Language-based Colorization of Scene Sketches

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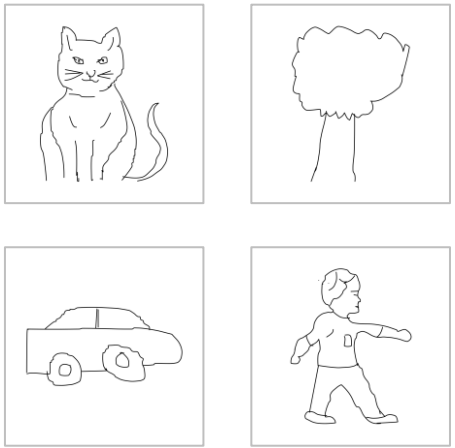
Motivation: Abstract Data and Human Cognition

- **Sparse**
- **Highly abstract**

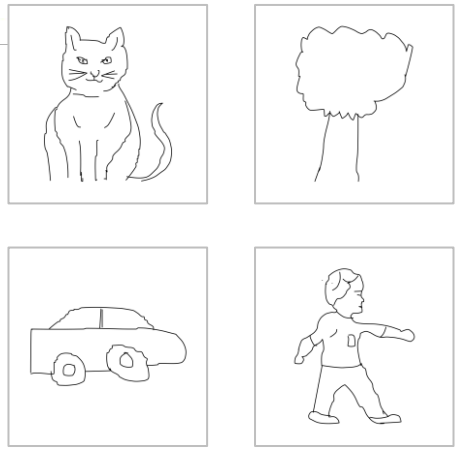
Motivation: Abstract Data Understanding

- **Lots of early exploration with computational models** [Eitz et. al 2012, Li et. al 2013, Schneider et. al 2014, Li et. al 2015]
- **Limited ability of understanding object-level sketches**

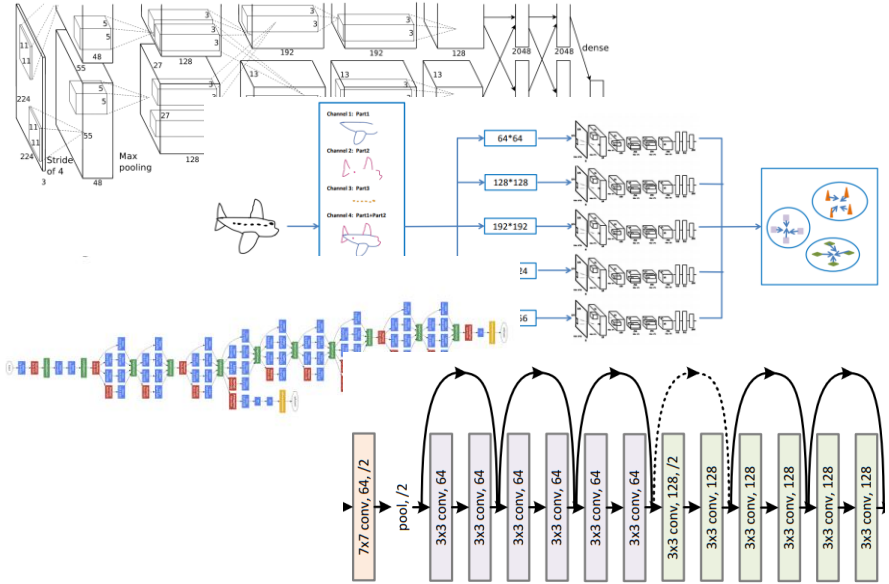


[1] M. Eitz, J. Hays, and M. Alexa. How do humans sketch objects? In SIGGRAPH, 2012.
[2] Y. Li, Y. Song, and S. Gong. Sketch recognition by ensemble matching of structured features. In BMVC, 2013.
[3] R. G. Schneider and T. Tuytelaars. Sketch classification and classification-driven analysis using fisher vectors. In SIGGRAPH Asia, 2014.
[4] Y. Li, T. M. Hospedales, Y. Song, and S. Gong. Free-hand sketch recognition by multikernel feature learning. CVIU, 2015.

Motivation: Sketch Understanding



TU-Berlin / Sketchy / QuickDraw



Motivation: Sketch Understanding

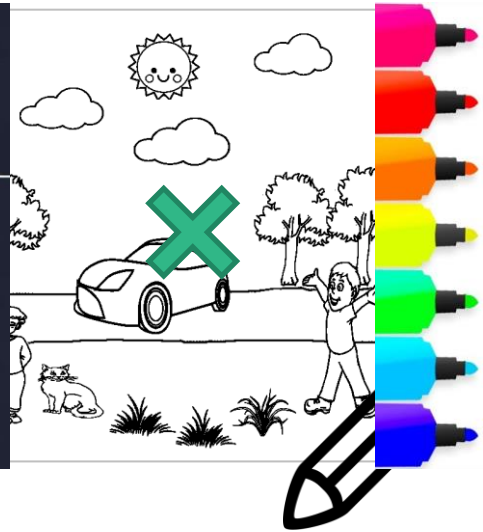
SketchyScene [Zou et. al 2018]

Scene-level sketch:

- **Interaction among multiply objects**
- **More empty region, lack of contextual information**

[1] Changqing Zou, et. al. SketchyScene: Richly-Annotated Scene Sketches. In ECCV, 2018.

Motivation: Scene Sketch Understanding

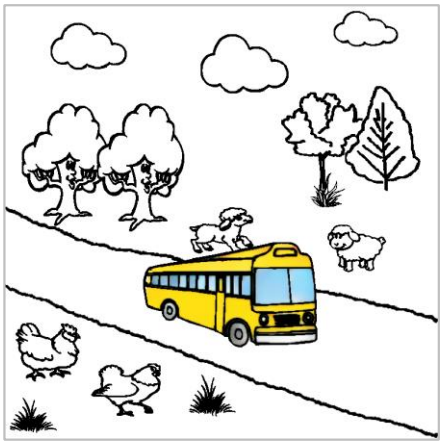


Natural language

Scene sketch colorization

Motivation: Why Language-based?

- **Natural: easily adopted by novice users**
- **Touchless: friendly for people with upper limb impairments**
- **Effective: support batch-processing colorization**

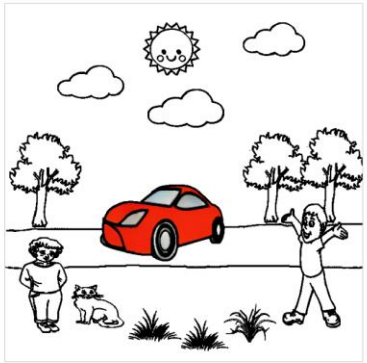


“the bus is yellow with blue windows”

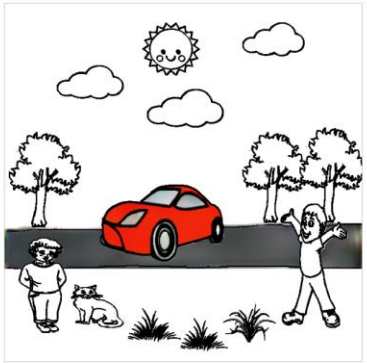
Motivation: Language-based Sketch Colorization

- **Toy problem, but not simple ……**

Scene sketch



*"the car is **red** with **black** windows"*



*"the road is **black**" / "colorize the road with **black**" / "**black** road"*

*"all the trees are **green**"*
*"the sun in the sky is **yellow**"*
.....
*"the grasses are **dark green**"*

*"the sky is **blue** and the ground is **green**"*

Challenges

A. Understanding scene-level sketch is very hard

- Too abstract
- Lack of contextual information

CMPlaces
[Castrejon et. al 2016]

Photo-Sketching
[Li et. al 2019]

SketchyScene
[Zou et. al 2018]

Challenges

B. Multimodal learning between language and scene sketch

- **Mapping between language and target objects**

*“the **dog** on the rightmost has orange body”*

Challenges

B. Multimodal learning between language and scene sketch

- Mapping between language and target objects
- **One or multiple objects with single instruction**

*"the **two trees** on the left of the house are light green"*

Challenges

B. Multimodal learning between language and scene sketch

- Mapping between language and target objects
- One or multiple objects with single instruction
- **Various free expressions of location**

*“the dog **in the middle** is gray ”*

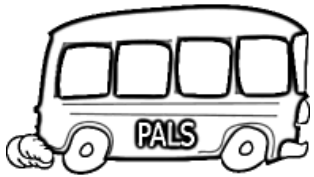
/

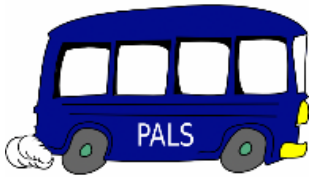
*“the dog **near the house** is gray”*

Challenges

C. Multimodal learning between language and object sketch

- **Object-part-level colorization**
- **Various free expressions of colors**





*“the bus is **dark (navy/…)** blue with **white windows**”*

Inspiration: Drawing and Intelligence Development

- Sensitive to line drawing and color
- Mode of thinking and creation

Inspiration: Language and Literacy Development

[Raffle et. al 2007]

- **Embedding voice in traditional drawings supports children's literacy development**

Related Work

Related Work

A. Language-based Image Segmentation

- Fusion of textual and visual information
- Only natural images
- Only one binary mask for single or multiple target objects

"second vase from right"

"the bottom two luggage cases being rolled"

[Ye et. al 2019]

the bus has orange body and blue windows

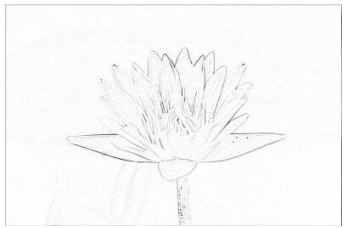
the two trees on the left of the house are light green

Our work

Related Work

B. Language-based Image Colorization

- **Language-based image editing (LBIE)** [Chen et. al 2018]
- **Require pair-wise scene-level sketch and color image**



"The flower has red petals with yellow stigmas in the middle"

[Chen et. al 2018]

Scene sketch

*"the house is **pink**"*

Our work

[1] Jianbo Chen, et. al. Language-Based Image Editing With Recurrent Attentive Models. In CVPR, 2018.

Our Work

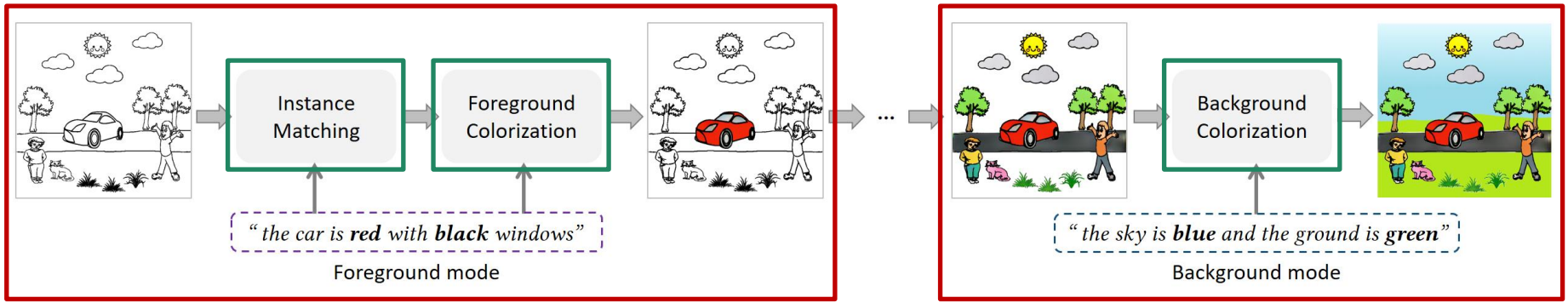
Main contributions

- Language-based colorization system for scene sketches
- Language-based instance segmentation network for scene sketches
- Three large-scale datasets for language-based scene sketch colorization

Proposed approach

A. System pipeline

- **Divide-and-conquer and progressive strategy**
- **Two modes (foreground and background)**
- **Three models (instance matching, foreground colorization, background colorization)**

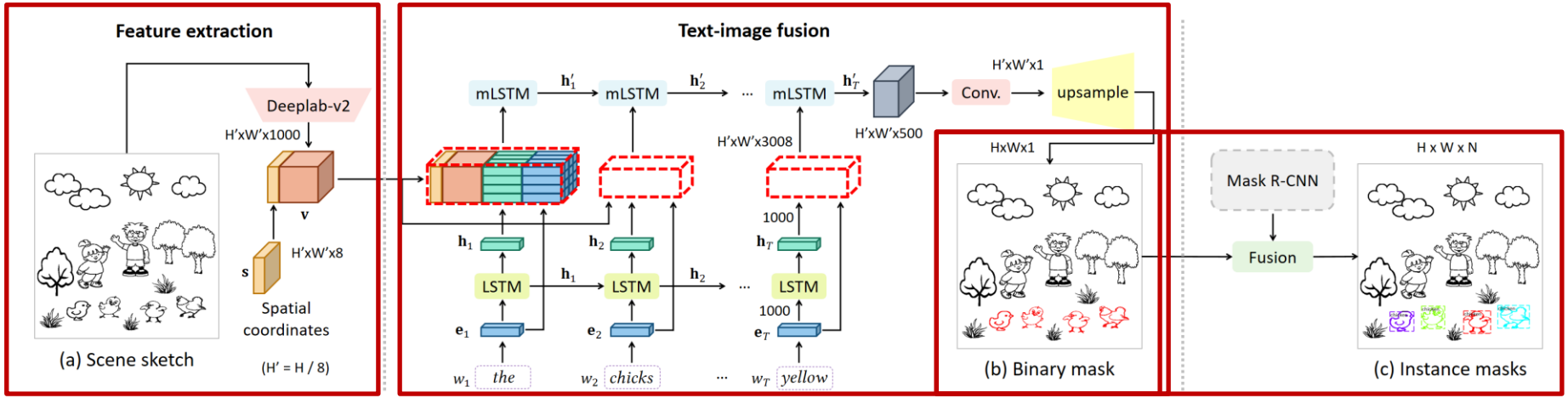


System pipeline

Proposed approach

B.1 Instance Matching Model

- Training: two phases for binary mask (b) generation
- Inferring: fuse binary mask with instance segmentation results

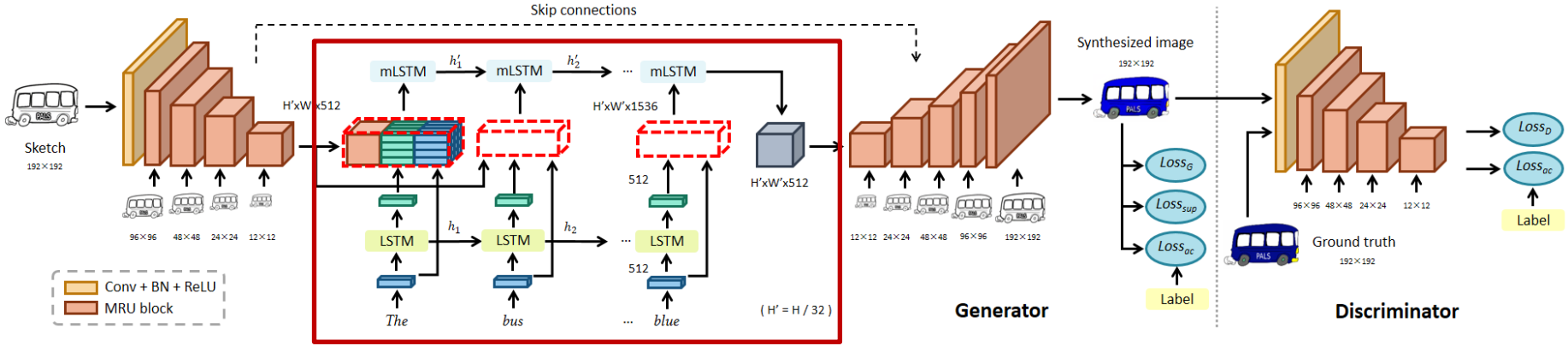


Foreground mode

Proposed approach

B.2 Foreground Colorization Model

- GAN + fusion module
- Colorize objects from different categories

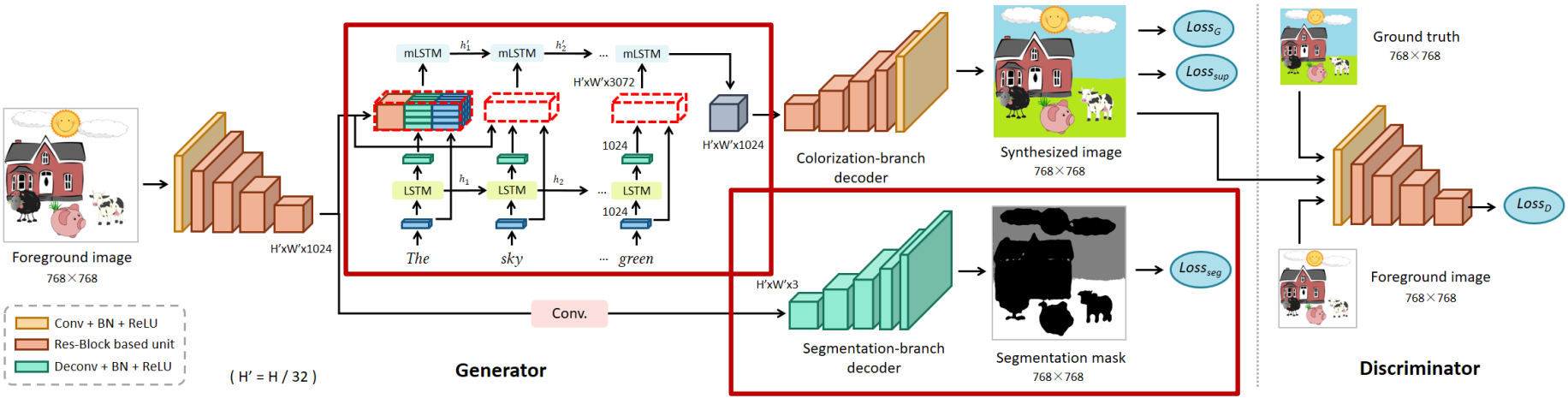


Foreground mode

Proposed approach

B.3 Background Colorization Model

- cGAN + two-branch decoder
  - Colorization branch
  - Explicit segmentation branch (segmentation loss)

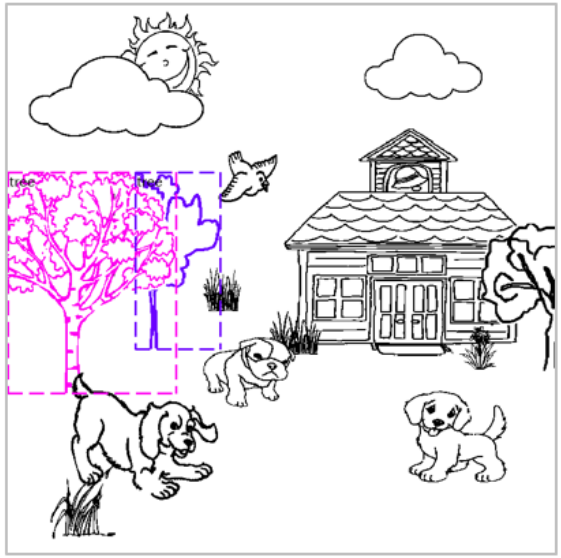


Background mode

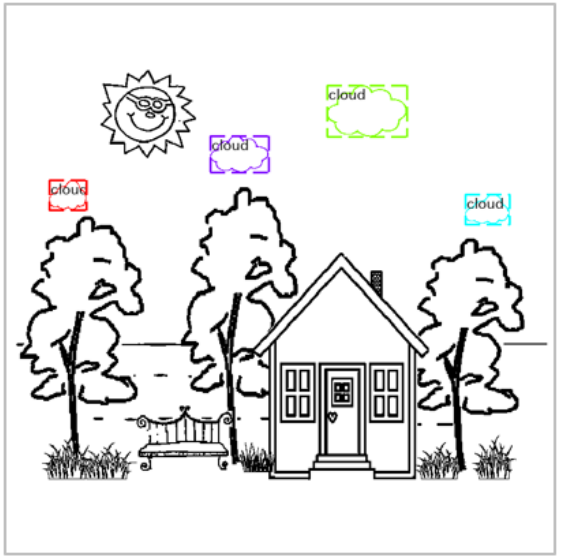
Datasets

- ***MATCHING dataset***: **38k groups of text-based instance segmentation data.**

the bus has orange body and blue windows



the two trees on the left of the house are light green



all the clouds are dark gray

Datasets

- *MATCHING dataset*: 38k groups of text-based instance segmentation data.
- ***FOREGROUND dataset***: **4k groups of text-based sketch object colorization data.**

Datasets

- *MATCHING dataset*: 38k groups of text-based instance segmentation data.
- *FOREGROUND dataset*: 4k groups of text-based sketch object colorization data.
- ***BACKGROUND dataset***: **20k groups of text-based background colorization data.**

(a) Sketch template

(b) Foreground image

(c) Segmentation

*"the sky is **blue** and the ground is **green**"*

*"the sky is **brown** and the ground is **black**"*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Single object**

“the bus is yellow with blue windows”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Single object**

“the bus is yellow with blue windows”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Multiple objects**

*"**all** the trees are dark green"*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Multiple objects**

*"**all** the trees are dark green"*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Colorize the background before all foregrounds**

“the sky is blue and the ground is green”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Colorize the background before all foregrounds**

“the sky is blue and the ground is green”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Language grammar error**

*“the clouds are **are** in dark gray”*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Language grammar error**

*“the clouds are **are** in dark gray”*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

“the sun is yellow”

“the bird on the left is red”

“the bird on the right is dark brown”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

“the sun is yellow”

“the bird on the left is red”

“the bird on the right is dark brown”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Unsupported words**

*"**let** the rabbit **be in** pink"*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Unsupported words**

*"**let** the rabbit **be in** pink"*

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

“the duck on the right is orange”

“dark green grasses”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

“the duck on the right is orange”

“dark green grasses”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Re-colorization**

“colorize the bus in purple”

Results: Un-targeted

A. Un-targeted colorization experiment

- **Colorize a sketch with free instructions**

- **Re-colorization**

“colorize the bus in purple”

Results: Un-targeted

A. Un-targeted colorization experiment

*"the house is **orange** with **dark brown** roof"*

*"the two trees on the left are **dark green**"*

*"the three trees on the right are **dark green**"*

*"the sky is **cyan** and the ground is **gray**"*

*"let the dog to be **gray**"*
...

Results: Un-targeted

A. Un-targeted colorization experiment

*"the person on the left has **red** hair and is in **dark brown** shirt with **light blue** pants"*

*"the person on the right has **red** hair and is in **orange** shirt with **yellow** pants"*

*"colorize the sky **purple** and ground **yellow**"*

*"the two ducks are **yellow**"*
*"the pig on the left is **pink**"*

*"clouds are **blue** in the sky"*
*"grasses are **green**"*

Results: Targeted

B. Targeted colorization experiment

- **Colorize a sketch into target color images**

"The sun is yellow"

"All the chickens are yellow"

"The house is red with dark brown roof ***and light blue windows****"*

"The sun is yellow ***with orange flame****"*

"All chickens are yellow ***with red crest and yellow feet****"*

*"****The walls of the house*** *are brown and the roof of the house is red"*

Target

User A

User B

Results: Targeted

B. Targeted colorization experiment

- **Colorize a sketch into target color images**

"the house is yellow with red roof"

*"**one duck on the left** is purple"*

*"**the other duck on the right** is white"*

*"the house with red roofs **has yellow doors**"*

*"**the left duck** is purple"*

*"**the right duck** is white"*

Target

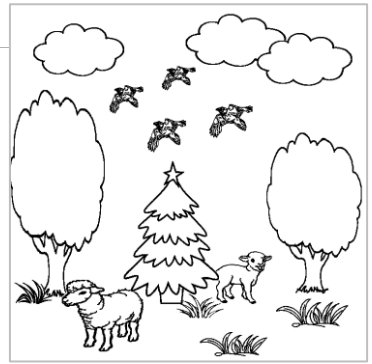
User A

User B

Results: Targeted

B. Targeted colorization experiment

- **Colorize a sketch into target color images**



*"**the leftmost** bird is **dark** blue"*

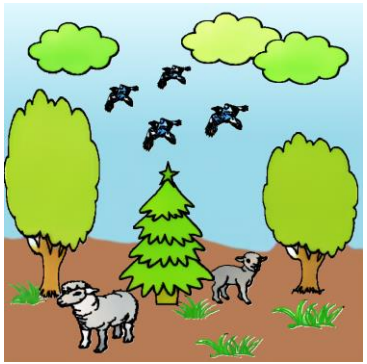
*"the bird **on the right most** is **dark** blue"*

*"**the two middle** birds **have blue body**"*

*"the birds **are all** blue"*

Target

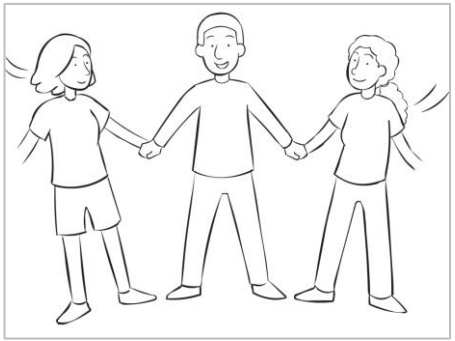
User A

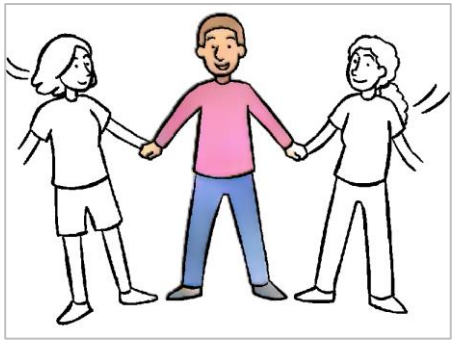


User B

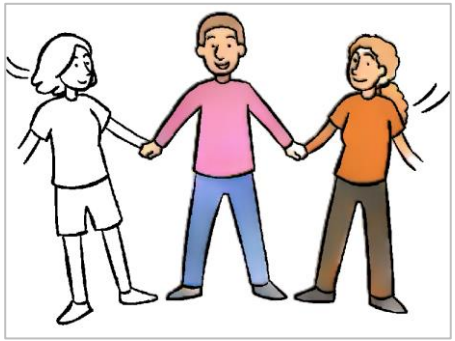
Results: Generalization

C.1 Generalization experiment: cartoon-style drawings





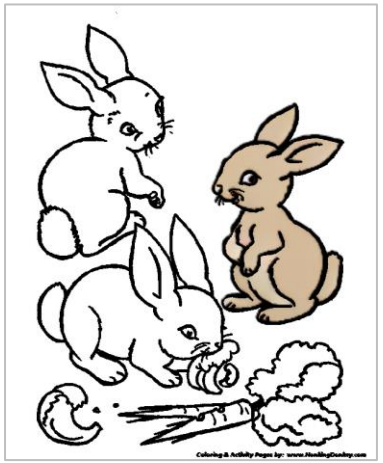
*"the person in the middle has **dark brown** hair and is in **pink** shirt with **light gray** pants"*



*"the person on the right has **light brown** hair and is in **orange** shirt with **black** pants"*

Results: Generalization

C.1 Generalization experiment: cartoon-style drawings



*“the rabbit on the right is **light brown**”*

*“the rabbit on the upper left is **dark gray**”*

Results: Generalization

C.2 Generalization experiment: anime line art

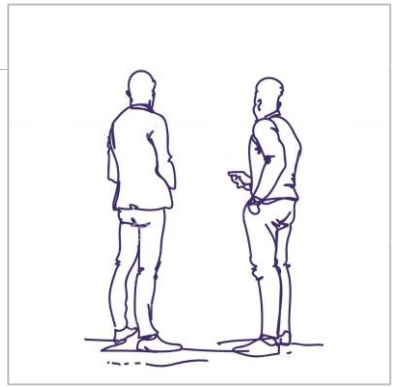
*"the person on the left has **light brown** hair and is in **red** shirt with **dark gray** pants"*

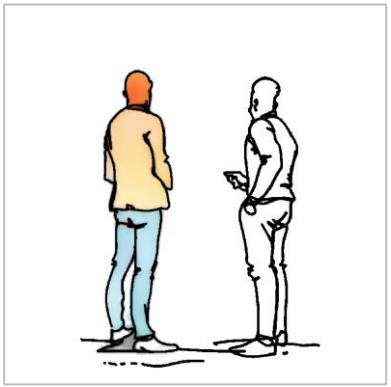
*"the person on the right has **red** hair and is in **orange** shirt with **cyan** skirt"*

*"the sky is **pink** and the ground is **yellow**"*

Results: Generalization

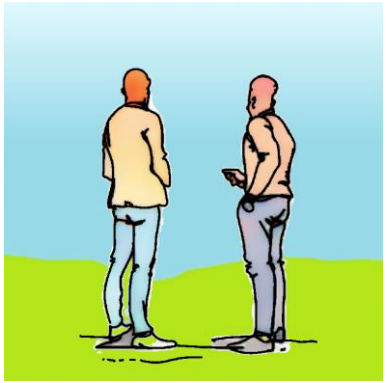
C.3 Generalization experiment: artist freehand drawing





*"the person on the left has **red** hair and is in **yellow** shirt with **cyan** pants"*

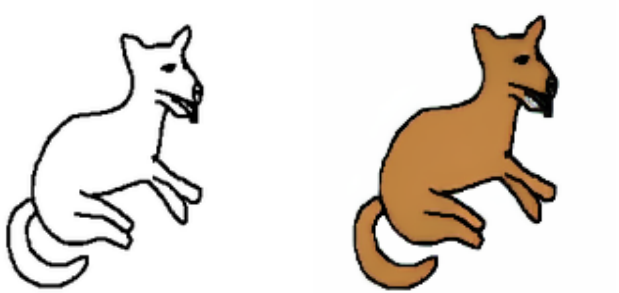
*"the person on the right has **red** hair and is in **light brown** shirt with **purple** pants"*



*"the sky is **blue** and the ground is **green**"*

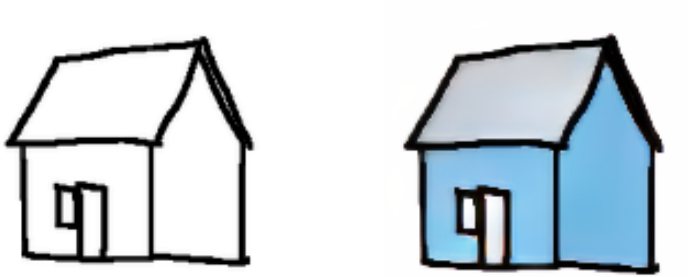
Results: Generalization

C.4 Generalization experiment: non-artist freehand sketches



*"the dog is **dark brown**"*

*"the car is **yellow** with **blue** window"*

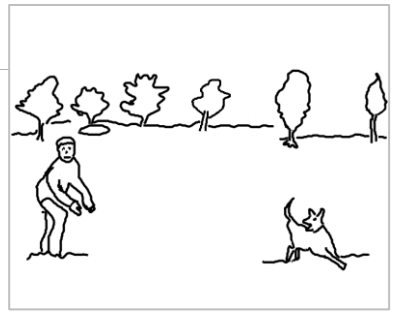


*"the house is **blue** with **gray** roof"*

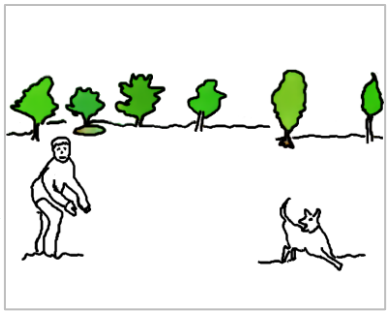
Sketchy
[Sangkloy et al. 2016]

Results: Generalization

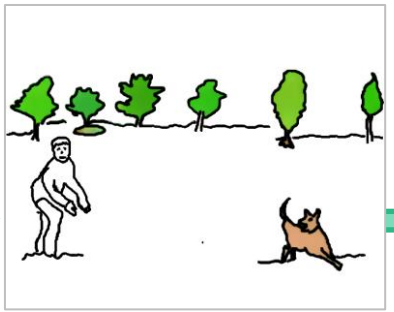
C.4 Generalization experiment: non-artist freehand sketches



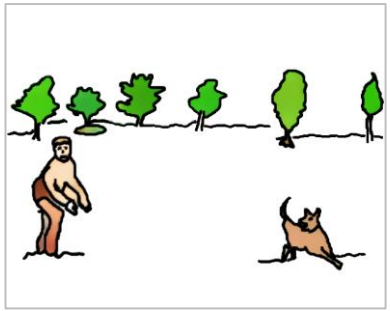
*"all the trees are **dark green**"*



*"the dog on the right is **dark brown**"*



*"the person is in **light brown** shirt with **red** pants"*



*"the sky is **blue** and the ground is **green**"*

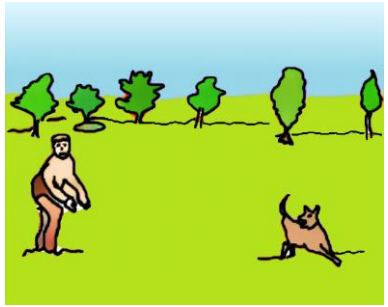
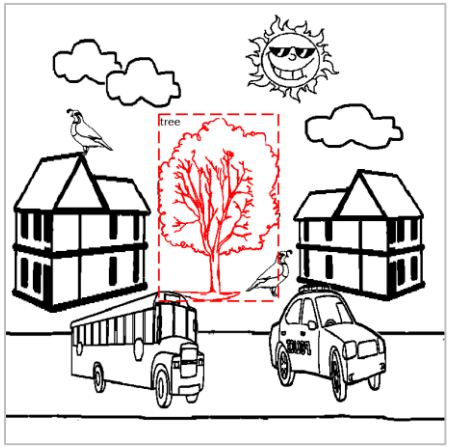


Photo-Sketching
[Li et al. 2019]

Limitations: Language Generality for Matching

*"the **bus** is blue and the **tree** is light green"*

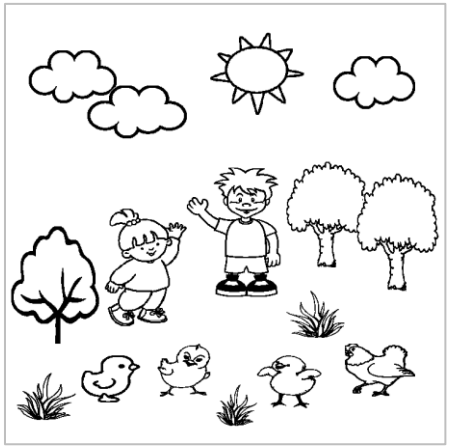


*"the **tree** is light green and the **bus** is blue"*

- **Multiple objects of different categories**

Limitations: Language Generality for Matching

*"the **taxi** is yellow with blue windows"*



*"the **little boy** has …"*
*"the **little girl** is in …"*

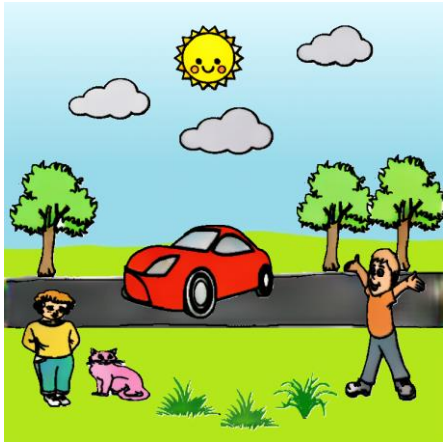
- **Alternative category names not in training data**

Limitations: Language Generality for Colorization

- **Arbitrary part-level information**
- **Arbitrary colors**

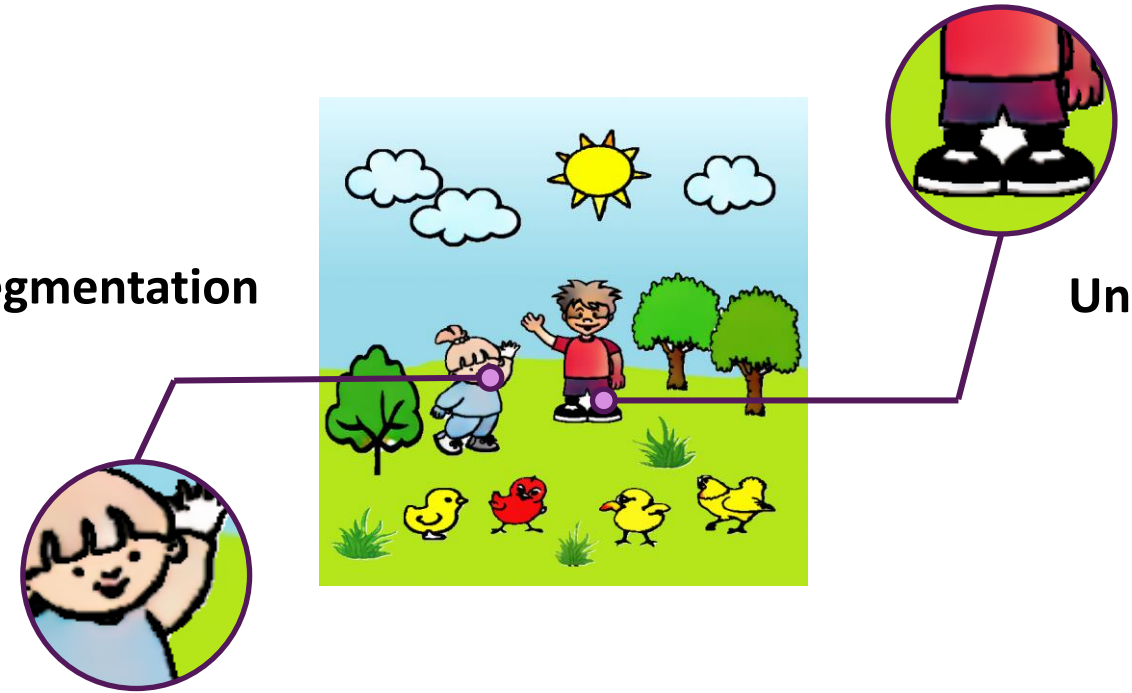
*"the **wheels** of the car is…"*

*"… **blonde** hair"*



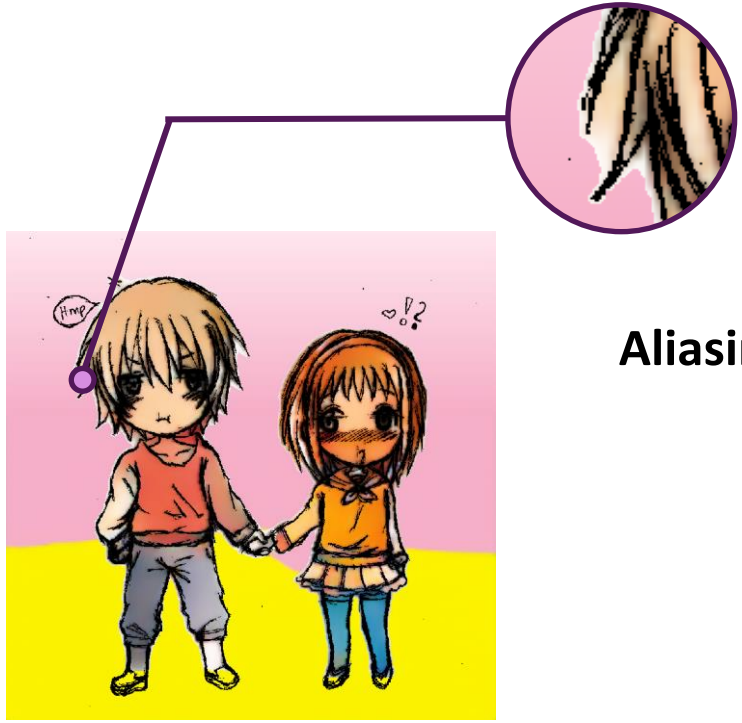
Limitations: Colorization Artifacts

Incorrect segmentation



Uncolored pixels

Limitations: Colorization Artifacts



Aliasing artifact

Future work: Multimodal Colorization System

- Language-based: more natural and accessible
- Scribble-based: direct and precise control

To conclude

- Human's understanding of abstract data at scene level.
- The first language-based colorization system for scene sketches.
- Three large-scale datasets for language-based scene sketch colorization.
- Plausible results with room for improvement.

Dataset and code

- **Project Page: https://sketchyscene.github.io/SketchySceneColorization/**
- **Code: https://github.com/SketchyScene/SketchySceneColorization**
- **Lab. Homepage: http://sysu-imsl.com/**

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Thank you!