

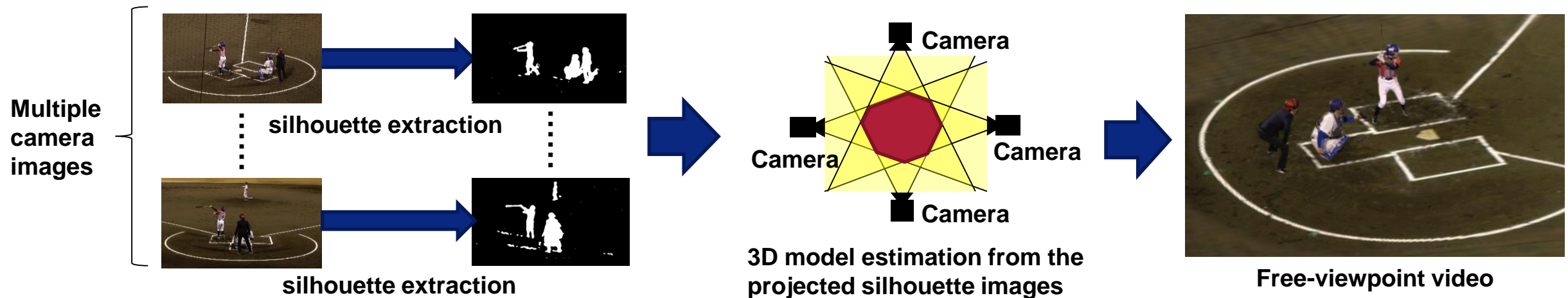
# **Accurate Background Subtraction Using Dynamic Object Presence Probability in Sports Scenes**

**Ryosuke Watanabe, Jun Chen, Tomoaki Konno, and Sei Naito  
(KDDI Research, Inc.)**

## ■ Motivation

- In recent years, silhouette extraction technologies play an essential role in following applications.
  - free-viewpoint video (FVV) [1]
  - sports video analysis [2].
- Accurate silhouette extraction in a sports scene is an important research topic.

### Free-viewpoint video production [1]



[1] J. Chen, et al, "Fast Free viewpoint Video Synthesis Algorithm for Sports Scenes", IROS 2019, pp. 3209 3215 (2019).

[2] M. Mentzelopoulos, et al, "Active Foreground Region Extraction and Tracking for Sports Video Annotation," Neural Process Lett 37, pp. 3346, (2013).

## ■ Issues to be improved in conventional approaches

### ● Background subtraction [3-6]

- Difficult to correctly extract under complicated lighting situation

### ● Deep-learning based segmentation [7]

- Recognition error
- Unclear silhouette outline

## ■ Our proposal

- We propose an accurate silhouette extraction method called **“Dynamic Object Presence Probability (DOPP)”**.



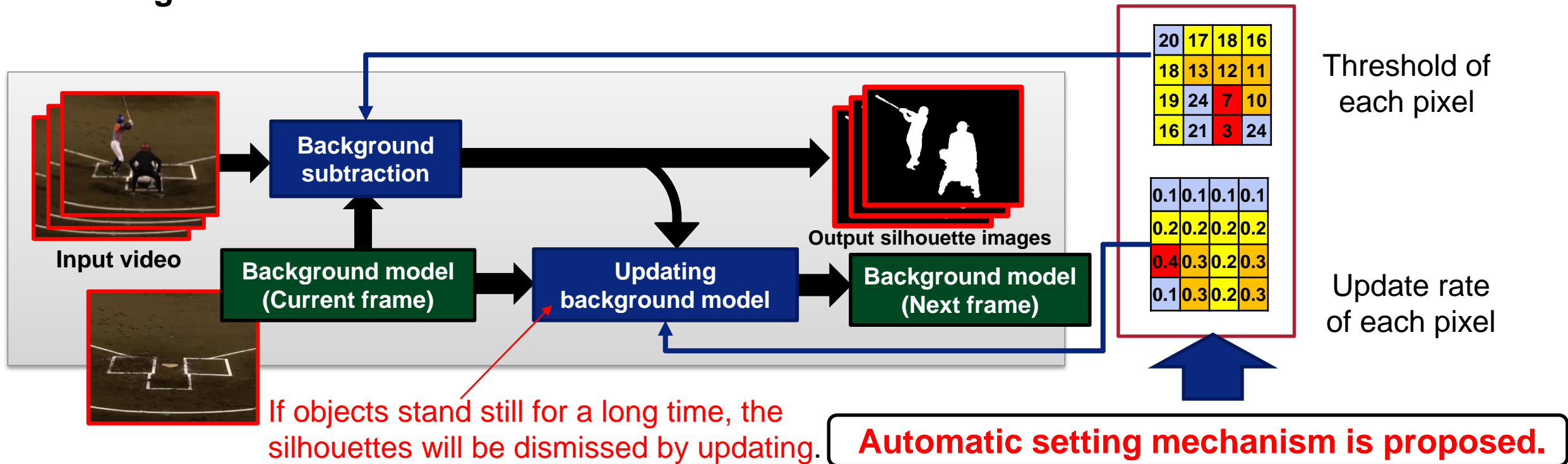
Processing



Sihouette extraction by [7]

- [3] P. KaewTraKulPong, et al, "An improved Adaptive Background Mixture Model for Real-time Tracking with Shadow Detection," Workshop on Advanced Video Based Surveillance Systems, (2001).  
[4] Z. Zivkovic, et al. Efficient adaptive density estimation per image pixel for the task of background subtraction," Pattern Recognition Letters, vol. 27, no. 7, pp. 773-780, (2006)  
[5] M. Hofmann, et al, "Background segmentation with feedback: The pixel-based adaptive segmenter," Computer Vision and Pattern Recognition Workshops, pp. 38-43, (2012).  
[6] P. St-Charles, et al, "SuBSENSE: A Universal Change Detection Method With Local Adaptive Sensitivity," IEEE Transactions on Image Processing, vol. 24, no. 1, pp. 359-373, (2015).  
[7] K. He, G. Gkioxari, P. Dollr and R. Girshick, "Mask R-CNN," 2017 IEEE International Conference on Computer Vision, pp. 2980-2988, (2017).

- Threshold and update rate of background subtraction are changed dynamically by the object recognition results.

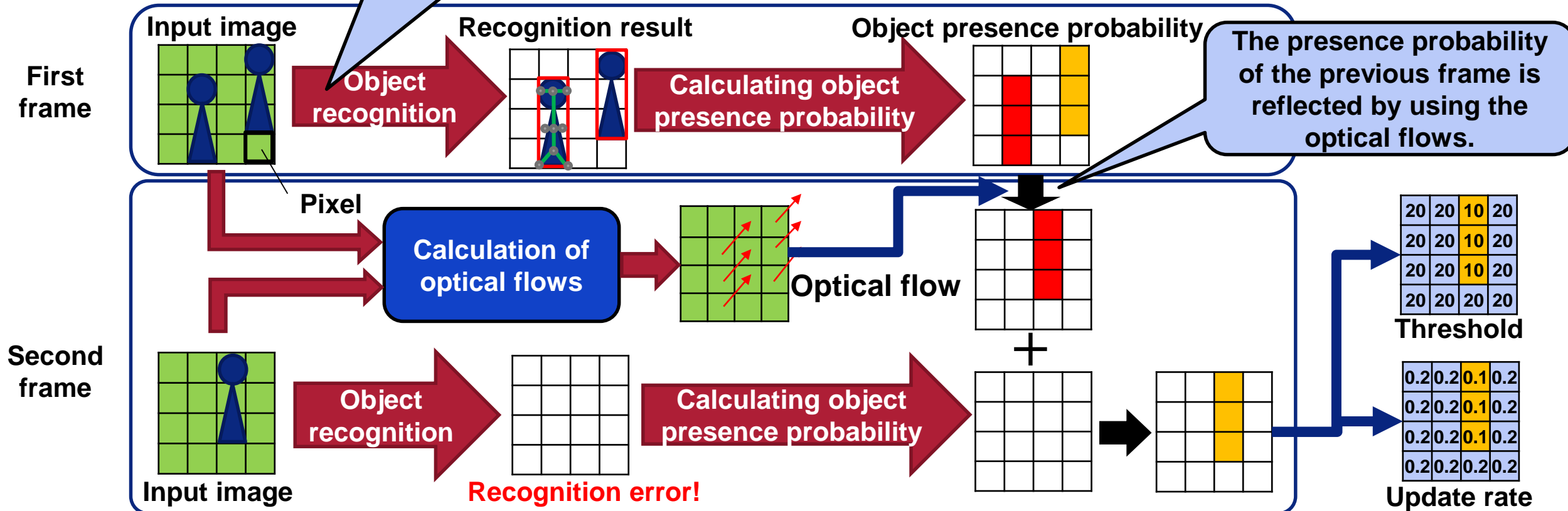


## ■ When objects are recognized...

- Setting low threshold → The pixels are easily determined as a foreground.
- Setting low update rate → Silhouettes of static objects are maintained.

# Proposed method

The high object presence probability is set to pixels where the objects are recognized by the Mask R-CNN [7] and OpenPose [8]



**By using optical flows, the effect of recognition errors is alleviated.**

[8] Z. Cao, T. Simon, et al, "Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields", IEEE Conference on Computer Vision and Pattern Recognition, pp. 7291–7299, (2017).

## ■ We evaluated three sports sequences (Baseball, Rugby and Badminton[9])

- Several conventional methods were compared with the DOPP method.
- F-Measure was used to evaluate the silhouette extraction quality.

Quantitative evaluation results

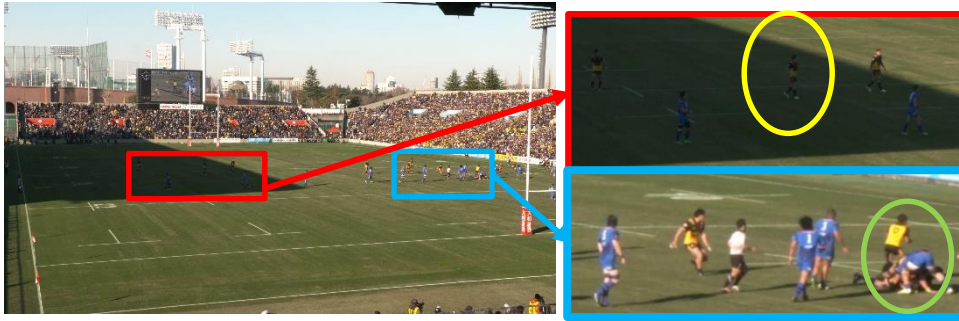
Method	Baseball	Rugby	Badminton[9]
DOPP (Proposed Method)	0.957	0.887	0.943
GMM[3]	0.539	0.513	0.601
KNN[4]	0.770	0.785	0.666
PBAS[5]	0.874	0.664	0.703
SubSENSE[6]	0.917	0.681	0.887
Mask R-CNN[7]	0.889	0.780	0.846

※ The red and blue characters show the first and the second highest F-measure, respectively.

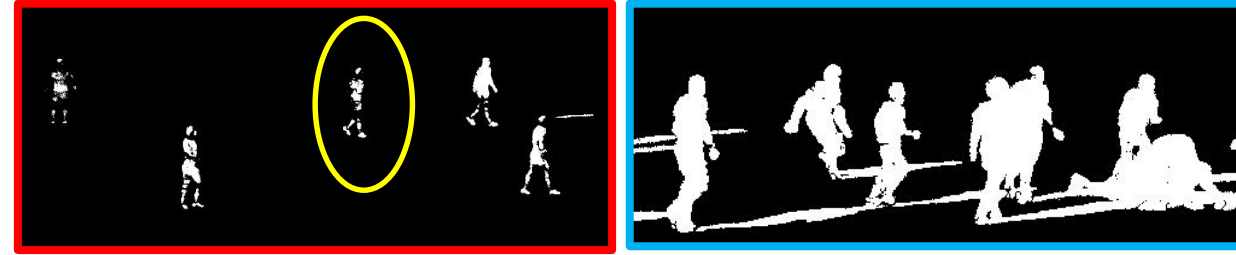
**Our DOPP method achieved the highest quality score for all sequences.**

[9] Y. Wang, et, al, "CDNET 2014: an expanded change detection benchmark dataset, "IEEE Conference on Computer Vision and Pattern Recognition Workshops, pp.387-394, (2014).

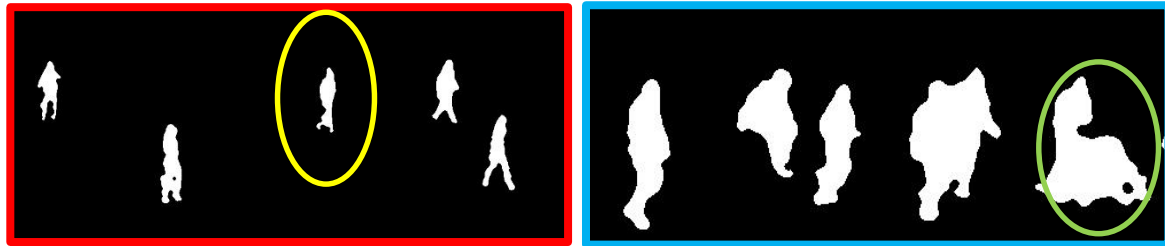
## ■ Extracted silhouettes comparison (Rugby)



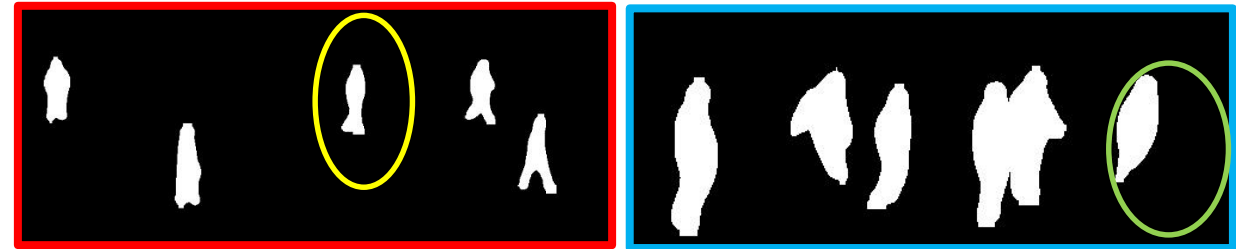
Input frame



KNN



DOPP (Proposed Method)



Mask R-CNN

## ■ Summary

- **The accurate background subtraction method called DOPP was proposed.**
  - Threshold and the update rate of background subtraction are dynamically changed by the object recognition results and optical flow.
  - The quality score of the proposed method outperformed that of the conventional methods.

## ■ Future work

- **Experiments with many datasets for confirming the robustness (e.g. other sports and bad weather condition)**
- **Acceleration for real-time calculation**