A bio-motivated vision system and artificial neural network for autonomous UAV obstacle avoidance

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1

Introduction

- UAVs are accessible, they have tremendous market potential
- Autonomous flight may provide solution in many fields (e.g. rail inspection, reaching dangerous or hardly accessable locations, etc.)
- Biological inspiration may provide base for great algorithms (e.g. Nitin et. al, 2018

2

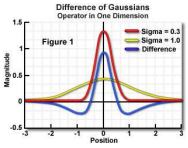
Goals

- Create a biologically motivated image processing system
- Build a neural network for autonomous obstacle recognition
- Use the created models for system which avoids the predefined (display panel) obstacle real-time

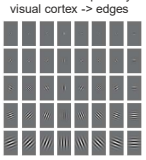
3

Biologically inspired image processing

Difference of Gaussians as retinal ganglion cells –> contrast images



Gabor filter as primary visual cortex -> edges



Output images:
- **„Rod" pathway** – grayscale image
- **„Amacrine" pathway** – grayscale image
- **Red-green discrimination** – R and G channels
- **Blue-yellow discrimination** – R, G, B channels
- **Three channel discrimination** – R, G, B channels
- **S – cone** – blue color channel
- **Gabor filters** – 4 directions x 5 kernel sizes – 20 edge images with edge information

$$\Phi(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{1}{(2\pi\sigma^2}(x^2+y^2))}$$

$$g_c(x,y) := cos(\omega_x x + \omega_y y) e^{\left\{-\frac{x^2+y^2}{2\sigma^2}\right\}}$$

$$g_s(x,y) := \sin(\omega_x x + \omega_y y) e^{\left\{-\frac{x^2+y^2}{2\sigma^2}\right\}}$$

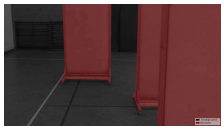
$$RG_{input} = \frac{R+G}{\sqrt{2}}$$

$$YB_{input} = \frac{R+G-2B}{\sqrt{6}}$$

4

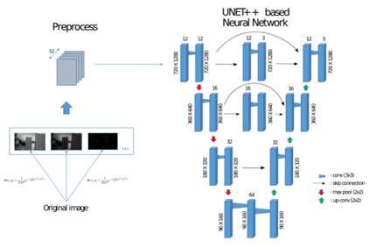
Annotation

- 1534 annotated images
- 800 images used for training
- 734 images used as test set
- 4 variation with the above



5

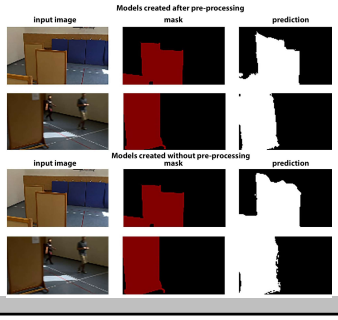
Schematic of U-net and path finding



6

Results II – Efficiency of the tested models

- Visual „inspection”
- With preprocessing
  - Less noise
  - Less FP
  - Faster learning



7

Discussion

- Recognition achieved with good efficiency (best model had a precision of 0.9766±0.0502, and a recall of 0.9718±0.0974
- The system was capable of real time obstacle avoidance using moderate flight speed

8

Future work

- Incororpate the pre-processing methods to the neural network for further advancing speed
- Test more neural network types (e.g. YOLO, maskR CNN), build new hybrid type for the current problem
- Extend the set of recognizable obstacles types
- Foveal processing based on IMU (movement direction)

9

Thank you for your attention!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Main points:
- Biologically motivated pre-processing of the input images
- U-net based neural network for learning
- Autonomous flight and real-time obstacle recognition and avoidance

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10