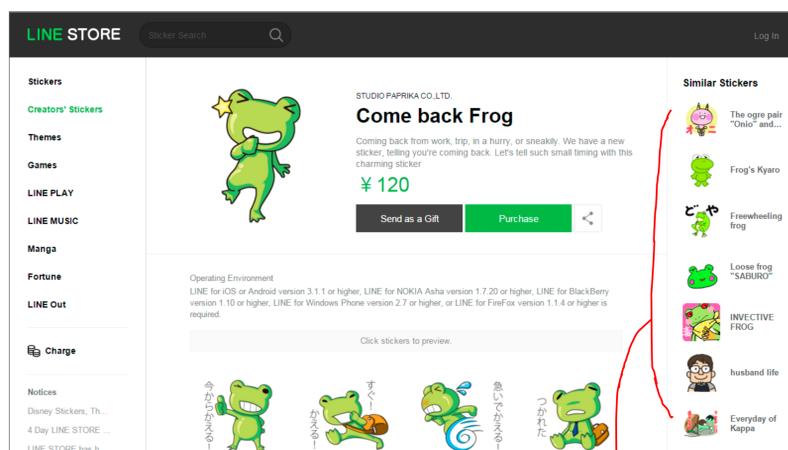


# Image-Based Sticker Recommendation using Deep Learning

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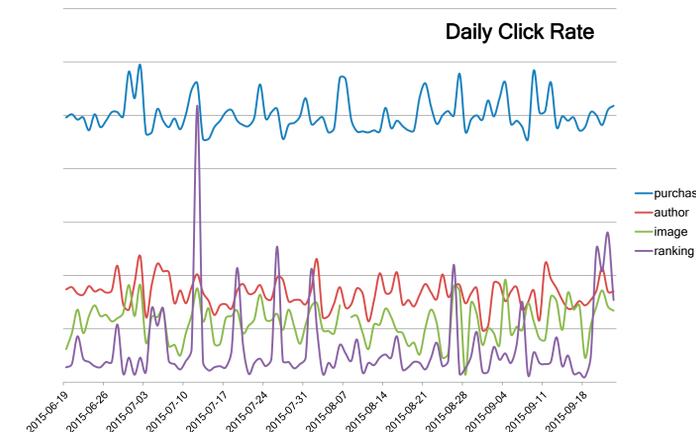
## Introduction

- LINE Sticker Shop receives a set of new incoming stickers designed by independent artists every day.
- Stickers are recommended by collaborative filtering which selects stickers based on user purchase history (shown in the rightmost column of screenshot).
- However, new stickers fail to get recommended due to the absence of purchase history.
- We propose to solve this “cold start” problem by learning to recommend visually similar stickers based on image content, using deep learning on GPU.



Recommended stickers

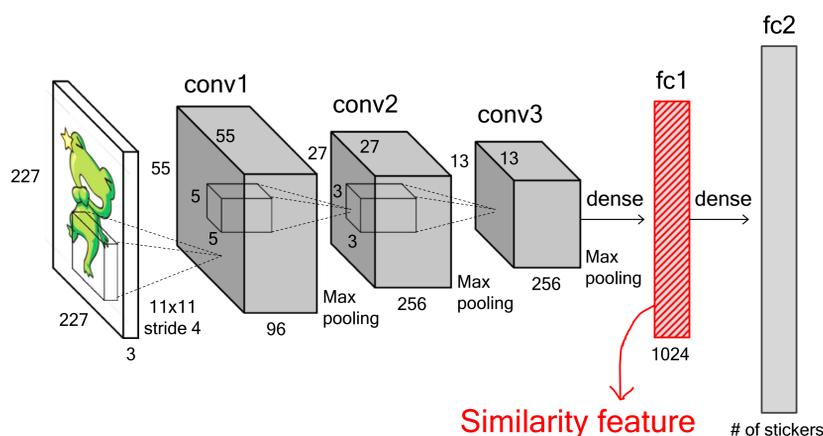
## Results



Purchase	Author	Image	Ranking
1.00	0.32	0.21	0.07

Total click rate, normalized with respect to purchase-based recommendation scheme

## Convolutional Neural Network



- Convolutional neural networks have recently shown state-of-the-art performance on image classification [1].
- Output from CNN's post-convolution hidden layer has also been used as semantic image feature with very good results [2].
- We trained a CNN with 3 convolutional layers and 2 fully connected layers to classify stickers in the training set, using an NVIDIA GTX Titan GPU.
- Each sticker has 40 images, and we divided them into halves for training and validation. Then we retrained the same network using all 40 images.
- We used 1024-dimensional vector output from fc1 layer as features for measuring similarity between stickers.

## Sticker Recommendation

- Stickers are recommended in following order, proceeding to next scheme if stickers matching given description do not exist:
  1. Stickers sharing user purchase history
  2. Other stickers by the same author
  3. Visually similar stickers
  4. Top stickers on sales ranking
- Image-based recommendation (step 3 from above):
  1. Retrieve new stickers and add them to existing sticker set
  2. Extract 1024-dim fc1 features for new stickers
  3. Compute pairwise feature distances between new and existing stickers
  4. Sort and list top-N closest stickers for each sticker
- The procedure described above is repeated on a daily basis on a dedicated server equipped with an NVIDIA K40 GPU.

- Click rate is defined as the number of actual clicks divided by the number of page views. It is a measure of corresponding recommendation scheme's relevance.
- Image-based recommendation performs slightly worse than author-based recommendation, but clearly better than ranking-based (default) recommendation.
- Ranking-based recommendation's daily click rate shows somewhat periodic fluctuation. We suspect that it is related to the weekly public release of new stickers.

## Conclusion and Future Work

- CNN image classifier works reasonably well for measuring visual similarity between a large number of stickers.
- GPU is essential for building and running the CNN model, which comprises the core of image-based sticker recommendation process.
- As more new stickers accumulate, it may make sense to incrementally update the CNN model to reflect the visual style of more recently added stickers.

[1] Krizhevsky et al., ImageNet Classification with Deep Convolutional Neural Networks. NIPS 2012.

[2] Donahue et al., DeCAF: A Deep Convolutional Activation Feature for Generic Visual Recognition. ICML 2014.