Research of ELM real-time Recognition based on Deep Learning

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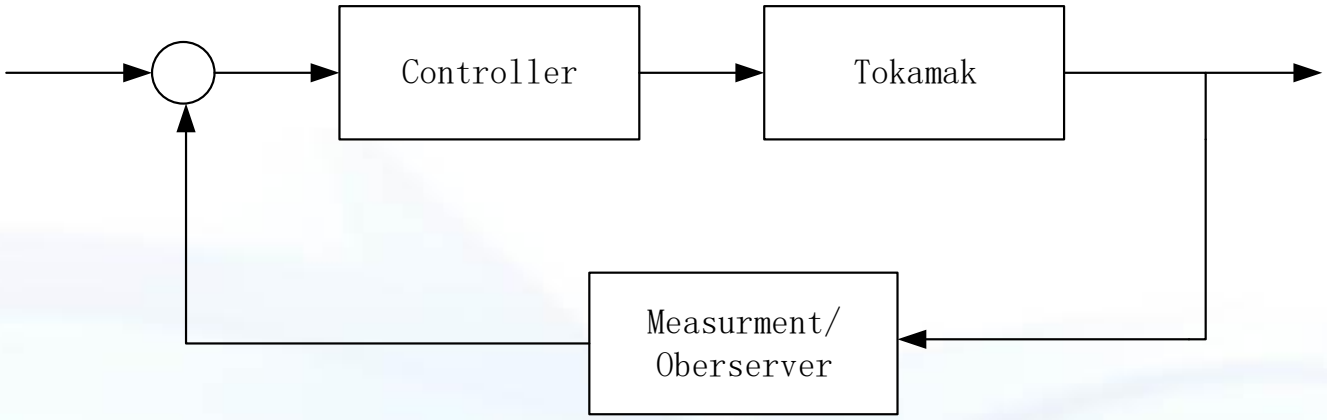
Prerequisite Declaration



- ELM need to be controlled in RT
- ELM must be observed first in RT
- We use Deep Learning Technology to Recognize ELM in RT

Dataset for ELM Recognition

◆We use Hα signal as the basis for ELM Recognition

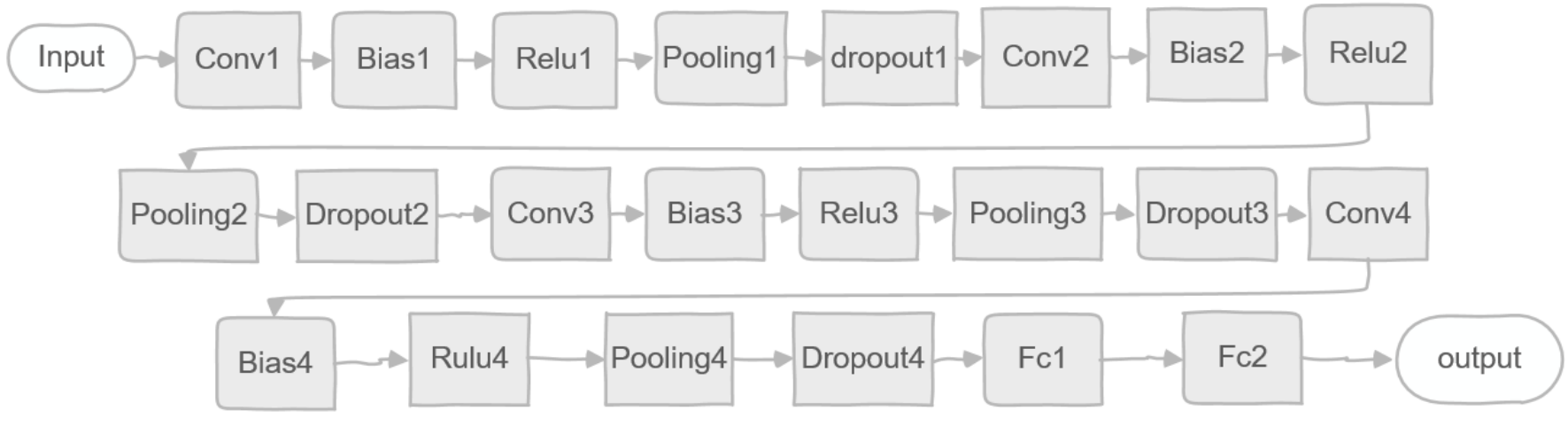
- Uniform resampling to 10 kHz;
- Data Sample Window is 30ms;
- Window Step is 1ms;
- Normalize the data in each Data Sample Window.

◆ Data Set in HL-2A

- Shot Range: 20000~25200 , from 2012~2014 HL-2A Campaign
- Total Data Sample Window: 241,900
- Every Data Sample Window is tagged
- Data Sample Ratio for Training : Validation : Test is 8:1:1

22 Layers NN structure

- Based on the AlexNet network (CNN) , after more than 70 network structure adjustments, we used a 22-layer neural network for ELM Recognition finally



- The network training results for Data Sample Window Set

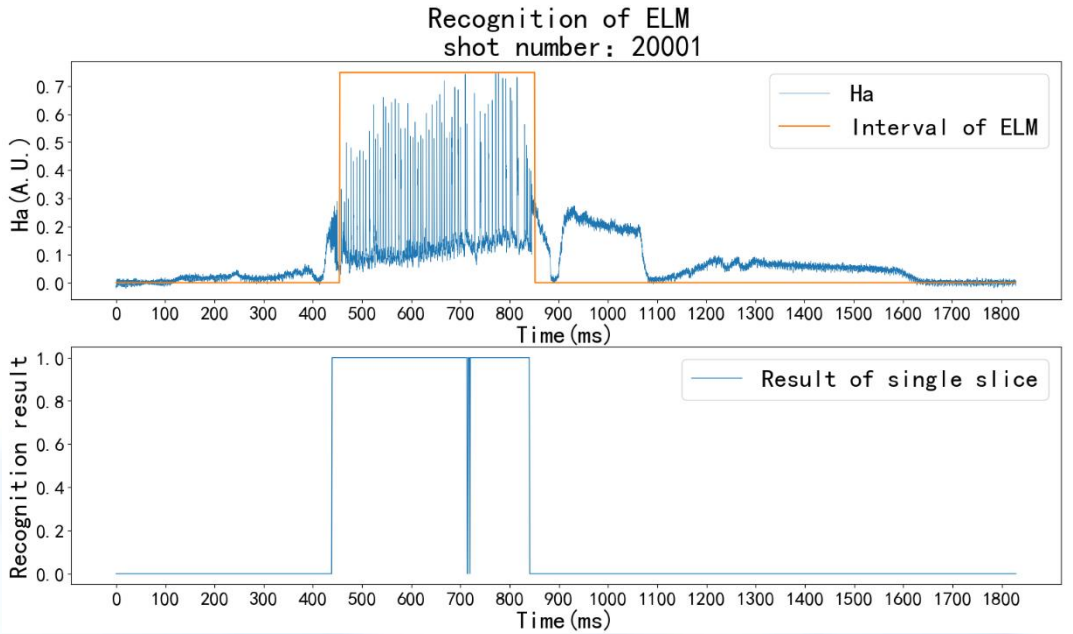
Data Set	Recognition Success Rate
Training set	99.4%
Validation set	98.8%
Test set	99.3%

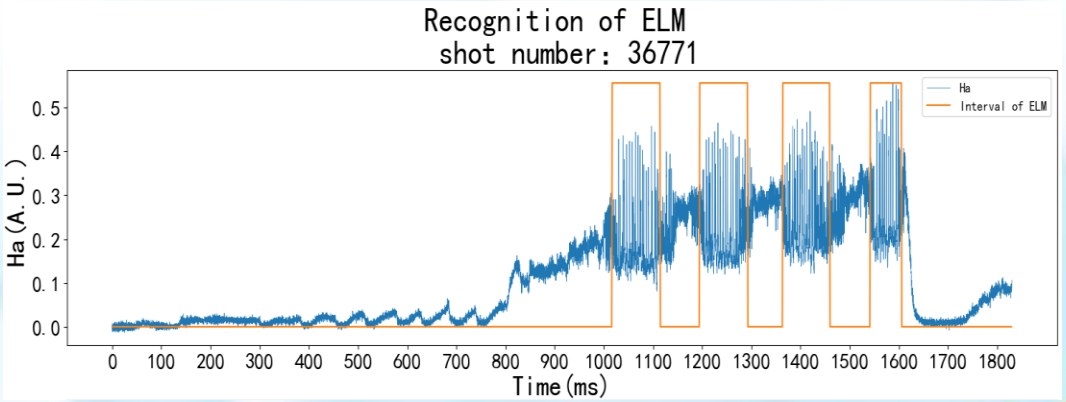
ELM Assert Policy for One Shot

Window Size:30ms
Step Size: 1ms
Group Size:20

- ◆ Start Signal Assert：
  - ➢ More than 16 ELM Signals in one group, Start Signal is asserted
  - ➢ Stop to find Start Signal, Transfer to find ELM End Signal

- ◆ End Signal Assert:
  - ➢ Start Signal is asserted
  - ➢ Less than 10 ELM Signals in one group, End Signal is asserted.
  - ➢ Stop to find End Signal, Transfer to find another ELM Start Signal





Test for All HL-2A Shot

All data from the HL-2A from 2009 when the first H-mode occurred are tested:

Campaign	Shots	False R	FPR	Miss R	FNR
2018	(31983, 35915)	7/190	3.69%	0/183	0%
2017	(29893, 31982)	3/147	2.04%	1/145	0.69%
2016	(28052, 29892)	2/180	1.11%	0/178	0%
2015	(26579, 28051)	2/229	0.87%	0/227	0%
2014	(23074, 26578)	3/92	3.26%	0/89	0%
2013	(21326, 23073)	6/216	2.78%	0/210	0%
2012	(18219, 21325)	2/224	0.89%	2/224	0.89%
2011	(15118, 18218)	7/191	3.66%	1/185	0.54%
2010	(13434, 15117)	1/55	1.82%	0/54	0%
2009	(10595, 13433)	2/131	1.53%	0/129	0%
Total	(10595, 35915)	35/1665	2.10%	4/1634	0.24%

Recognized H-mode: 1665;
False recognized: 35;
FPR(False positive rate):2.10%.

Actually H-mode: 1634;
Miss recognized: 4;
FNR(False negative rate):0.24%.

- The 39 error (35+4) recognition shots is in the L-H transition state.
- All the recognition error of the start/end times does not exceed 20ms.

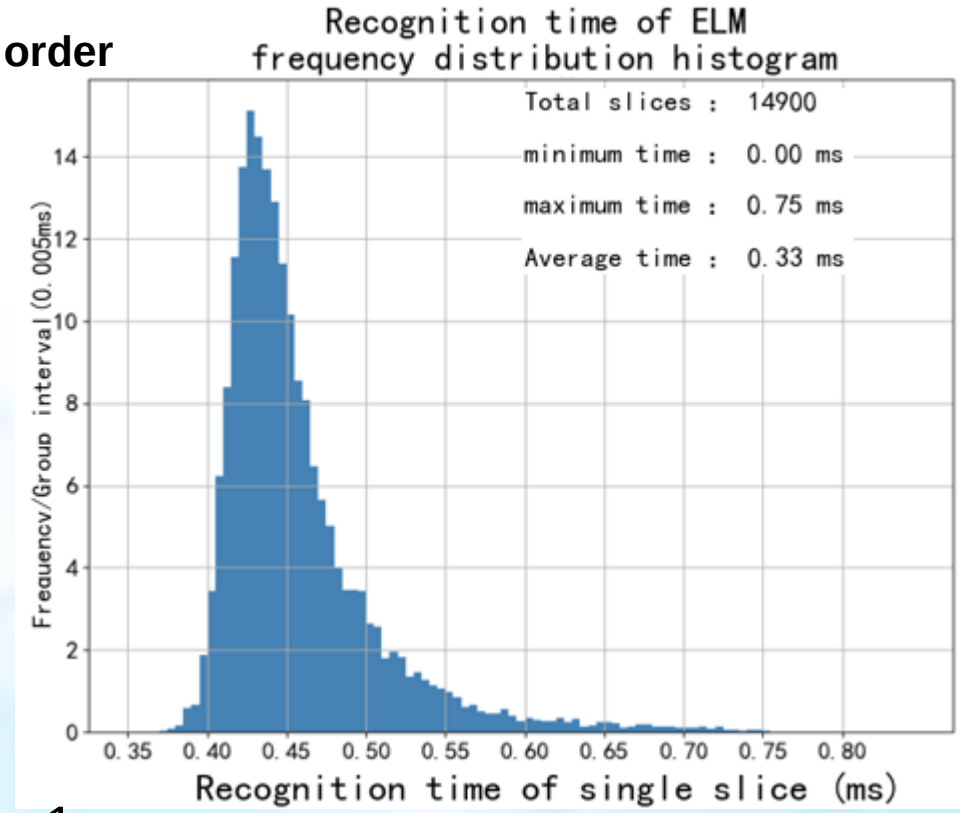
Performance Test For RT Control

speed test platform:

- **Based on Linux, C**
- **Real-time control data processing order**
- **Use a total of 14900 time slices**

Time Consumption for one slice:

- **Minimum : 0.37 ms**
- **Maximum : 0.75 ms**
- **Average : 0.46 ms**



- The Control Cycle of HL-2A PCS is 1ms.
- It is proved that the model can be used in HL-2A RT Control
- We will put it into practice for HL-2A campaign in 2020

Thank you!