Deep Learning for Speech Recognition

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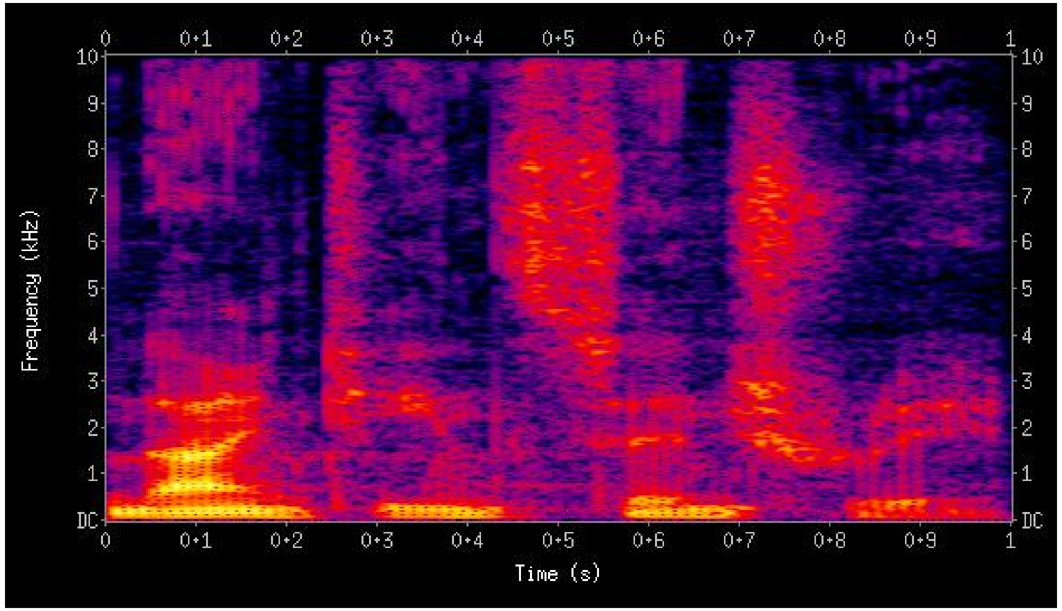
with NVIDIA Corporation

What is speech recognition?

- Recognition and translation of spoken language into text by computers
- Crucial problem for many areas of modern technology industry
- Communicating with electronic devices by talking to them
- Before - solutions which use complex algorithms and fine-tuned parameters
- Now - fully deep learning approach
- In our thesis we concentrate on Deep Speech 2 neural net model (published by Baidu) and experiment with it

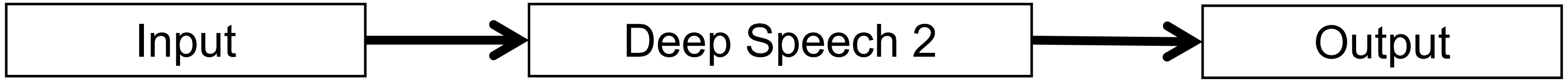
Formal specification of the problem

Dataset - set of pairs (input, output)



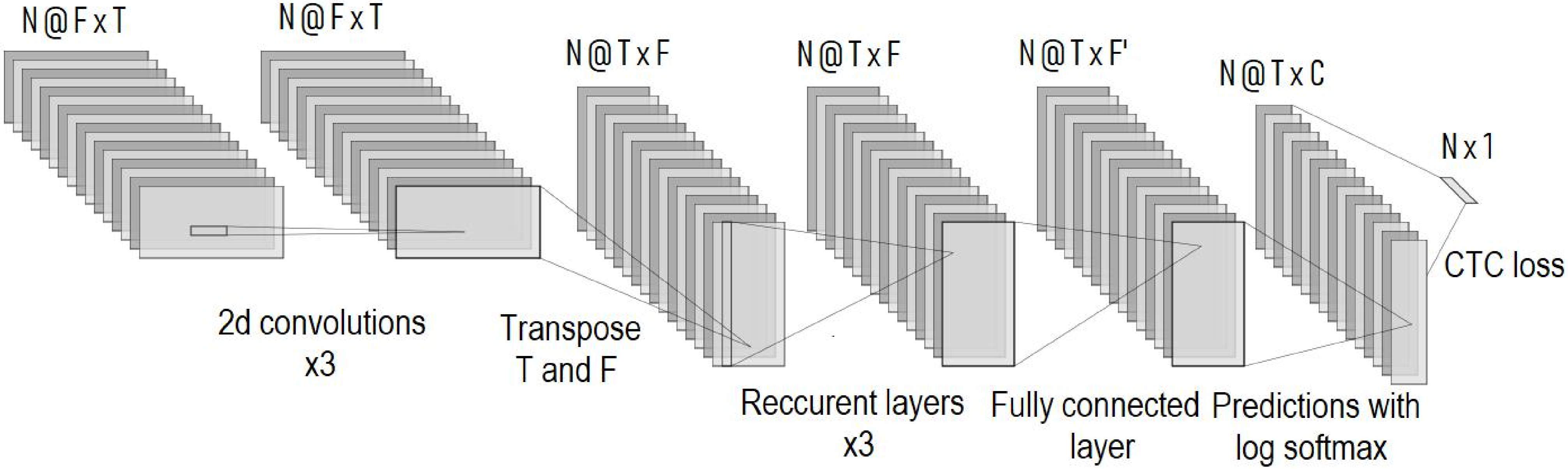
Picture from Wikipedia

to be or not to be
that is the question ...


Input → Deep Speech 2 → Output

Model architecture

- Combination of convolutional, recurrent and fully connected layers



Loss function - Connectionist Temporal Classification

- Loss function designed for tasks where the timing is variable (and length of the output is not a function of length of the input)
- Special symbol blank added to our alphabet

mary -> mary, marry, mmmmaaarry, m__marr_r_r_y_y_y

marry -> mar_ry, mmmaa_arrr_r_rr_ryy, marrrrr_ryy_y

Language model

- We decided to use 4grams

4-gram	Probability
to be or not	0.00001%
milk computer dance me	0%
lambda calculus is the	0.00000003%
to be or nein	0%

Generating transcriptions

- Neural net returns matrix TxC where C is number of symbols in our alphabet and T is time series length. Each cell of this matrix contains probability of a given symbol in a given timestamp
- In the formula below y is a transcription and x is an output of our model

$$Q(y) = \log\left(\mathbb{P}_{ctc}(y|x)\right) + \alpha \cdot \log\left(\mathbb{P}_{lm}(y)\right) + \beta \cdot word\_count(y)$$

- We use beam search algorithm to generate final transcriptions

Measuring results - Word Error Rate

- For measuring quality of our results we use Word Error Rate (WER) metric

$$WER = \frac{S+D+I}{N} = \frac{S+D+I}{S+D+C}$$

- S – the number of substitutions,
- D – the number of deletions,
- I – the number of insertions,
- C – the number of correct words,
- N – the number of words in the reference ($N = S + D + C$).

Model output	Real transcription	WER
twil you forgiti me now	will you forgive me now	40%
tfer welm ma am	farewell madam	200%

Results

Model	Dataset size	WER
Baidu	12000h	8.5%
Baidu	1200h	13.8%
Mozilla	~3000h	6.5%
Our model	960h	10.4%
Native speaker	whole life	~5.8%

Audio examples

Our model	Transcription	WER

Audio examples

Our model	Transcription	WER
AS A MATTER OF FACT HE COULD NOT SAID SOLMS FOR I ENTERED BY THE SIDE DOOR		

Audio examples

Our model	Transcription	WER
AS A MATTER OF FACT HE COULD NOT SAID SOLMS FOR I ENTERED BY THE SIDE DOOR		
YOU HEAR WHAT SIR FERDINAND A BROWN HA SAT REPLIED CAPTAIN BATLEAX		

Audio examples

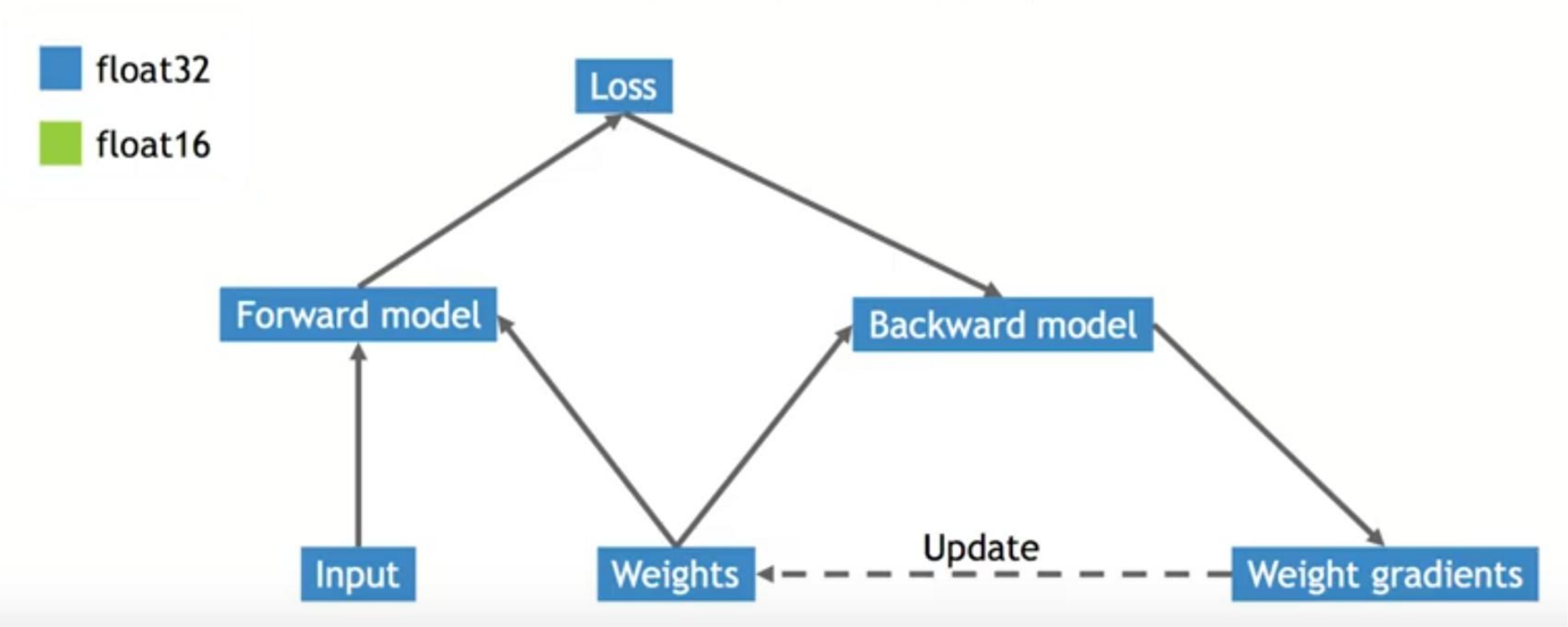
Our model	Transcription	WER
AS A MATTER OF FACT HE COULD NOT SAID SOLMS FOR I ENTERED BY THE SIDE DOOR		
YOU HEAR WHAT SIR FERDINAND A BROWN HA SAT REPLIED CAPTAIN BATLEAX		
THE ARMY SOUND THE PEOPLE IN POVERTY AND LEFT THEM IN COMPARATIVE WEALTH		

Audio examples

Our model	Transcription	WER
AS A MATTER OF FACT HE COULD NOT SAID SOLMS FOR I ENTERED BY THE SIDE DOOR	AS A MATTER OF FACT HE COULD NOT SAID SOAMES FOR I ENTERED BY THE SIDE DOOR	6%
YOU HEAR WHAT SIR FERDINAND A BROWN HA SAT REPLIED CAPTAIN BATLEAX	YOU HEAR WHAT SIR FERDINANDO BROWN HAS SAID REPLIED CAPTAIN BATTLEAX	45%
THE ARMY SOUND THE PEOPLE IN POVERTY AND LEFT THEM IN COMPARATIVE WEALTH	THE ARMY FOUND THE PEOPLE IN POVERTY AND LEFT THEM IN COMPARATIVE WEALTH	8%

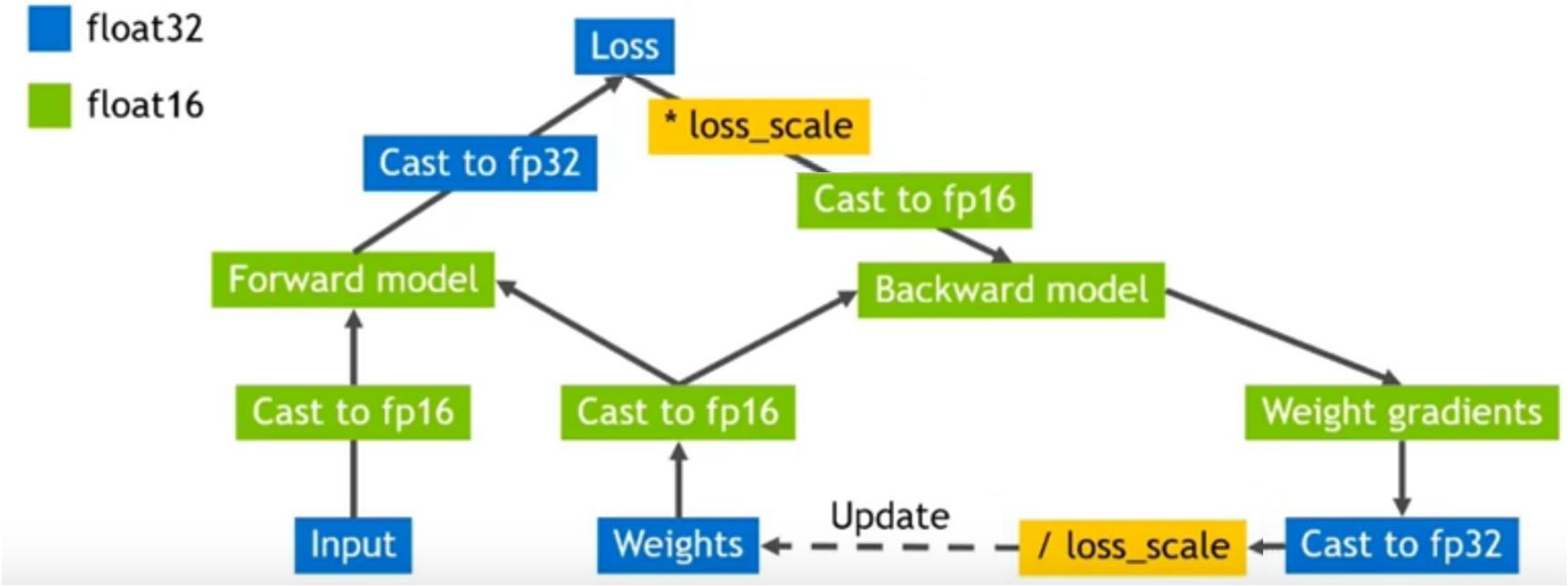
Experiments

Usual training process



Picture from NVIDIA developer YouTube channel

Mixed precision training



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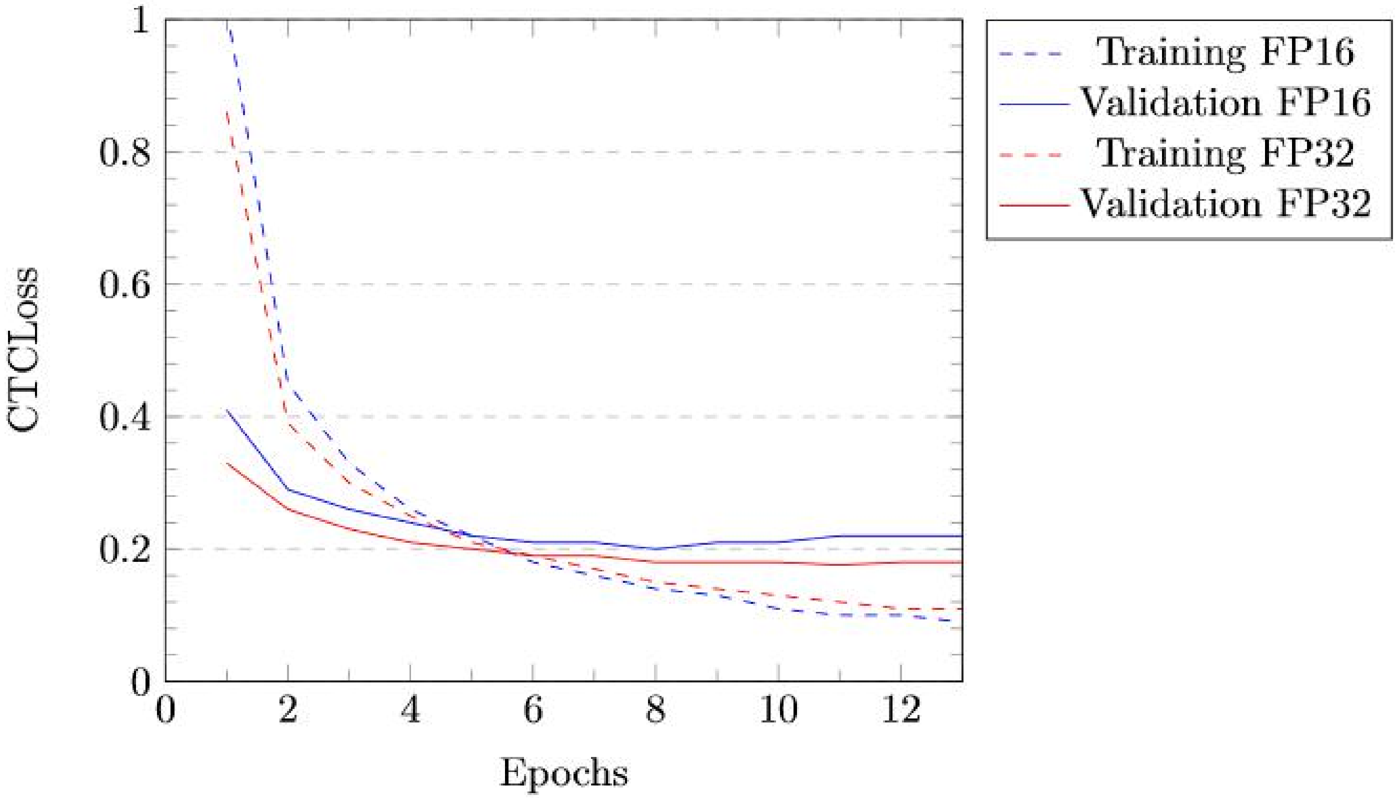

Epoch on fp32 takes around 135 minutes

Epoch on fp16 takes around 75 minutes

Multi-GPU scaling

Number of GPUs	Time per one epoch	Speedup
1	118 minutes	1
2	75 minutes	1.57
4	35 minutes	3.37

Ablation study

- Batch normalization
- Dropout
- L2 regularization
- Reccurent unit type
- Sortagrad
- Xavier initialization

Thank you for your attention!

Special thanks to our supervisor
Janina Mincer-Daszkiewicz PhD
and NVIDIA Corporation with our mentor
Grzegorz Karch PhD