A Robust Visual System for Small Target Motion Detection

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Introduction

The Definition of Small Targets

Figure: An example of a small moving target in the cluttered background.

- When an object such as UAV, is far away from the observer, it always appears as a small dim speckle in the field of view.

The Definition of Small Targets

Figure: An example of a small moving target in the cluttered background.

- The size of the small dim speckle may vary from 1 pixel to a few pixels, such as 10 $\times$ 10 pixels.

Small Target Motion Detection

- Small target motion detection aims to detect objects of interest which move against cluttered natural environments and appear as small dim speckles in images.

Small Target Motion Detection

- Small target motion detection has a wide variety of applications in defences, surveillance, security and road safety.

Small Target Motion Detection

- However, detecting small targets against cluttered moving backgrounds is always a challenge for artificial visual systems.

Difficulties in Small Target Motion Detection

Figure: A small target is moving in the cluttered background which contains a number of small-target-like features.

- Limited physical cues. For a small target, its physical cues such as shape, texture and color, are difficult to recognize and cannot be used for motion detection.

Difficulties in Small Target Motion Detection

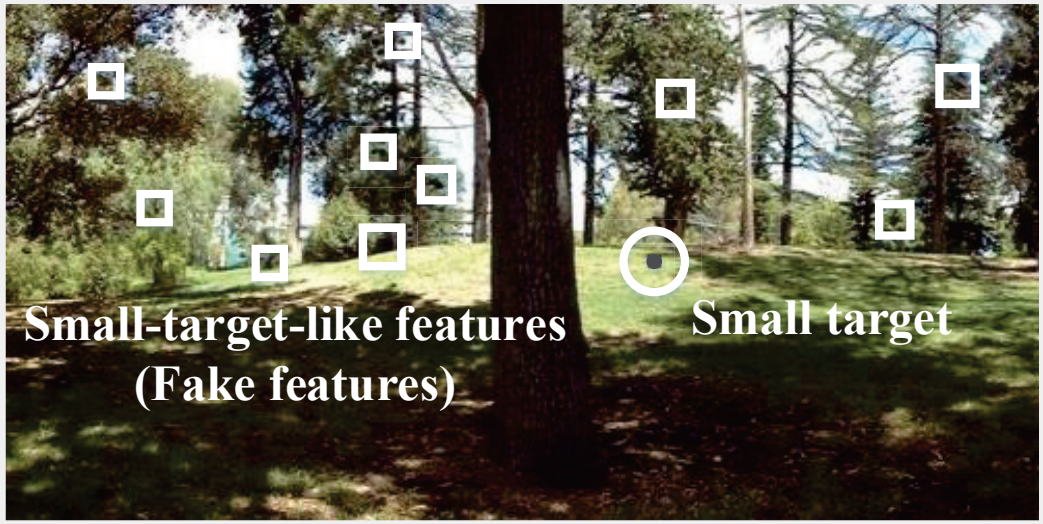

Figure: A small target is moving in the cluttered background which contains a number of small-target-like features.

- The extremely cluttered backgrounds and a number of small-target-like features. The cluttered background always contains a number of features which are quite similar to small targets.

Difficulties in Small Target Motion Detection

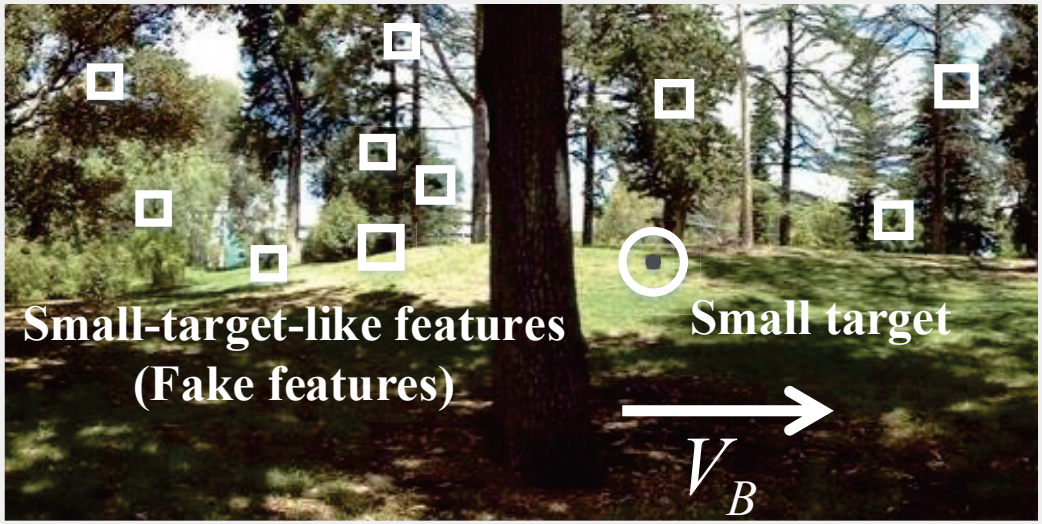

Figure: A small target is moving in the cluttered background which contains a number of small-target-like features. The background is also moving and its motion direction is denoted by the arrow V_B.

- Free motion of camera. It is difficult to discriminate moving objects with different sizes, such as trees, bushes and small insects.

An Input Image Sequence

Biological Background

Small Target Motion Detectors (STMDs)

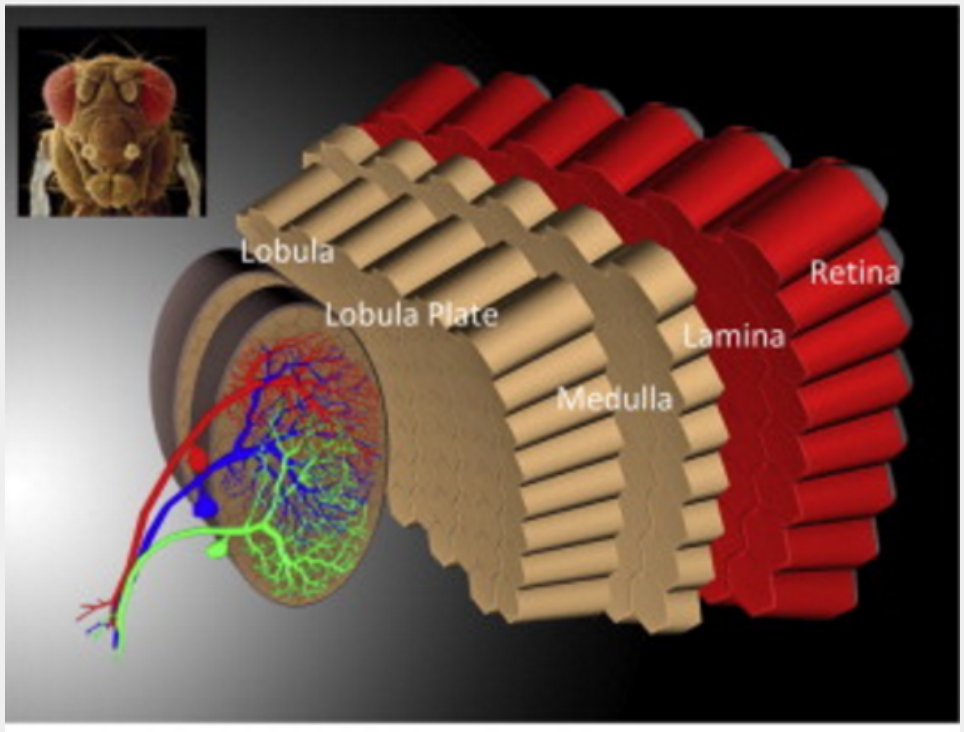

Figure: Schematic of the insect's visual system.

- As a source of inspiration, insects are quite apt at searching for mates or tracking prey - which always appear as small dim speckles in the visual field.

Small Target Motion Detectors (STMDs)

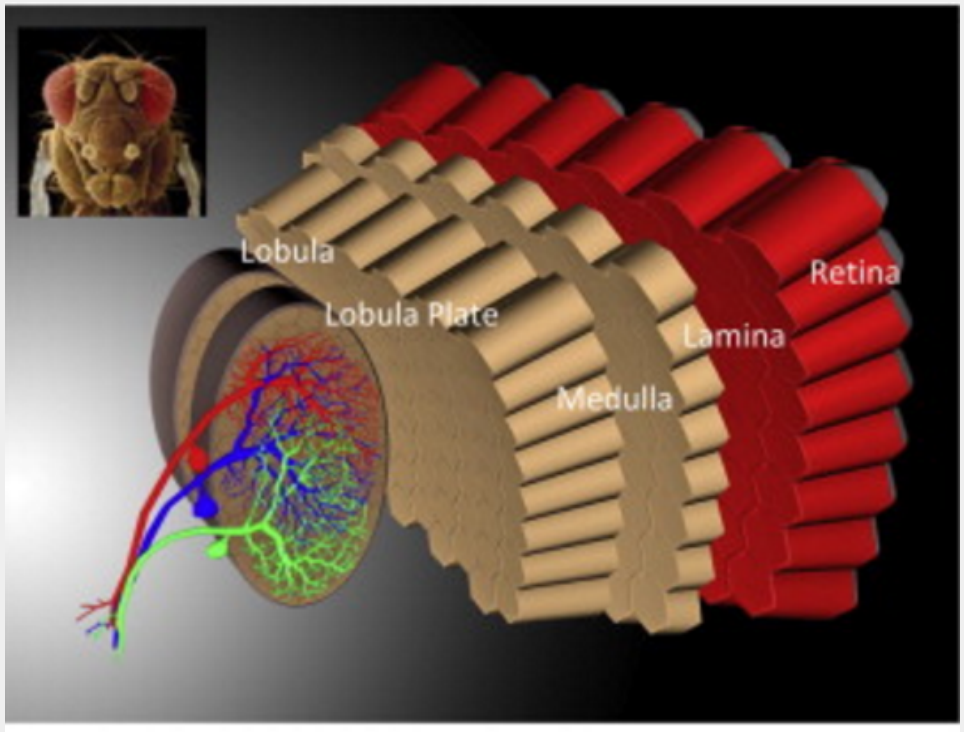

Figure: Schematic of the insect's visual system.

- As revealed recently, the exquisite sensitivity of insects for small target motion is coming from a class of specific neurons called small target motion detectors (STMDs).

Small Target Motion Detectors (STMDs)

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- Size selectivity.
- Direction selectivity.

Objectives

Based on the above biological findings, we are supposed to proposed a neural network for small target motion detection. It should satisfy

- size and direction selectivities.
- robust ability to detect small targets in cluttered backgrounds.

Modeling

ESTMD and DSTMD

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ESTMD and DSTMD

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- However, it did not consider direction selectivity and showed no different responses to small target motion oriented along different directions.
- In order to account for both size and direction selectivities, we proposed a directionally selective small target motion detector (DSTMD) [1].

ESTMD and DSTMD

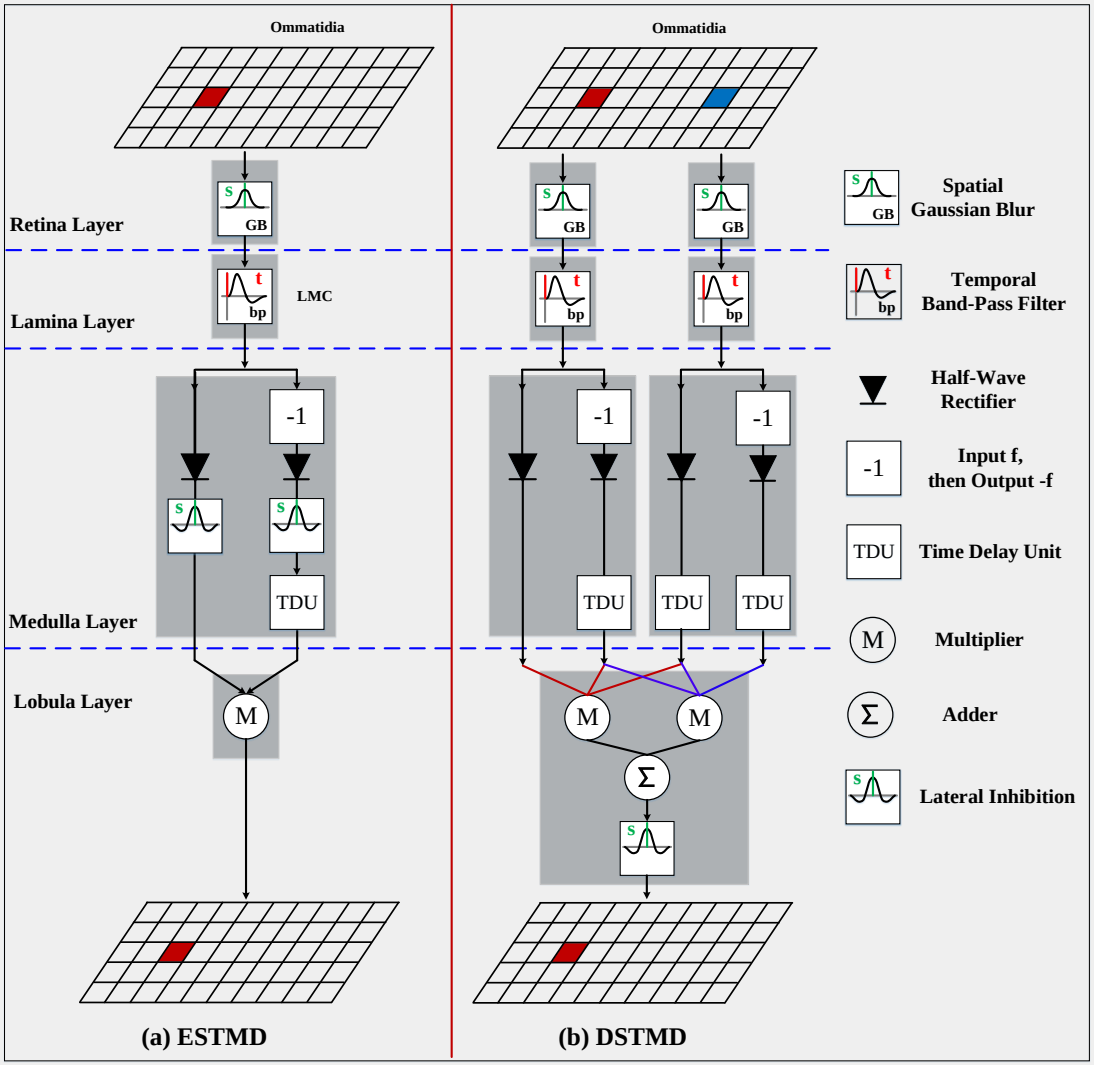
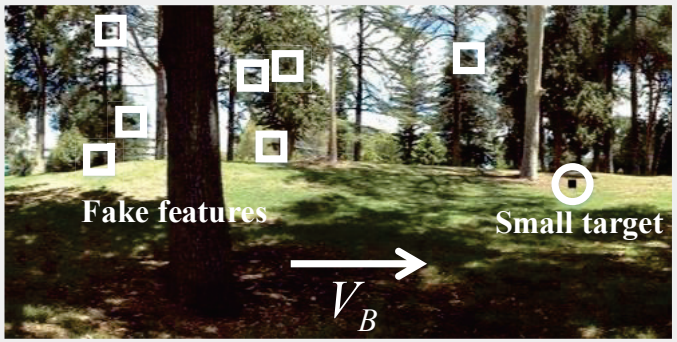
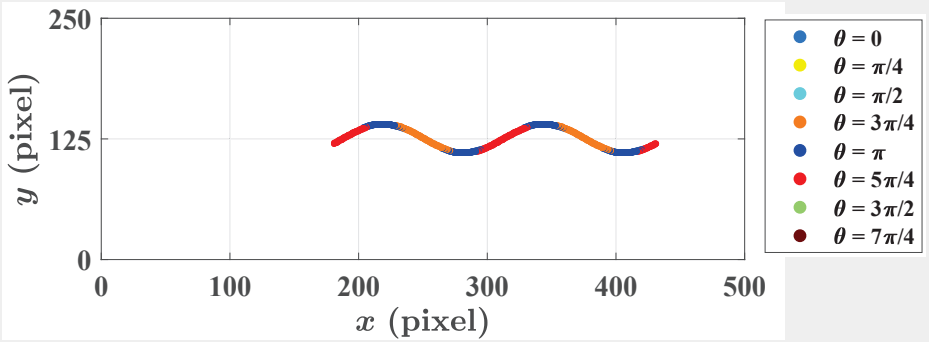


Figure: Models of ESTMD and DSTMD

ESTMD and DSTMD



(a)



(b)

Figure: (a) Representative frame of the input image sequence. (b) The motion trace of the small target during time period [0, 1000] ms, i.e., ground truth.

ESTMD and DSTMD

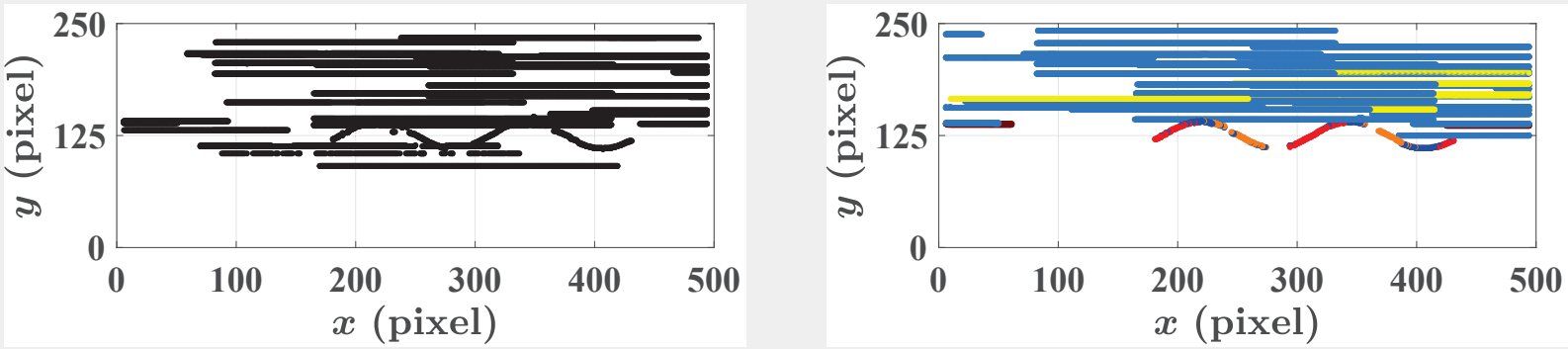


Figure: Motion traces detected by the ESTMD and DSTMD. For fair comparison, the three models have fixed detection rates ($D_R = 0.85$). (a) ESTMD. (b) DSTMD. Since the ESTMD cannot detect motion direction, its outputs are all shown in black color.

STMD Plus

- In the insects' visual systems, multiple visual cues are extracted by different specialized neural circuits.

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- In the insects' visual systems, multiple visual cues are extracted by different specialized neural circuits.
- Multiple neural circuits could be coordinated to discriminate small target motion.

STMD Plus

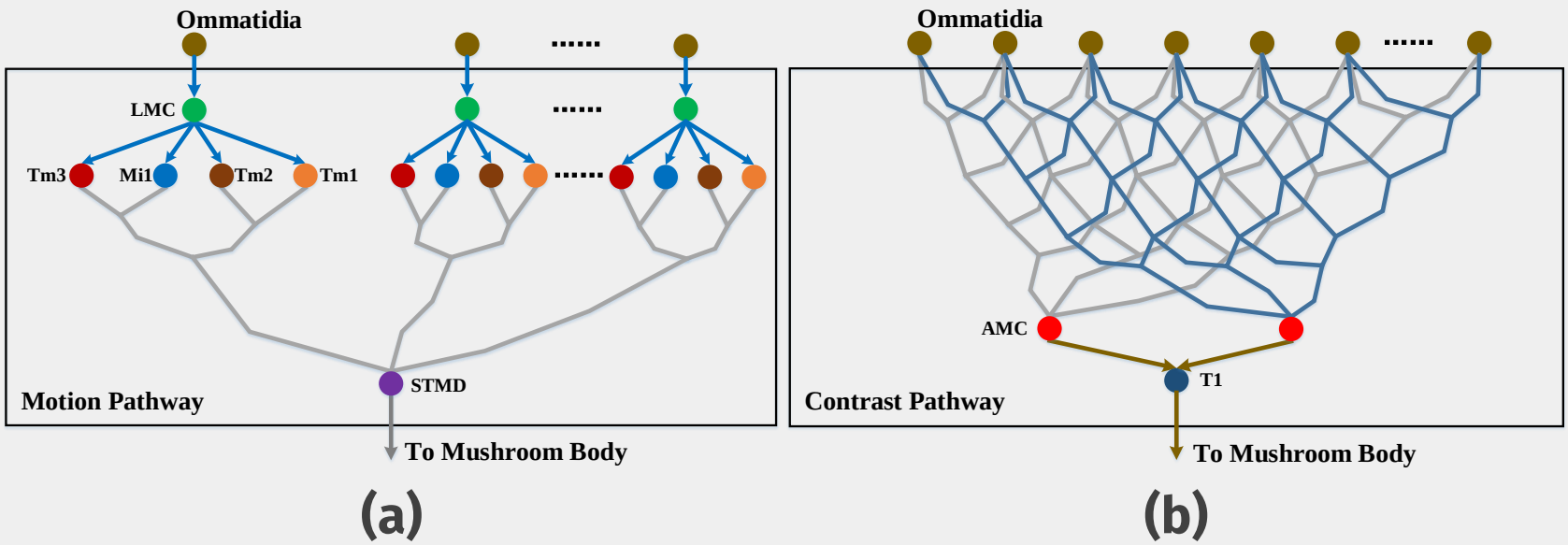


Figure: Wiring sketches of motion and contrast pathways. (a) Motion Pathway. (b) Contrast Pathway.

STMD Plus

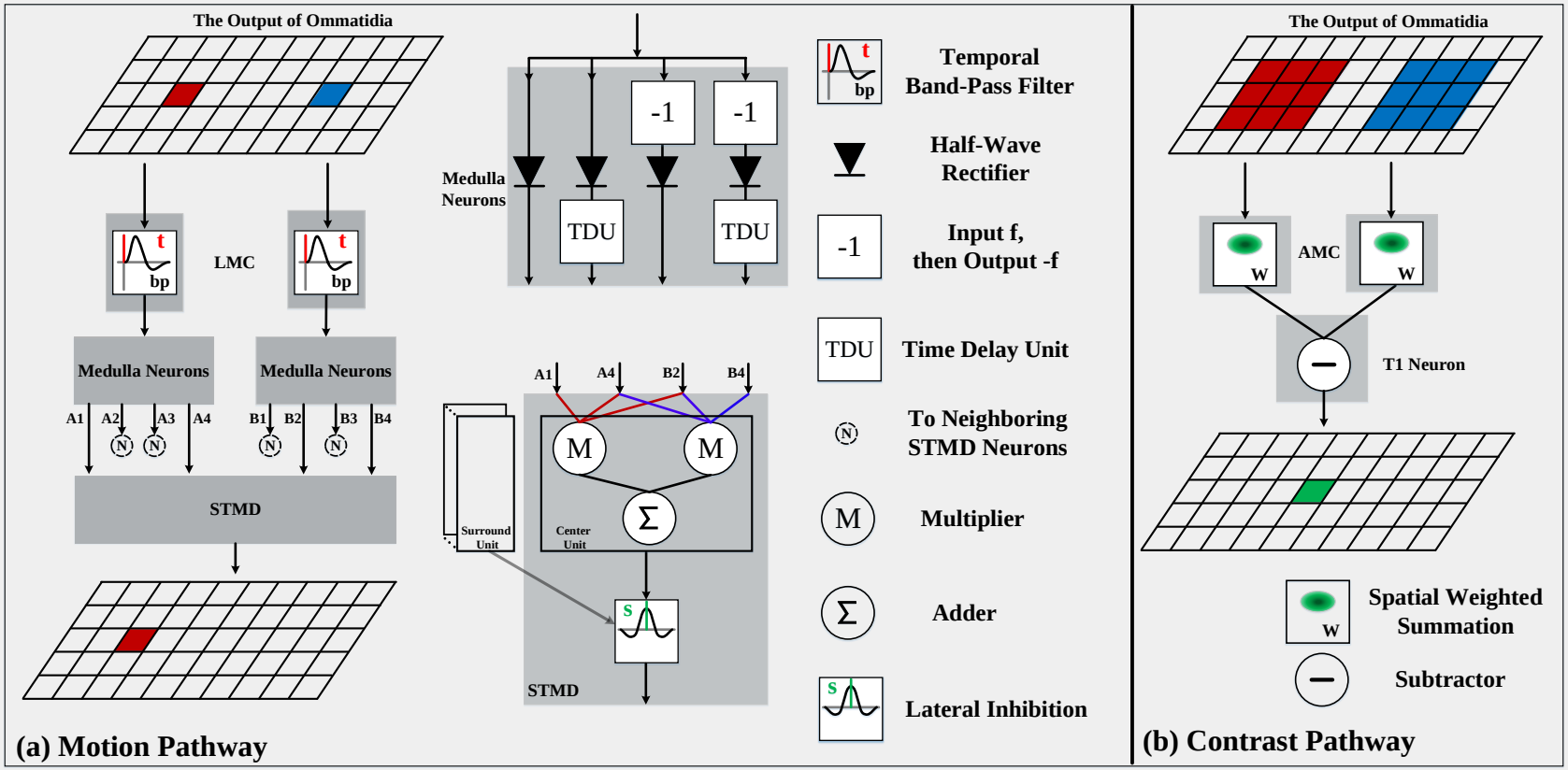


Figure: Schematic illustration of models of motion and contrast pathways.

STMD Plus

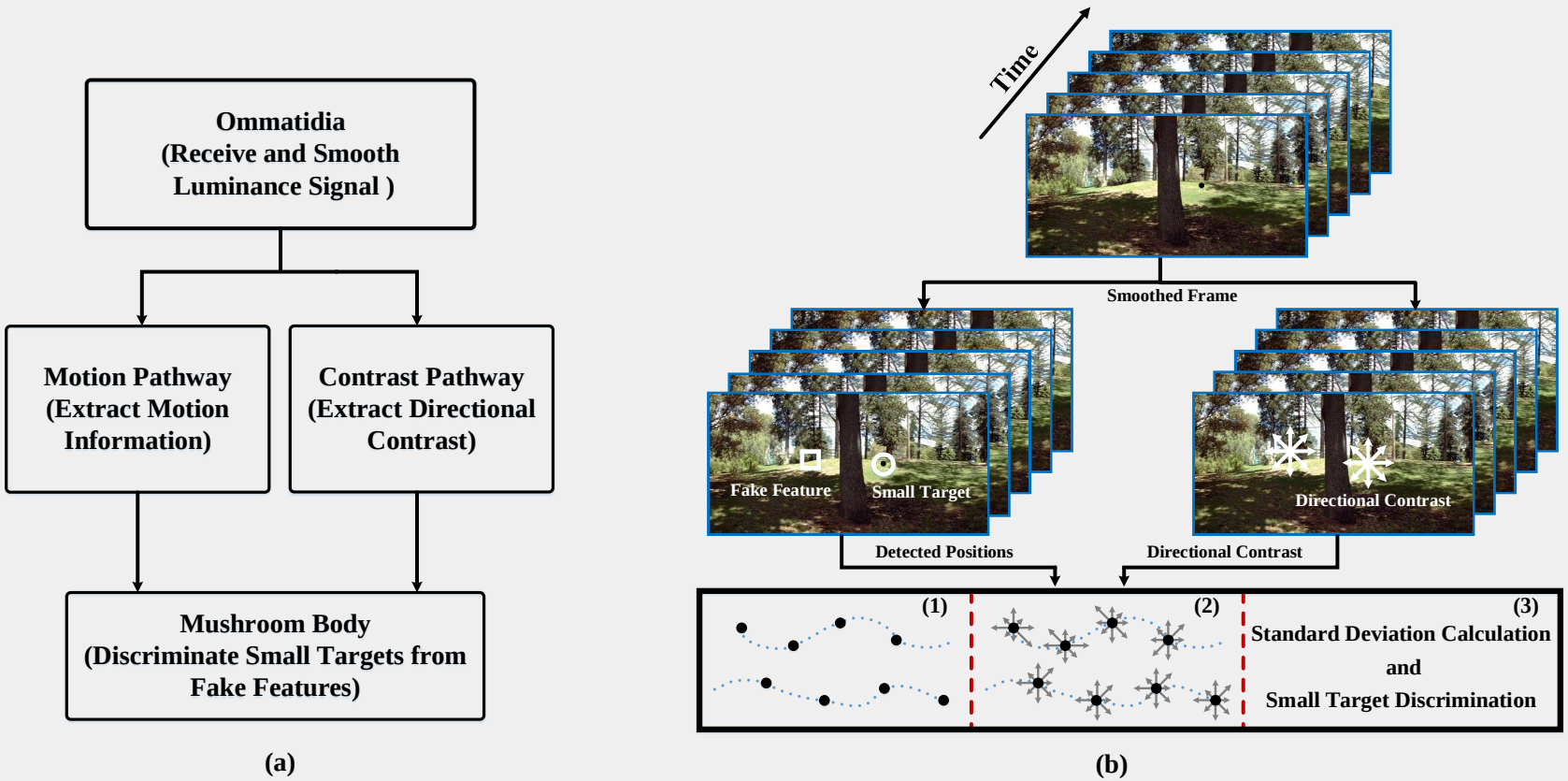


Figure: (a) Schematic illustration of the proposed visual system model (STMD+). (b) The image processing of the proposed visual system model.

STMD Plus

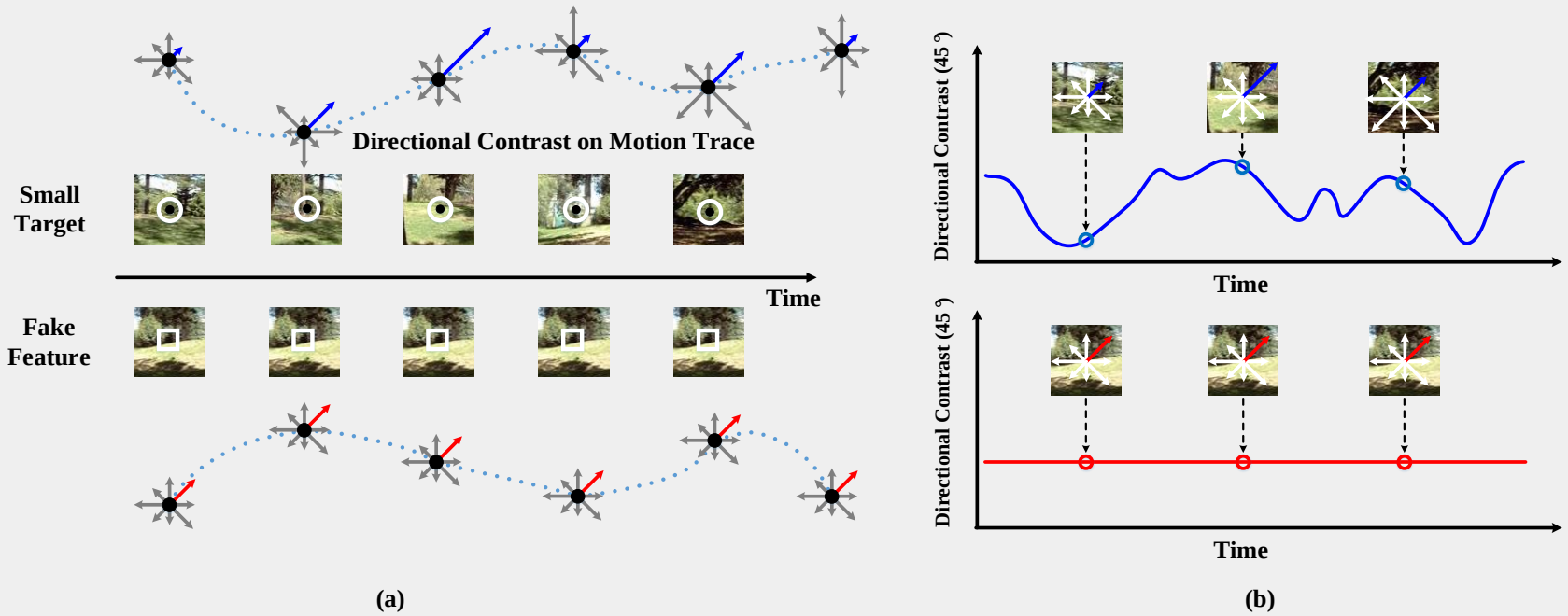
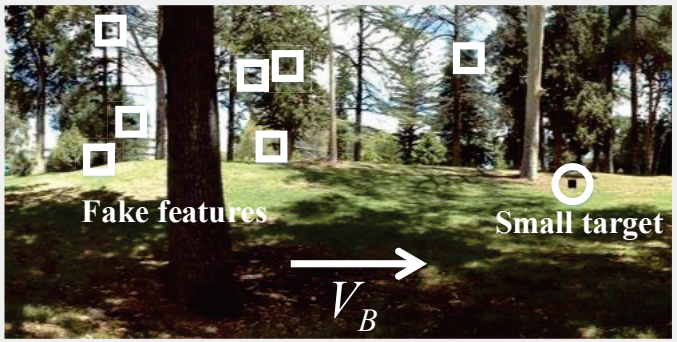


Figure: (a) Directional contrast on two motion traces which are caused by the small target and fake feature, respectively. (b) Directional contrast along 45° direction of the small target (top) and fake feature (bottom) with respect to time.



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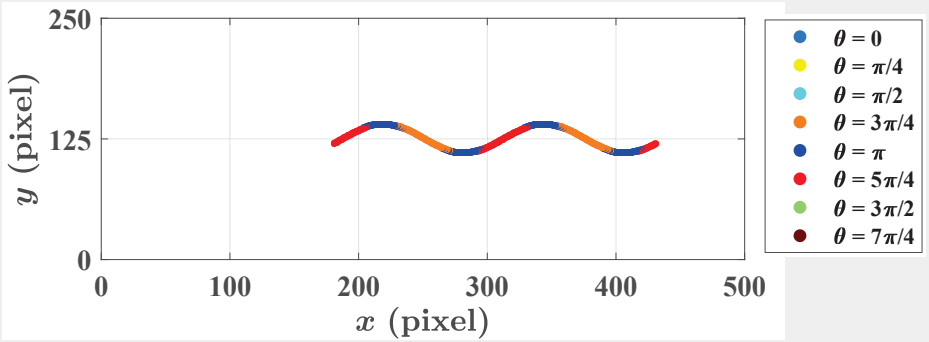

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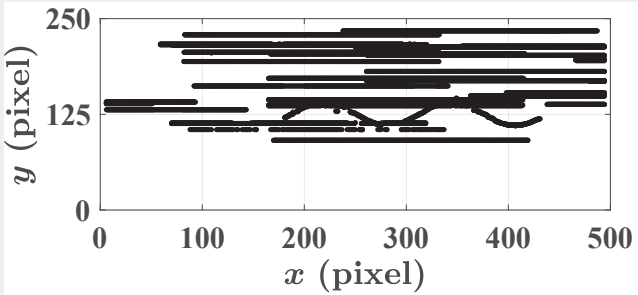

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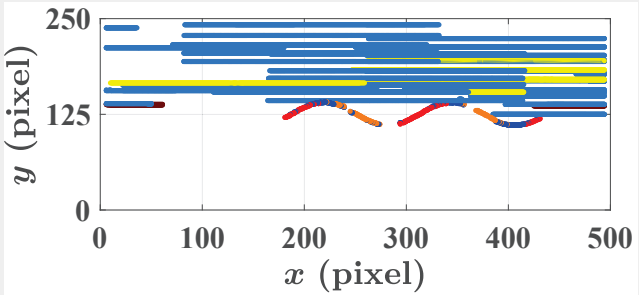
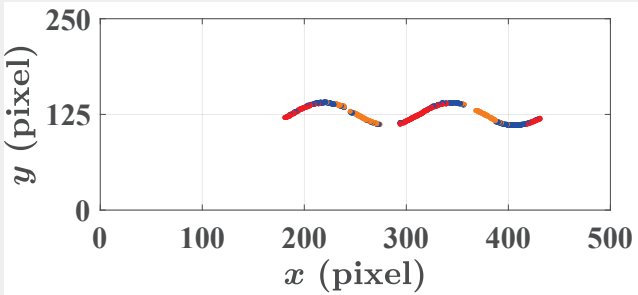


(b)



(c)

Figure: Motion traces detected by the ESTMD, DSTMD and STMD+. For fair comparison, the three models have fixed detection rates ($D_R = 0.85$). (a) ESTMD. (b) DSTMD. (c) STMD+.

References

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