SCIENCE CHINA
Information Sciences

• Supplementary File •

High-speed target tracking system based on multi-interconnection heterogeneous processor and multi-descriptor algorithm

Jiaqing Wang[1,3], Yongxing Yang[1], Liyuan Liu[1,3] & Nanjian Wu[1,2,3*]

[1]*State Key Laboratory for Superlattices and Microstructures, Institute of Semiconductors;*
[2]*Center for Excellence in Brain Science and Intelligence Technology;*
[3]*University of Chinese Academy of Sciences, Beijing,* 100083*, China*

Appendix A Experiments

Figure A1 shows the result of the target tracking. The target is a toy jeep car. The tracking system identifies the target and takes the camera to the right place to make the target locate within the central area of the image. The deviation between the centroid of the image and the jeep is shown in Figure A1(a) where the green and red lines represent the deviations in x and y coordinates in the images, respectively. Because of the limitation of motor potential ability, the tracking error of 10 pixels is allowed to avoid the actuator vibrating back and forth when the target moves in a high speed. The car moves around a cycle, and as we can see, the deviation is strictly kept in 10 pixels even if there are many other objects, such as boxes and the corner of the table. The trajectories of the actuator are also given in Figure A1(b). The tilt (green line) and pan (red line) movement correspond to the periodical motion of the target.

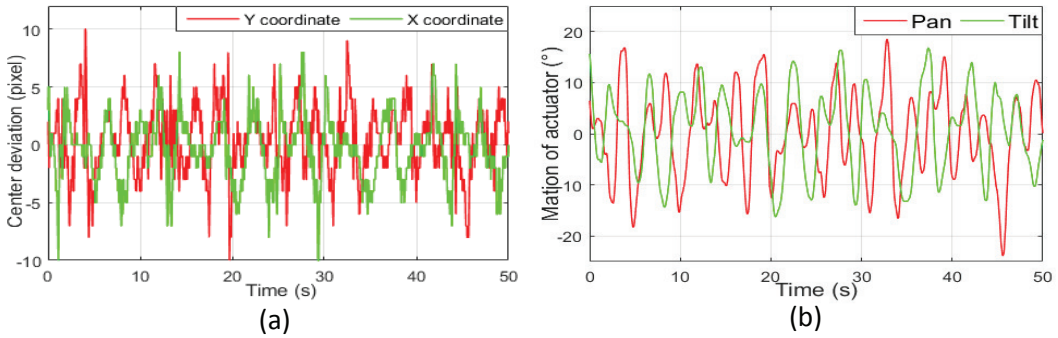

Figure A1 Target tracking result: (a) Deviation between target center and vision center, (b) Trajectory of the pan motor and the tilt motor.

Figure A2(a) and Figure A2(b) show the actual centroid position (solid line) and the calculated centroid position of the jeep car. The calculated position by GLLBP tracking (dash-dotted line) is drift away from the ground truth (solid line) at the beginning of tracking. And the calculated position by LBP tracking (dashed line) keeps with the ground truth until the jeep moves close to a box. Only the calculated position by multi-descriptor tracking can retain the same trajectory with the ground truth. Although errors exist, they are tolerable for a suitable control algorithm.

Figure A3 shows a comparison with previously reported tracking systems. The algorithms proposed in these studies either utilize binary image based methods [3,4] or single descriptor based methods [1,2]. The binary image based methods can only work in artificial environments with a clear background and constant illumination. And the single descriptor based methods, as mentioned above, has an incomplete description program. The proposed algorithm adopts multi descriptors

* Corresponding author (email: nanjian@red.semi.ac.cn)

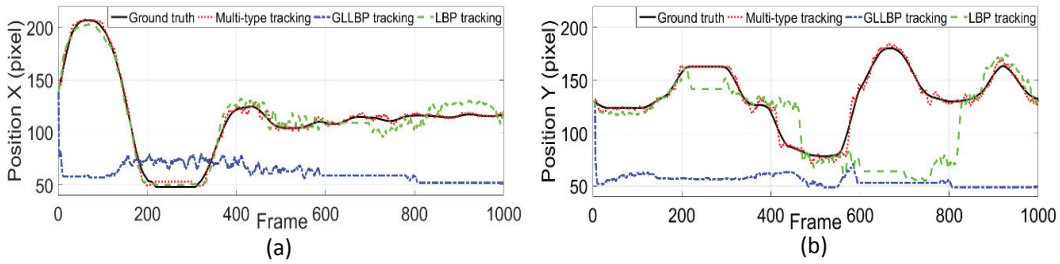

Figure A2 The result of three kinds of tracking algorithm: (a) x coordinate of desired (solid line), multi-descriptor tracking (dotted line), GLLBP tracking (dash-dotted line) and LBP tracking (dashed line) center. (b) y coordinate of desired (solid line), multi-descriptor tracking (dotted line), GLLBP tracking (dash-dotted line) and LBP tracking (dashed line) center.

that can work in much more complex environments. But it increases the calculation quantity of the histogram statistics, so we improve the hardware to accelerate the histogram statistics. And the tracking speed can achieve 950 fps.

To make a simple analysis of power consumption, we assume that each instruction consumes the same power, which means that an algorithm executing more instructions would consume more power. From Figure A3, we can know that the GLLBP based algorithm [1] contains 35714 instructions and the LBP based algorithm [2] contains 50000 instructions, while the proposed algorithm contains 103510 instructions. Also showed in Figure A3, the proposed algorithm searches 961 times, while the GLLBP based algorithm and the LBP based algorithm only search 121 times, that means the proposed algorithm executes 108 instructions on one object window, while 295 instructions for the GLLBP based algorithm and 413 instructions for the LBP based algorithm. Although the previous algorithms consume less power, the proposed algorithm is more efficient when making operations on one object window. It attributes the success to the multi-Interconnection heterogeneous processor which using more hardware resources.

	This work	Ref.[1]	Ref.[2]	Ref.[3]	Ref.[4]
Image	8 bit mono	8 bit mono	8 bit mono	2 bit binary	8 bit mono
Resolution	2048*1088	750*480	128*128	16*16	64*64
Algorithm	Multi-descriptor based	GLLBP based	LBP based	Binary image based	Binary image based
Search times	961	121	121	N/A	N/A
Frequency (MHz)	100	100	50	20	N/A
Tracking speed (fps)	950	2800	1000	1000	100

Figure A3 Comparison with previous studies.

References

1 Yang Y, Yang J, Liu L, et al. High-Speed Target Tracking System Based on a Hierarchical Parallel Vision Processor and Gray-Level LBP Algorithm. IEEE Trans Syst Man Cybern: Syst, 2016, 47: 950-964
2 Yang J, Shi C, Liu L, et al. Heterogeneous vision chip and LBP-based algorithm for high-speed tracking. Electron Lett, 2014, 50: 438-439
3 Miao W, Lin Q, Zhang W, et al. A programmable SIMD vision chip for real-time vision applications. IEEE J Solid-State Circuits, 2008, 43: 1470-1479
4 Zhao B, Zhang X, Chen S, et al. A 64 64 CMOS image sensor with on-chip moving object detection and localization. IEEE Trans Circuits Syst Video Technol, 2012, 22: 581-588