Generative Adversarial Networks in Neural Machine Translation

Master 2 Internship - Computer Science Research - Paris-Saclay University

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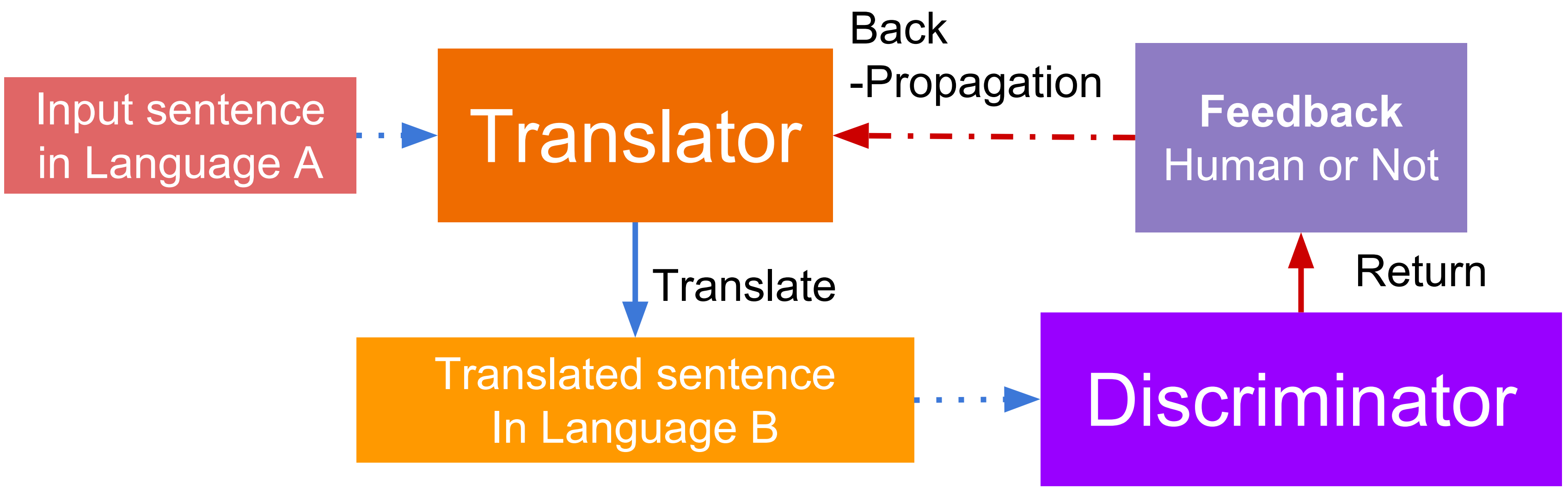
Outline

- Main idea: **Applying GANs in NMT, based on the work of [Yang et al, 2017]**
- Model architecture
- Algorithm
- Results and Experiments
- Conclusion

Main idea

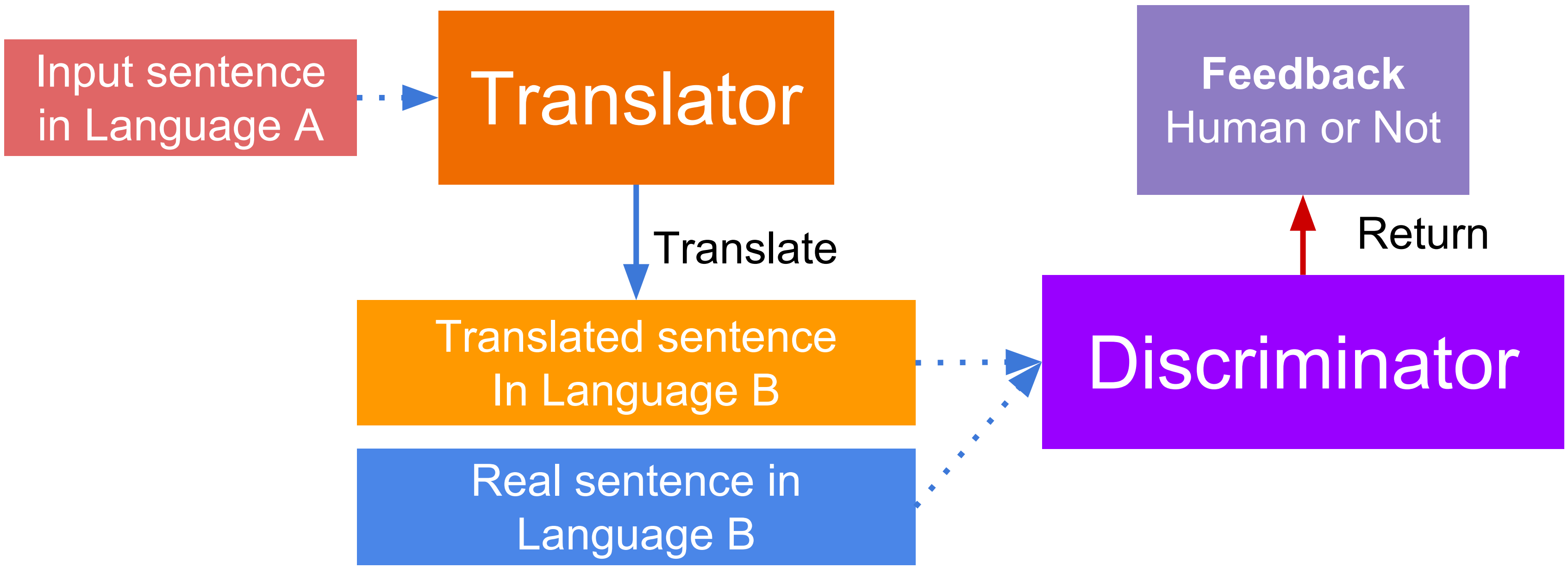
Applying GANs in NMT [Yang et al, 2017]



- There are two objectives:
  - **Translator tries to fool Discriminator**
  - Discriminator tries to distinguish well

Main idea

Applying GANs in NMT [Yang et al, 2017]



- There are two objectives:
  - Translator tries to fool Discriminator
  - **Discriminator tries to distinguish well**

Model architecture

GANs in NMT

- **Translator:** *Attention-based NMT model*
  - *Maximize the expected end reward of a sequence (Reinforcement learning)*

$$\nabla J_G = \sum_{y_t} R_D^G((y_{1:t-1}, x), y_t) \nabla_\theta \, log \, p_G(y_t|y_{1:t-1}, x) \qquad (3.2)$$

- **Discriminator**: *Binary classifier discriminates the machine-translated sentence from the human-translated sentence.*
  - **Probability of a sentence being human translated.** $D(y, x)$

Model architecture

GANs in NMT

- **Translator:** *Attention-based NMT model*
  - *Maximize the expected end reward of a sequence (Reinforcement learning)*

$$\bigtriangledown J_G = \sum_{y_t} R_D^G((y_{1:t-1}, x), y_t) \bigtriangledown_\theta log\, p_G(y_t|y_{1:t-1}, x) \tag{3.2}$$

- **Reward strategies:** $R_D^G((y_{1:t-1}, x), y_t)$
  - Monte-Carlo search strategy *[Yang et al, 2017]*
  - **Discriminator strategy [Li et al, 2017]**
  - **Language model strategy**

Model architecture

GANs in NMT

- **Reward strategy:**
  - Monte-Carlo search strategy *[Yang et al, 2017]*
    - Discriminator is a **full sentence** classifier.
    - MC search samples the rest of sequence for each token.

$$R_D^G((y_{1:t-1}, x), y_t) = \begin{cases} \frac{1}{N} \sum_{n=1}^{N} D(y_{1:L_n}^n, x),\ y_{1:L_n}^n \in MC^G((y_{1:t}, x), N) & \text{for } t < L \\ D(y_{1:T}, x) & \text{for } t = L \end{cases} \tag{3.4}$$

Model architecture

GANs in NMT

- **Reward strategy:**
    - Discriminator strategy *[Li et al, 2017]*
        - Discriminator is a **partially generated sentence** classifier.
        - Example: "Discriminator is a classifier ."
            - "Discriminator", "Discriminator is", "Discriminator is a", "Discriminator is a classifier", "Discriminator is a classifier ."

$$R_D^G((y_{1:t-1}, x), y_t) = D(y_{1:t}, x) \qquad (3.5)$$

Model architecture

GANs in NMT

- **Reward strategy:**
  - Language model strategy
    - Discriminator reward: Monte-Carlo search strategy or Discriminator strategy.
    - **Language model is an extra quality evaluator**. (Dual learning of *[He et al, 2016])*

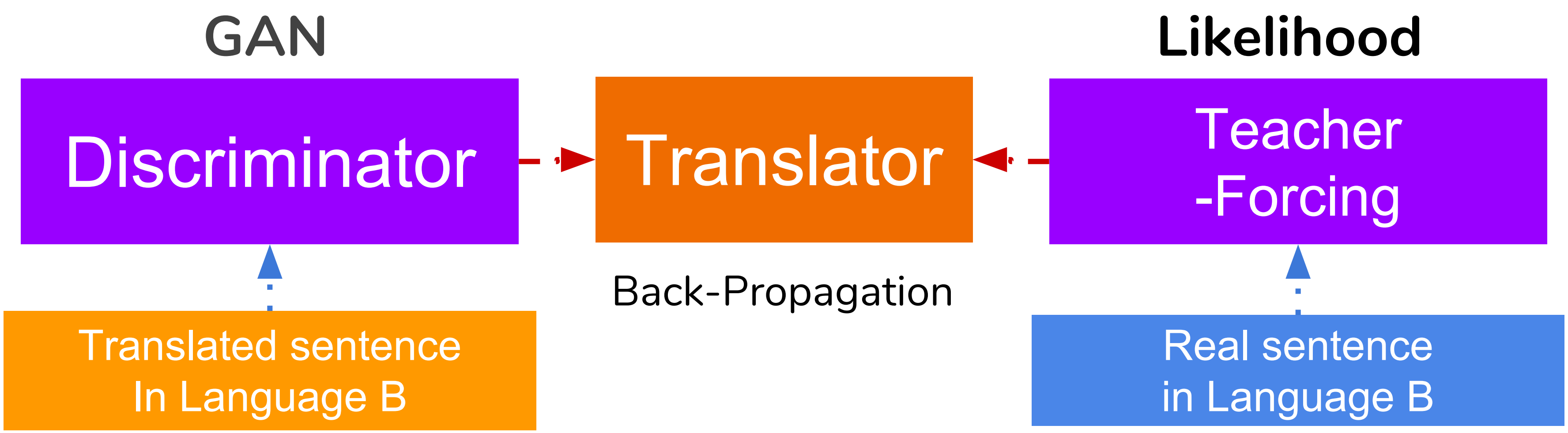
$$R_D^G((y_{1:t-1}, x), y_t) = \alpha * D(y_{1:t}, x) + (1-\alpha) * LM(y_t | y_{1:t-1}) \tag{3.6}$$

Model architecture

GANs in NMT

- **Teacher Forcing:** *[Yang et al, 2017]*
  - Return reward from **true target sentence**.

$$\nabla J_G = \sum_{y_t} 1 * \nabla_\theta log\, p_G(y_t|y_{1:t-1}, x) \qquad (3.7)$$



Algorithm

while *not convergence* **do**

Sample randomly a batch: Input sentences and its human-translated sentences $(X, hY)_{1:S}$

for *g-steps* **do**

for $s \in 1{:}S$ **do**

G translates X_s into machine-translated sentence $mY_{1:T} = (my_1, ..., my_T)$ by beam-search

for $t \in 1{:}T$ **do**

Compute reward $R_D^G(my_{1:t-1}, my_t)$ by Equation 3.4, 3.5 or 3.6

end

end

Update G with Discriminator: Update with $mY_{1:S}$ by Equation 3.2

Update G with Teacher Forcing: Update with hY by Equation 3.7

end

for *d-steps* **do**

G translate $X_{1:S}$ into machine-translated sentences $mY'_{1:S}$ as Negative examples

$hY_{1:S}$ Human-generated sentences as Positive examples

Update D: Update by Equation 3.3

end

end

Results and Experiments

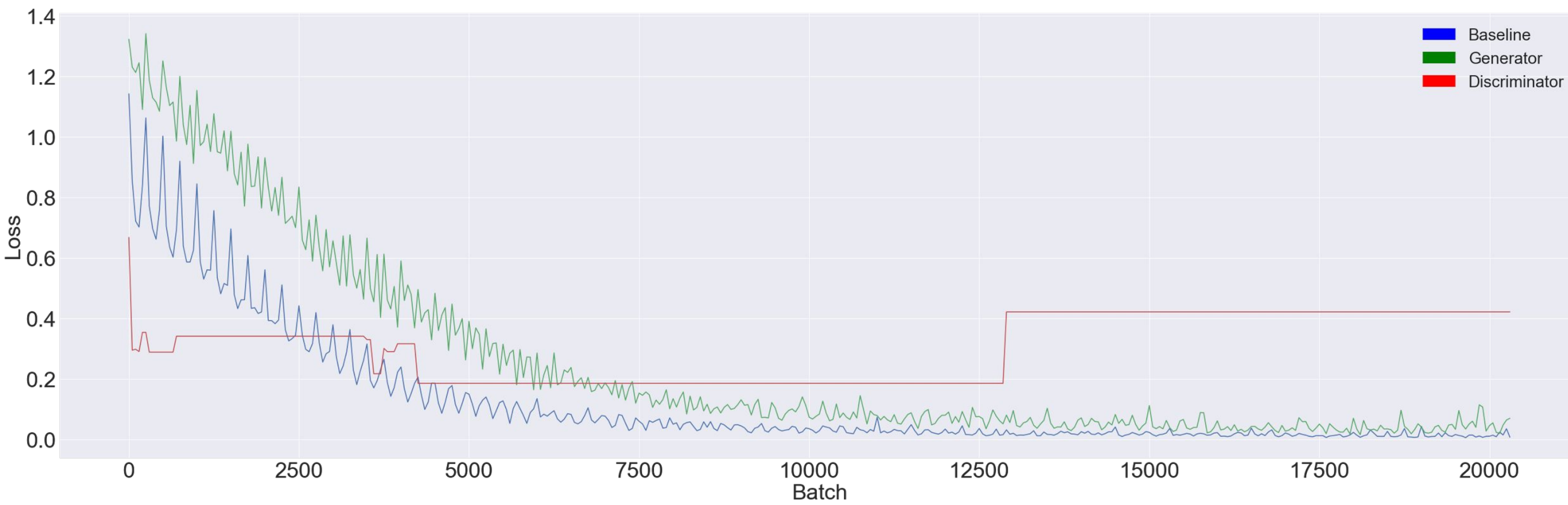
English-French translation task

- **Dataset:** BTEC
  - Training set: 19972 sentences
  - Development set: 506 sentences
  - Testing set: 469 sentences
- **Initial models:**
  - Baseline: NMT model with BLEU 38.8 on development set
  - Accuracy of discriminator:
    - MC search strategy: 0.78
    - Discriminator strategy: 0.83
    - In the range [0.75, 0.85]

Results and Experiments

English-French translation task

- **Discriminator strategy:**
    - Train loss

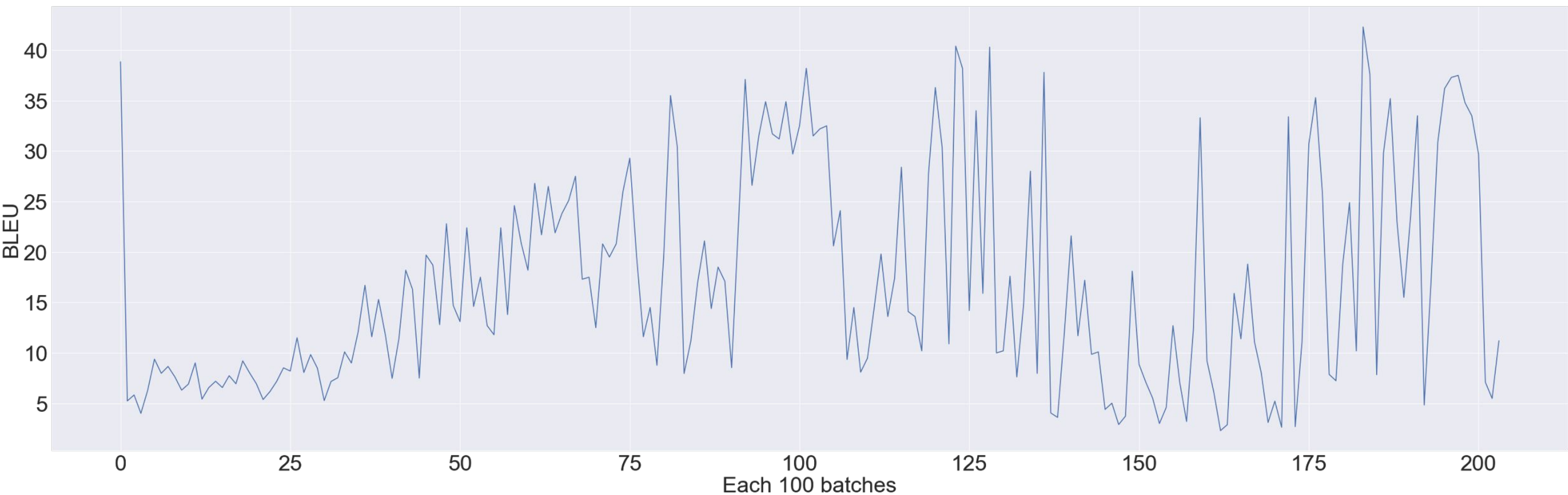


Results and Experiments

English-French translation task

- **Discriminator strategy:**
    - Validation BLEU score

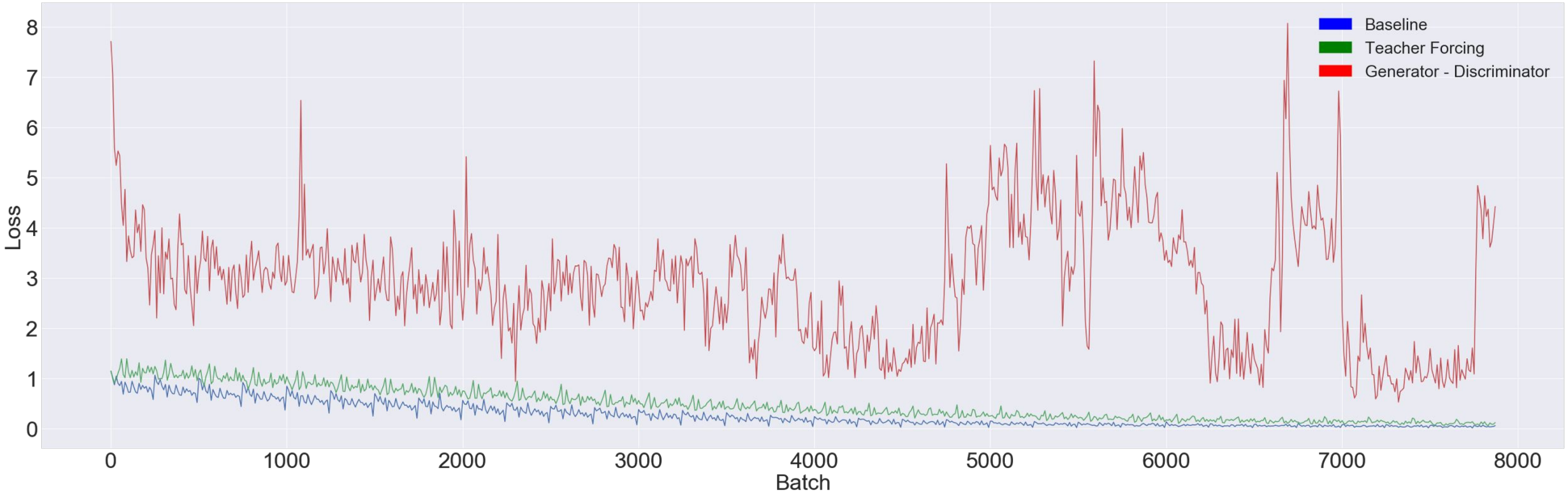
Model	Initial model	GANs	Improve
Train	46.71	92.38	+45.67
Dev	38.85	42.340	+3.49
Test	38.39	36.15	-2.24



Appendix: Results and Experiments

English-French translation task

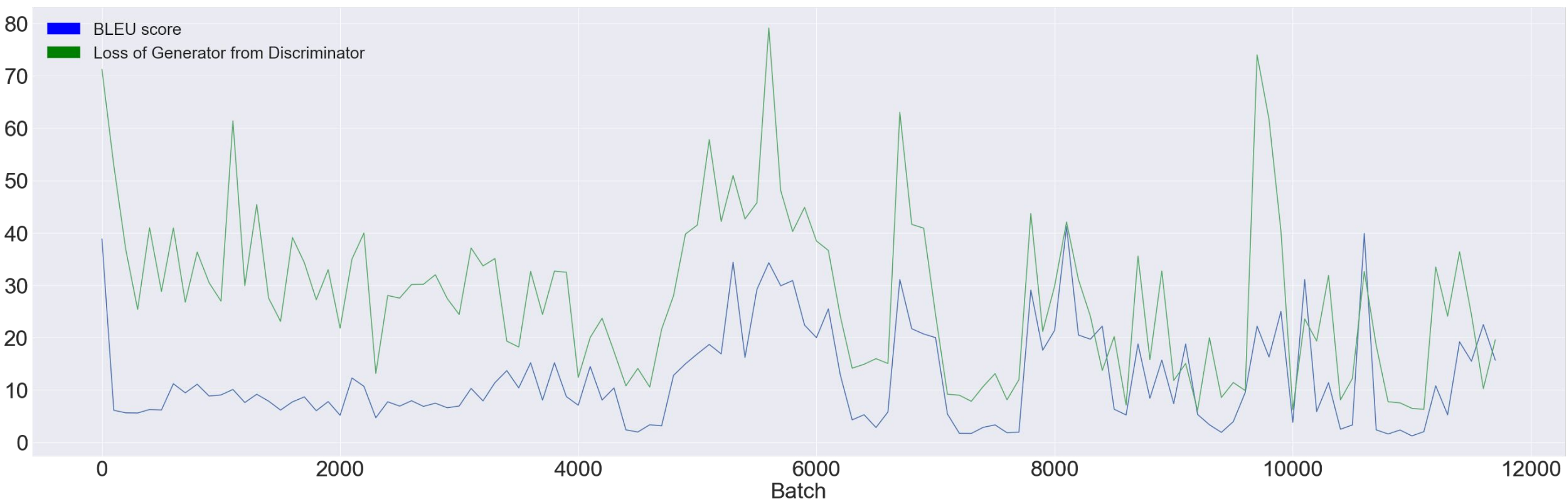
- **Discriminator strategy:**
  - Train loss: Teacher forcing and Discriminator reward



Results and Experiments

English-French translation task

- **Discriminator strategy:**
  - Relationship between BLEU score (Validation) and generator loss with discriminator reward (Train)

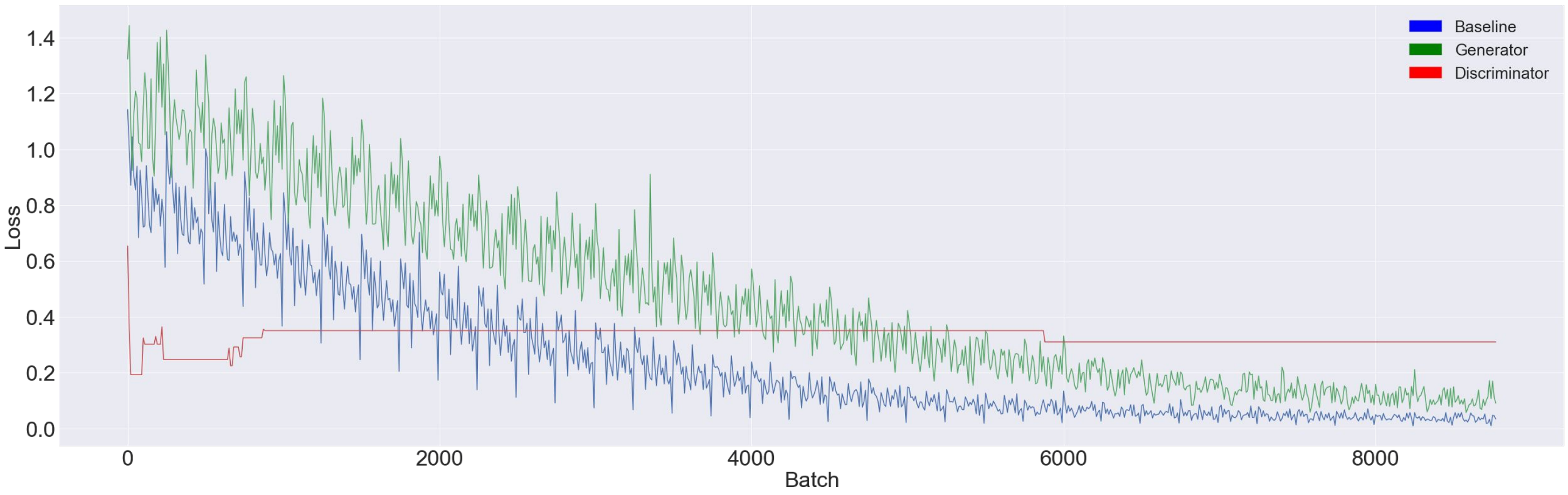


*Values are scaled

Results and Experiments

English-French translation task

- **Language model strategy:** without MC search
    - Train loss

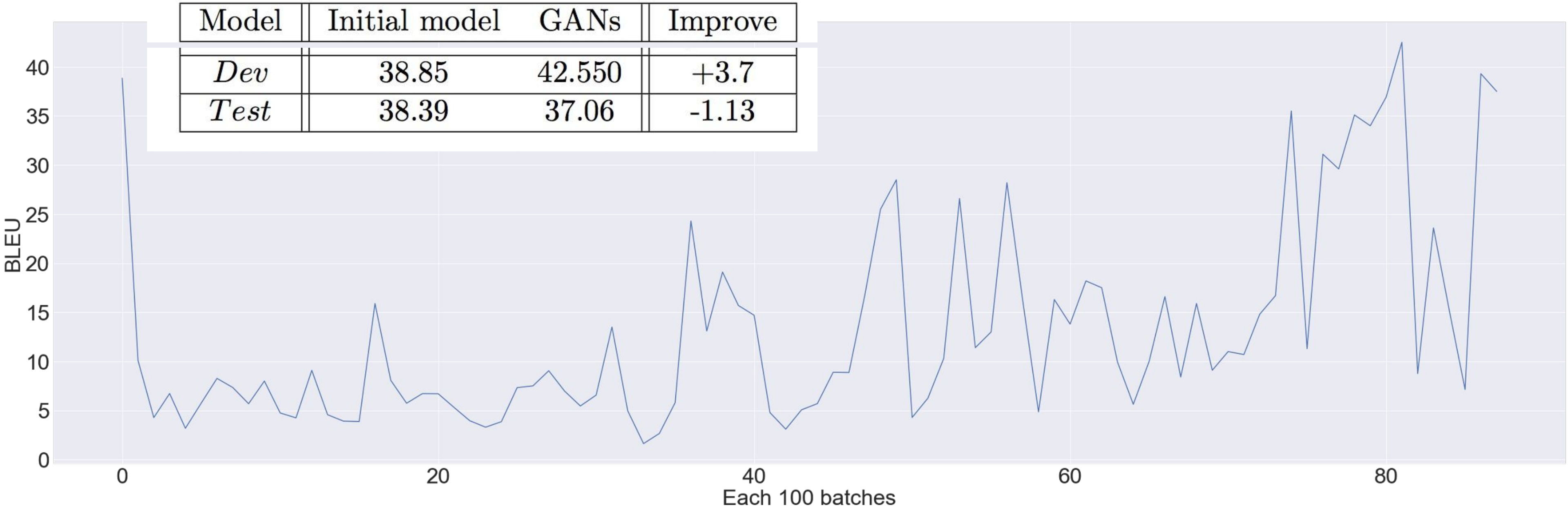


Results and Experiments

English-French translation task

- **Language model strategy:** without MC search
  - Validation BLEU score

Model	Initial model	GANs	Improve
Dev	38.85	42.550	+3.7
Test	38.39	37.06	-1.13



Conclusion
Until now

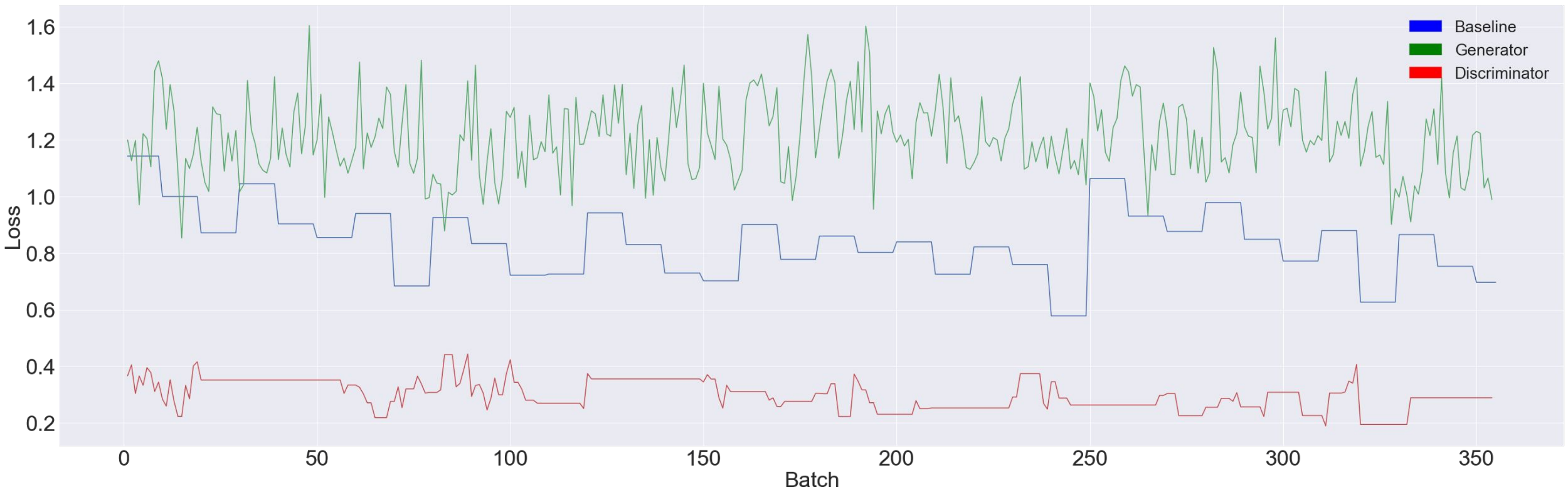
- GANs have a **similar** but **weaker** effect of the log likelihood on training NMT
- Ongoing work:
  - Analysis about the unstable training
    - Solving joint optimization issues (Discriminator Reward and Professor Forcing)
  - Experiments of the proposed strategies
    - MC search strategy and Language model strategy with MC search
  - Research about Variational Networks

Thank you!

Results and Experiments

English-French translation task

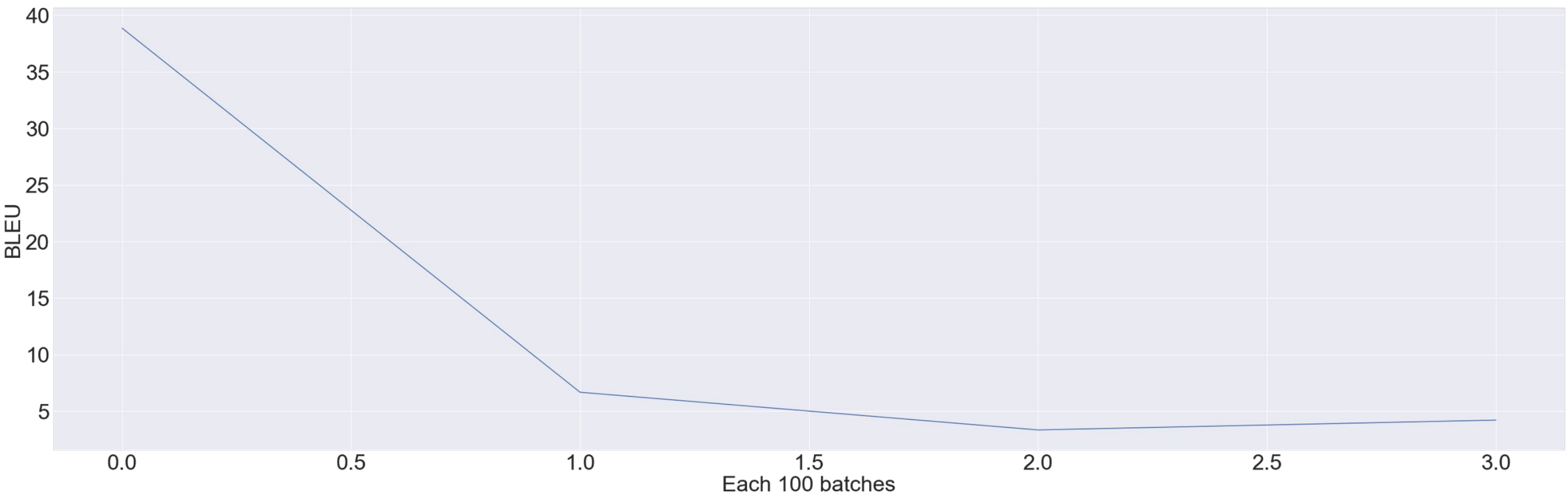
- **Monte-Carlo search strategy:**
  - Train loss



Appendix: Results and Experiments

English-French translation task

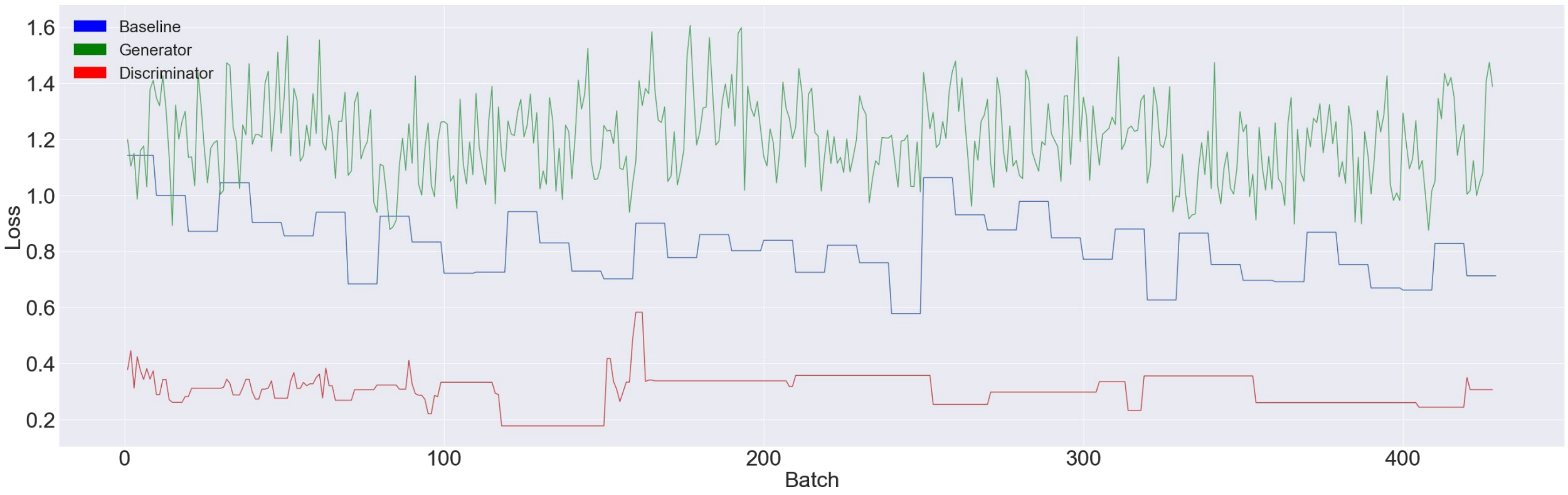
- **Monte-Carlo search strategy:**
  - Validation BLEU score



Results and Experiments

English-French translation task

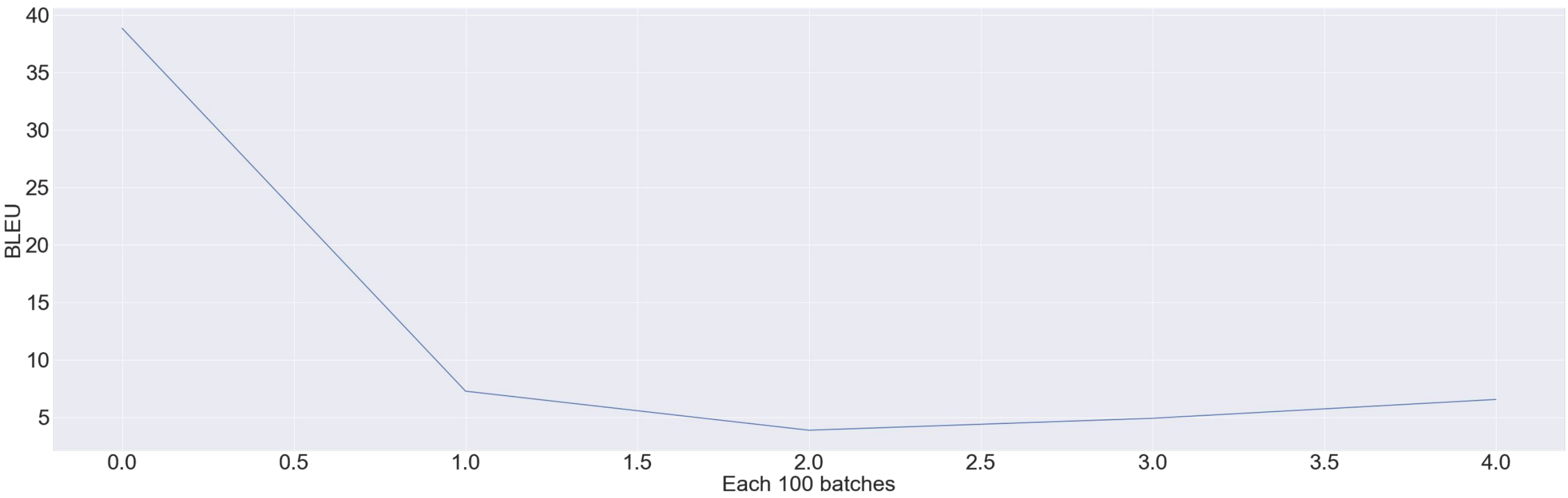
- **Language model strategy:** with MC search
  - Train loss



Appendix: Results and Experiments

English-French translation task

- **Language model strategy:** with MC search
    - Validation BLEU score



Results and Experiments

English-French translation task

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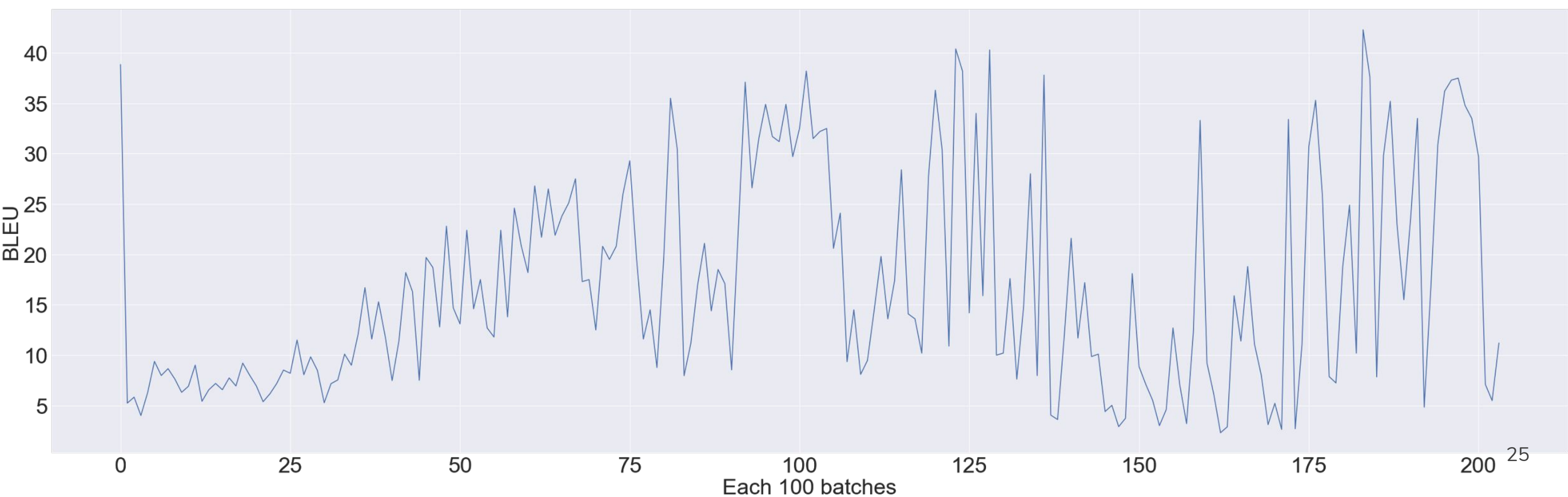
Dev	38.85	40.400	+1.55
Test	38.39	37.54	-0.85



Appendix: Results and Experiments

English-French translation task

- Monte-Carlo search strategy:

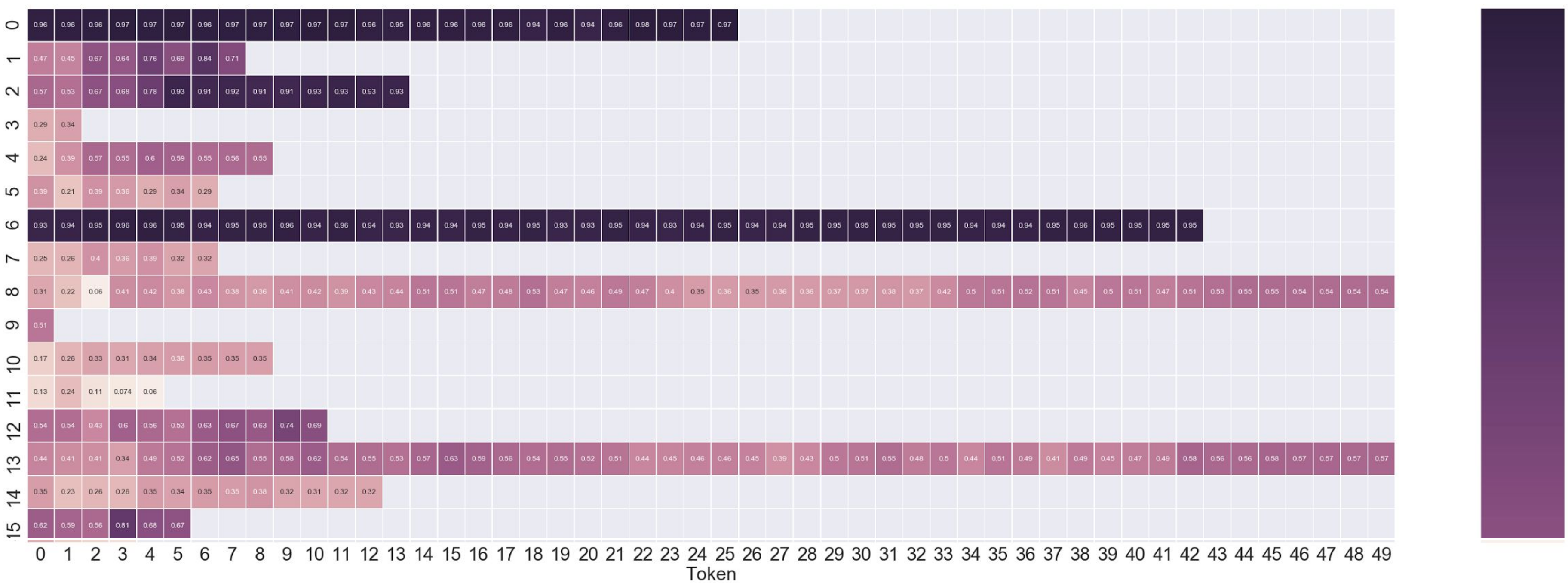


Figure A2: Epoch 1 - Batch 1

Appendix: Results and Experiments

English-French translation task

- **Monte-Carlo search strategy:**

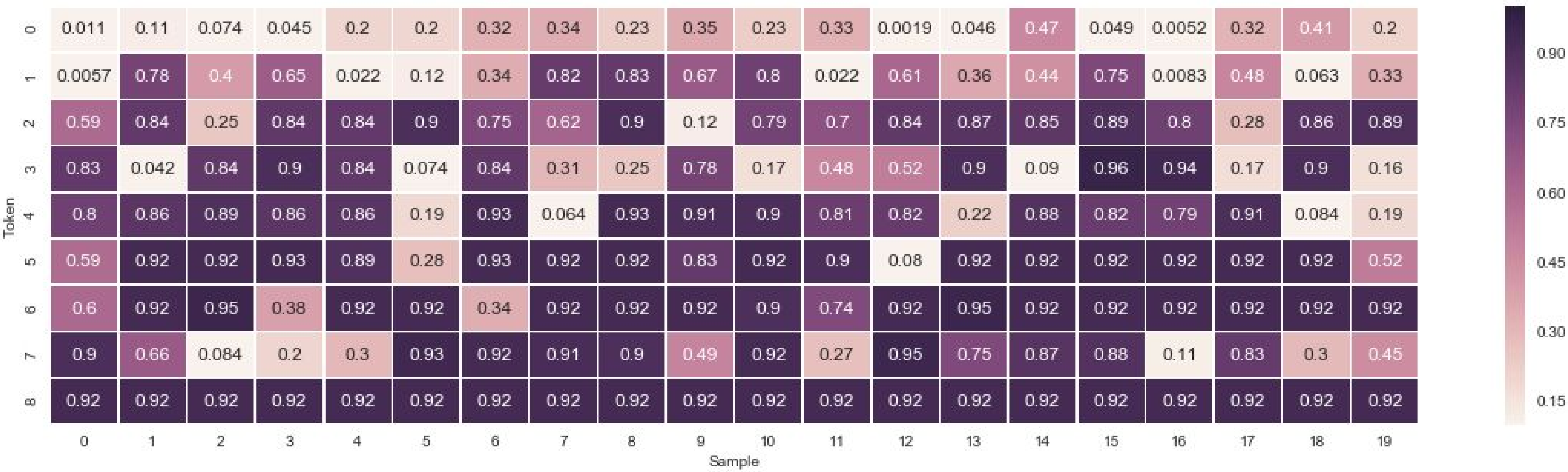


Figure A1: En sentence: I'd like to buy what I need . will you pay me back ?
Fr sentence: pourriez -vous me régler à mon retour ?

Appendix: Results and Experiments

English-French translation task

- Monte-Carlo search strategy:

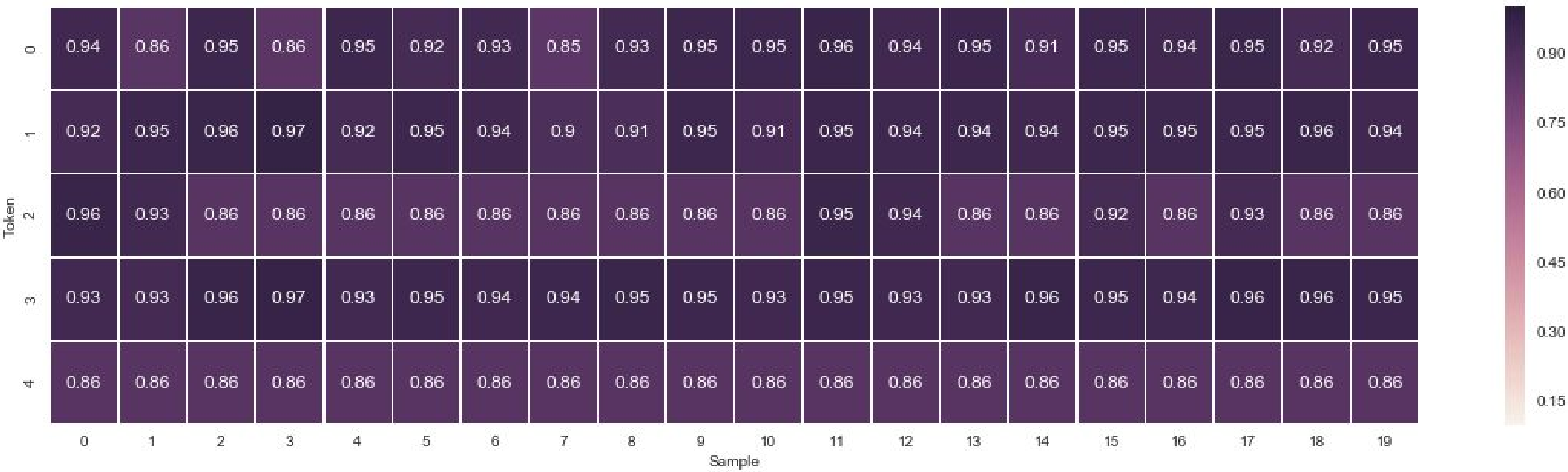


Figure A1: En sentence: yes , it's next door .
Fr sentence: c' est ouvert .

Appendix: Results and Experiments

English-French translation task

- **Monte-Carlo search strategy:**

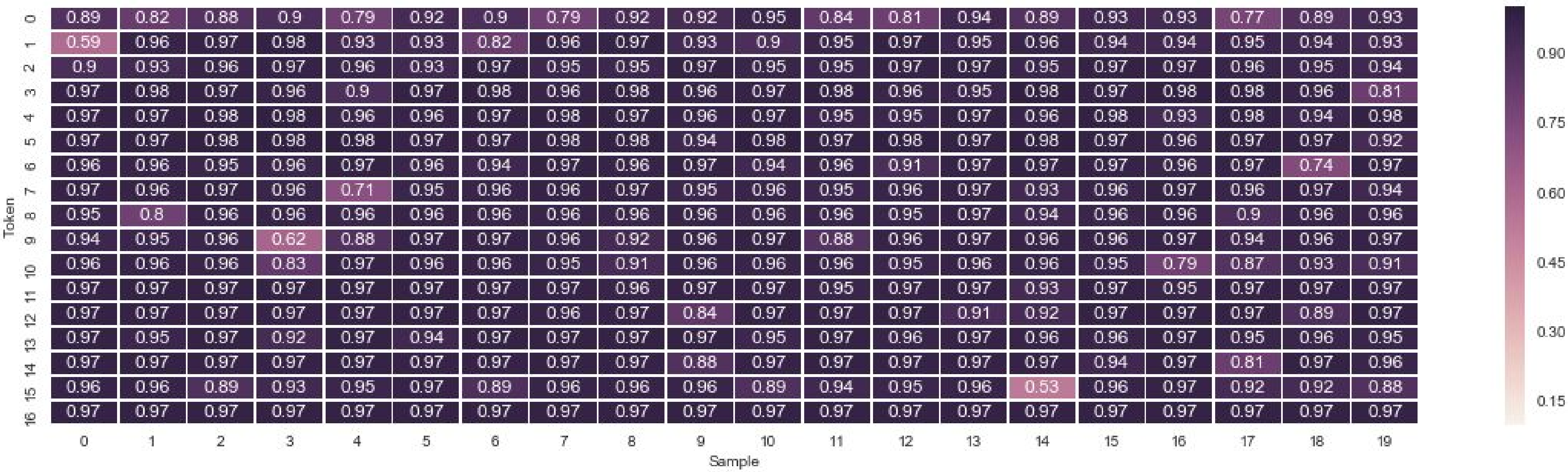


Figure A1: En sentence: the Japanese just can't get along without taking a bath every day .
Fr sentence: nous ne sont pas pris de nous faire un n' asseoir pas de la baignoire .

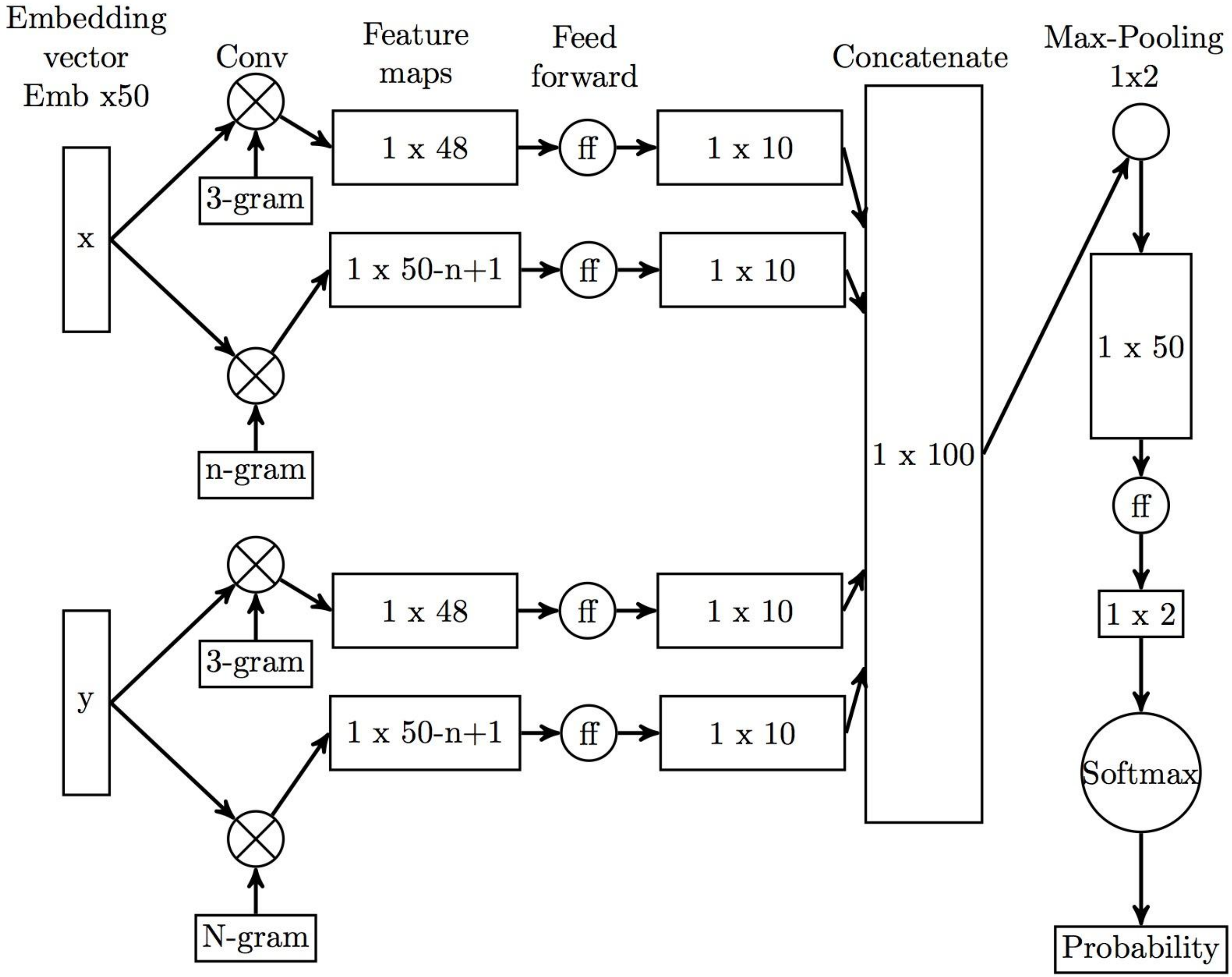


Figure 3.3: Discriminator architecture