Object Detection and Tracking Algorithms Using Brain-inspired Model and Deep Neural Networks

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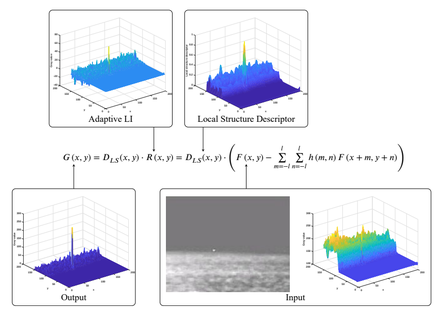
Introduction

- Recent IR object detection and tracking algorithms face several problems.
- For IR object detection, one problem is that the captured infrared target generally has a complex background. Another is that the detection methods are not suitable for various size.
- For IR target tracking, it mainly meets two main challenges, which include: (1) the challenges caused by the environment, such as the serious occlusions, illumination variations, background clutters. (2) The challenges caused by the target itself, such as the target geometric deformation, rotation and gesture variations.
- Applying the signal processing mechanisms of Human Visual System (HVS) in IR object detection and tracking field is beneficial to improve the anti-interference ability as well as the detection and tracking ability.

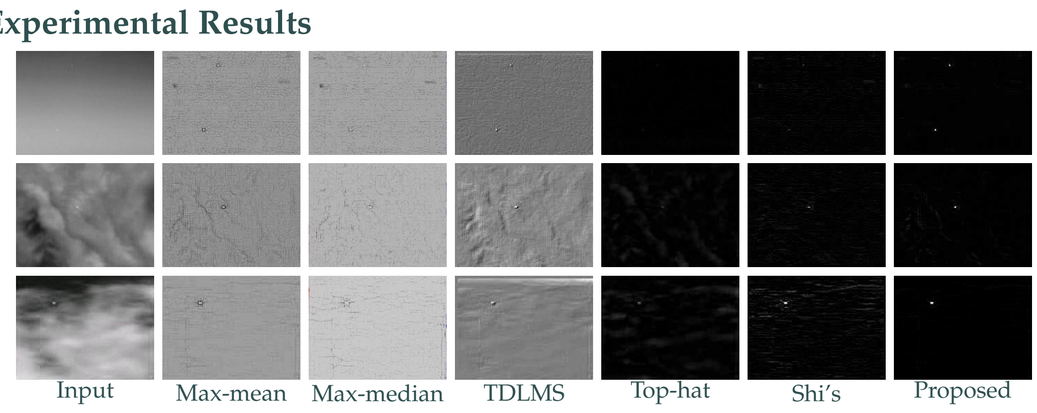
IR Object Detection Algorithm based on Lateral Inhibition and SVD

- **Algorithm process**
  - Lateral Inhibition network
    - Calculate the LI coefficient between two pixels adaptively according to the coordinates and gray values of the pixels.
  - Local Structure Descriptor
    - Calculate the gradient in pixel (x_i, y_i) of image $I(x, y)$
    - Sort the gradient into an $n \times 2$ matrix G and perform SVD operations on it
    - Construct the Local Structure Descriptor $D_{LS}, (0 \leq D_{LS} \leq 1)$, and divide the image pixels into three categories (plat area, edge area, and detailed area).

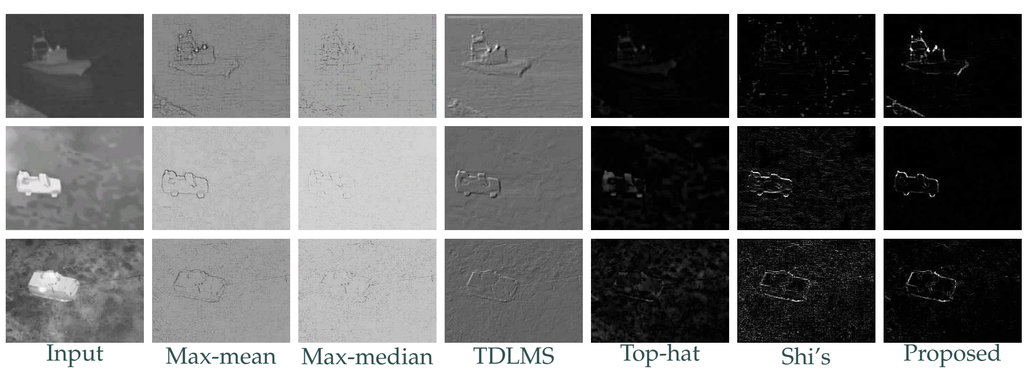


Adaptive LI network

- **Experimental Results**



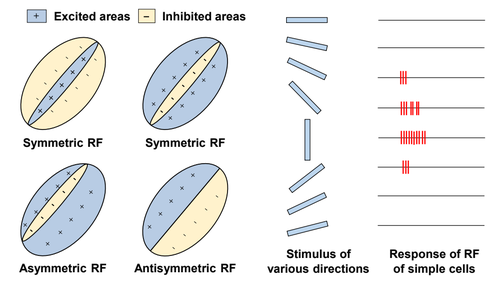
Small target detection results of six algorithms



Big target detection results of six algorithms

IR Object Detection Algorithm based on Receptive Field and Lateral Inhibition

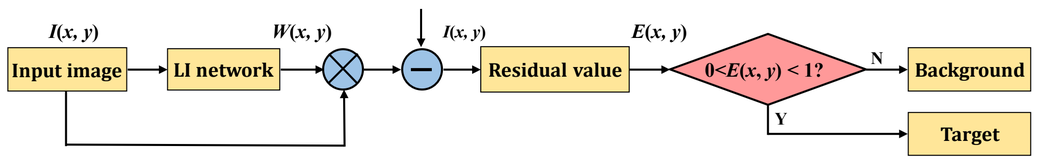
- **Receptive field**
  - Characteristics
    - The majority of neurons in the primary visual cortex respond to a certain direction in a given position of the visual field.
  - Adaptive Gabor Filter
    - First, the gradient direction of each pixel is calculated according to image information.
    - Then, the direction parameter θ is adaptively determined by the calculated gradient directions.
    - Finally, the complete edges corresponding to different directions can be extracted.



Schematic of the receptive fields

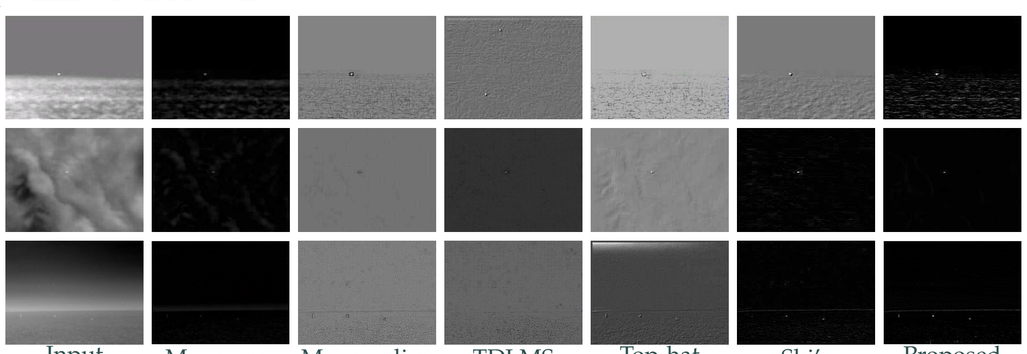
- **Background Prediction Based on LI**
  - The background of IR images is continuous and occupies most of the area, and each pixel of background can be predicted by the gray values of the surrounding pixels.
  - The gray values of pixels in the target contour are poor correlated with that of the surrounding pixels.
  - Background and target can be predicted according to the above characteristics.

$$E(x,y) = I(x,y) - \sum_{(p,q)\in S} W(p,q)\, I(m-p, n-q).$$

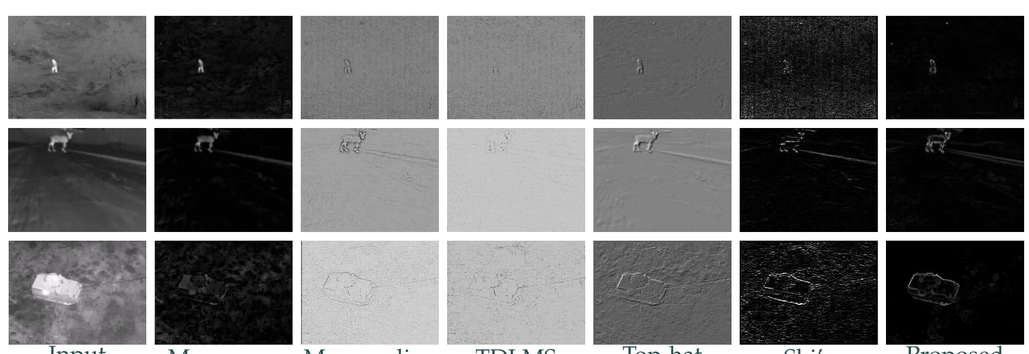


Process of background prediction based on LI

- **Experimental Results**



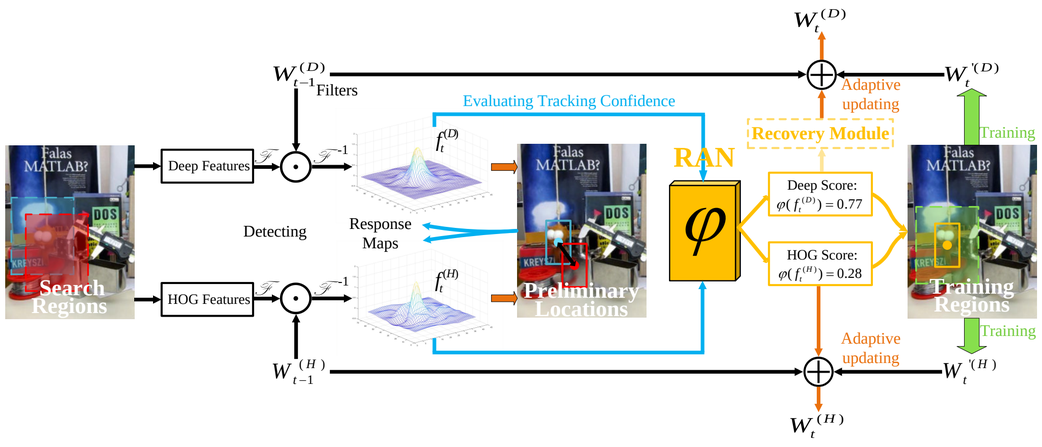
Small target detection results of six algorithms



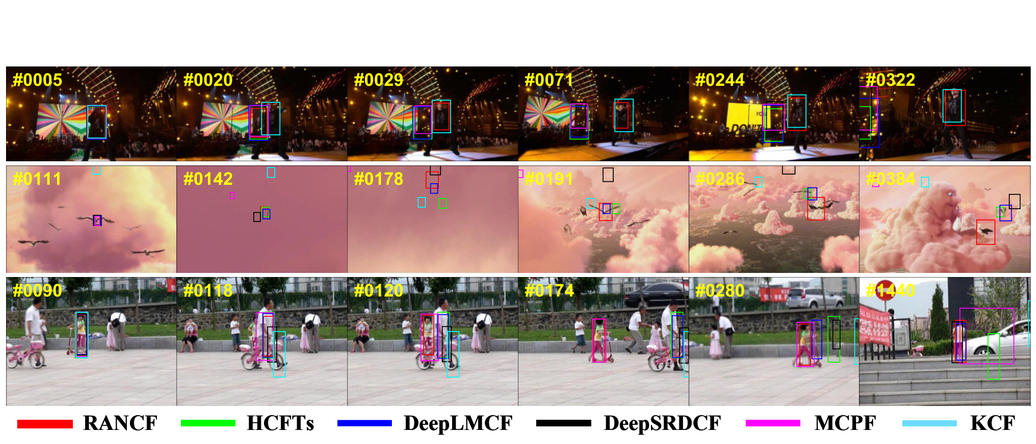
Big target detection results of six algorithms

KCF Tracking Algorithm based on Multi-channel Memory Model

- **Algorithm Process**
  - Multiple filters based on different features work together to use the best tracking results to estimate target movement;
  - Train a small-scale CNN-Response Map Analysis Network (RAN) to evaluate tracking confidence;
  - The frequency and learning rate of filter update are adaptively adjusted according to the score of tracking confidence;
  - Realize stable tracking when reappear after the target is blocked.



Process of KCF Tracking Algorithm based on Multi-channel Memory Model



Comparison Results

Summary

- As the most effective bio-intelligence system, HVS has significant advantages in image processing.
- In this paper, several brain-inspired models and corresponding mathematical models have been studied. Furthermore, the corresponding algorithms are proposed.
- The experimental results showed that, applying brain-inspired models and DNNs is beneficial to achieve accurate infrared target detection and robust tracking under complex conditions.