy traffic    | chinese restaurant  | 113 Arbol Dr          |
| Pizza My Heart        | 6 miles   | moderate traffic | pizza restaurant    | 528 Anton Ct          |
| Cafe Venetia          | 4 miles   | no traffic       | coffee or tea place | 269 Alger Dr          |
| <b>DRIVER</b>         | Find me a tea house   |                  |                     |                       |
| <i>Seq2seq</i>        | We' re 2 miles away from from and there is a road block nearby          |                  |                     |                       |
| <i>+att</i>           | We' re 4 miles away from Cafe Venetia and it s at 269 Alger drive       |                  |                     |                       |
| <i>PTRUNK</i>         | We' re 6 miles away from whole foods and you like the address on screen |                  |                     |                       |
| <i>Mem2Seq</i>        | We're 4 miles away from Cafe Venetia and there is no traffic            |                  |                     |                       |
| <b>GOLD</b>           | There is Cafe Venetia that's 4 miles away at 269 Alger dr               |                  |                     |                       |

Table 6: Example of generated responses for the In-Car Assistant on the navigation domain.

| distance       | traffic_info  | poi_type            | address          | poi                       |
|----------------|---|---------------------|------------------|---------------------------|
| 4 miles        | heavy traffic   | rest stop           | 578 Arbol Dr     | Hotel Keen                |
| 1 miles        | moderate traffic  | hospital            | 899 Ames Ct      | Stanford Childrens Health |
| 2 miles        | no traffic  | grocery store       | 452 Arcadia Pl   | Safeway                   |
| 1 miles        | moderate traffic  | coffee or tea place | 436 Alger Dr     | Palo Alto Cafe            |
| 1 miles        | heavy traffic   | grocery store       | 819 Alma St      | Whole Foods               |
| 6 miles        | moderate traffic  | coffee or tea place | 394 Van Ness Ave | Coupa                     |
| 6 miles        | heavy traffic   | coffee or tea place | 145 Amherst St   | Teavana                   |
| <b>DRIVER</b>  | Take me to a place where i can get some hot tea   |                     |                  |                           |
| <i>Seq2seq</i> | There is a away   |                     |                  |                           |
| <i>att</i>     | There is a Pizza Chicago and Teavana  |                     |                  |                           |
| <i>PTRUNK</i>  | I have a PAD away away  |                     |                  |                           |
| <i>Mem2Seq</i> | We' re 6 miles away from Palo Alto Cafe and 6 miles away from Coupa, which one do you prefer? |                     |                  |                           |
| <b>GOLD</b>    | Coupa is nearby and serves tea  |                     |                  |                           |

Table 7: Example of generated responses for the In-Car Assistant on the navigation domain.

| distance       | traffic_info   | poi_type           | address            | poi            |
|----------------|--|--------------------|--------------------|----------------|
| 3 miles        | no traffic   | chinese restaurant | 593 Arrowhead Way  | Chef Chu's     |
| 1 miles        | no traffic   | chinese restaurant | 669 El Camino Real | P.F. Changs    |
| 5 miles        | road block nearby  | gas station        | 200 Alester Ave    | Valero         |
| 3 miles        | no traffic   | pizza restaurant   | 528 Anton Ct       | Pizza My Heart |
| 4 miles        | heavy traffic  | rest stop          | 753 University Ave | Comfort Inn    |
| 5 miles        | heavy traffic  | chinese restaurant | 842 Arrowhead Way  | Panda Express  |
| 2 miles        | heavy traffic  | pizza restaurant   | 704 El Camino Real | Pizza Hut      |
| 6 miles        | no traffic   | friends house      | 864 Almanor Ln     | jacks house    |
| <b>DRIVER</b>  | Find me the nearest gas station.                                 |                    |                    |                |
| <i>Seq2seq</i> | the nearest parking garage is from at away                       |                    |                    |                |
| <i>+att</i>    | The is one is away away  |                    |                    |                |
| <i>PTRUNK</i>  | PAD nearest gas station is is is                                 |                    |                    |                |
| <i>Mem2Seq</i> | The nearest gas station is gas station which is you you          |                    |                    |                |
| <b>GOLD</b>    | The nearest gas station is located 5 miles away. Need more info? |                    |                    |                |



Table 8: Example of generated responses for the In-Car Assistant on the navigation domain.

| Poi                      | Distance | Traffic_info     | Poi_type           | Address             |
|--------------------------|----------|------------------|--------------------|---------------------|
| The Westin               | 4 miles  | no traffic       | rest stop          | 329 El Camino Real  |
| Palo Alto Garage R       | 2 miles  | moderate traffic | parking garage     | 481 Amaranta Ave    |
| Mandarin Roots           | 4 miles  | moderate traffic | chinese restaurant | 271 Springer Street |
| Sigona Farmers Market    | 4 miles  | no traffic       | grocery store      | 638 Amherst St      |
| Whole Foods              | 2 miles  | heavy traffic    | grocery store      | 819 Alma St         |
| Stanford Shopping Center | 2 miles  | moderate traffic | shopping center    | 773 Alger Dr        |
| toms house               | 1 miles  | no traffic       | friends house      | 580 Van Ness Ave    |

|                |  |
|----------------|--|
| <b>DRIVER</b>  | Give me directions to the closest grocery store  |
| <b>CAR</b>     | There are Whole Foods 2 miles away and Sigona Farmers Market 4 miles away. Where do we go?         |
| <b>DRIVER</b>  | I need the one that avoids all heavy traffic   |
| <i>Seq2seq</i> | he is is is is away at   |
| <i>+Att</i>    | Chef Chu s is located at 593 Arrowhead way   |
| <i>Ptr-Unk</i> | PAD is the is PAD the to   |
| <i>Mem2Seq</i> | Sigona Farmers Market is the only option i is 4 miles away with no traffic, setting navigation now |
| <b>GOLD</b>    | Sigona Farmers Market is located 4 miles away with no traffic. It's located at 638 Amherst St.     |

Table 9: Example of generated responses for the In-Car Assistant on the scheduling domain.

|                |  |
|----------------|--|
| <b>DRIVER</b>  | Set me a reminder for football activity at 1pm this month on the 11th with marie                           |
| <i>Seq2seq</i> | Okay I am scheduling a reminder with your for at on with at  |
| <i>att</i>     | Okay I am scheduling a football activity with on the 15th at 1pm this month on the 15th                    |
| <i>PTRUNK</i>  | Okay setting PAD reminder reminder football activity football activity for this this on the 11th month 1pm |
| <i>Mem2Seq</i> | Setting a reminder for football activity with marie on the 11th at 1pm                                     |
| <b>GOLD</b>    | Reminder for football on the 11th of this month at 1pm with marie is set                                   |

Table 10: Example of generated responses for the In-Car Assistant on the scheduling domain.

| room               | agenda             | time | date      | party               | event              |
|--------------------|--------------------|------|-----------|---------------------|--------------------|
| conference room 50 | discuss the merger | 1pm  | Wednesday | infrastructure team | conference         |
| -                  | -                  | 2pm  | Wednesday | -                   | yoga activity      |
| -                  | -                  | 2pm  | Wednesday | -                   | doctor appointment |
| conference room 50 | go over budget     | 7pm  | Monday    | infrastructure team | meeting            |
| -                  | -                  | 5pm  | Monday    | -                   | dinner             |
| -                  | -                  | 10am | Thursday  | -                   | medicine           |

|                |  |
|----------------|--|
| <b>DRIVER</b>  | Tell me when is my next meeting and who are invited in the meeting and what are the agenda of the next meeting |
| <i>Seq2seq</i> | The meeting is the meeting in conference room 100 at 1pm   |
| <i>+att</i>    | Your next meeting is on wednesday at 1pm   |
| <i>PTRUNK</i>  | your PAD meeting PAD the in in the to to the the the the   |
| <i>Mem2Seq</i> | Your next meeting is on Monday at 7pm hr is to hr in attendance to go over the budget                          |
| <b>GOLD</b>    | Your next meeting is on Monday at 7 pm with the infrastructure team to go over budget                          |