A Hybrid Video Anomaly Detection Framework via Memory-Augmented Flow Reconstruction and Flow-Guided Frame Prediction

Zhian Liu[1] Yongwei Nie[1*] Chengjiang Long[2] Qing Zhang[3] Guiqing Li[1]
[1]South China University of Technology [2]JD Finance America Corporation [3]Sun Yat-sen University

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Background & Motivation

- Surveillance system is widely used in many places.
- Video anomaly detection is an essential task to save human labor, with goal to identify unexpected events.
- Since the anomaly rarely happens and is free of forms, we treat it as an unsupervised learning problem with normal data only.

Contributions

- Design a novel hybrid framework, combining flow reconstruction and flow-guided frame prediction, named as HF^2-VAD.
- Design the Multi-Level Memory Autoencoder with Skip Connections (ML-MemAE-SC) for flow reconstruction.
- Propose to model the normal consistency between flows and frames by leveraging the conditional Variational Autoencoder (CVAE).

Datasets & Metric & Project

- Datasets: Ped2, Avenue, ShanghaiTech
- Metric: Area Under the Receiver Operation Characteristic (AUROC)
- Code: github.com/LiUzHiAn/hf2vad

Acknowledgment

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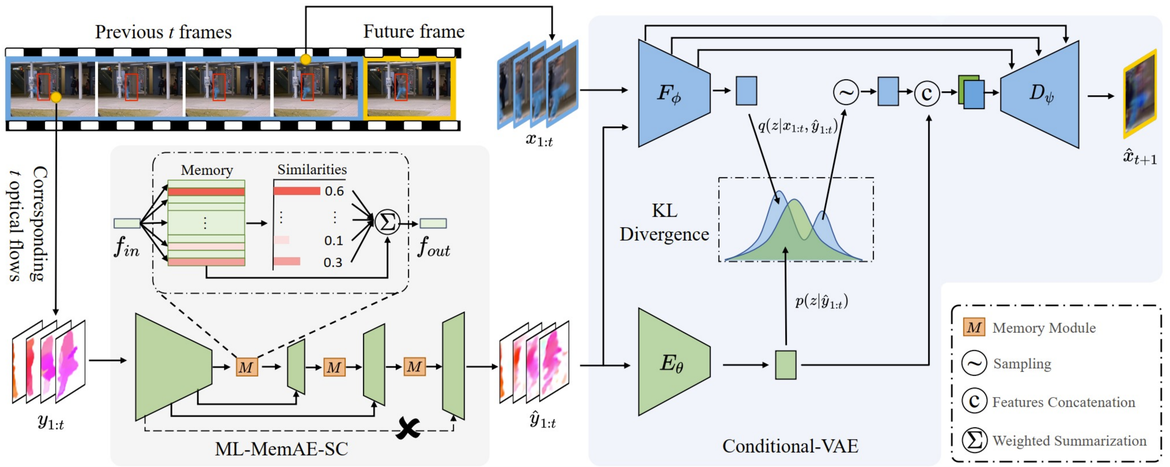
Proposed HF^2-VAD



$$\mathcal{L}_{ML-\text{MemAE-SC}} = \lambda_{\text{recon}}\mathcal{L}_{\text{recon}} + \lambda_{\text{ent}}\mathcal{L}_{\text{ent}}$$

$$\mathcal{L}_{\text{recon}} = \|y_{1:t} - \hat{y}_{1:t}\|_2^2 \quad \mathcal{L}_{\text{ent}} = \sum_{i=1}^{M}\sum_{k=1}^{N} -\hat{w}_{i,k}\log(\hat{w}_{i,k})$$

$$\mathcal{L} = \lambda_{CVAE}L_{CVAE} + \lambda_{gd}||\Delta\hat{x}_{t+1} - \Delta x_{t+1}||_1$$

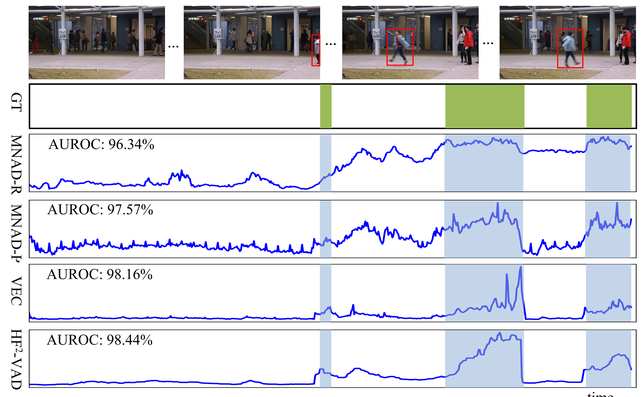
$$\mathcal{L}_{CVAE} = KL[q(z \mid x_{1:t}, y_{1:t})\|p(z \mid y_{1:t})] + \|x_{t+1} - \hat{x}_{t+1}\|_2^2$$

Anomaly score $S_r = \|\hat{y}_{1:t} - y_{1:t}\|_2^2 \quad S_p = \|\hat{x}_{t+1} - x_{t+1}\|_2^2 \quad S_{O_i} = w_r \cdot \frac{S_r - \mu_r}{\sigma_r} + w_p \cdot \frac{S_p - \mu_p}{\sigma_p}$

- Quantitative comparisons

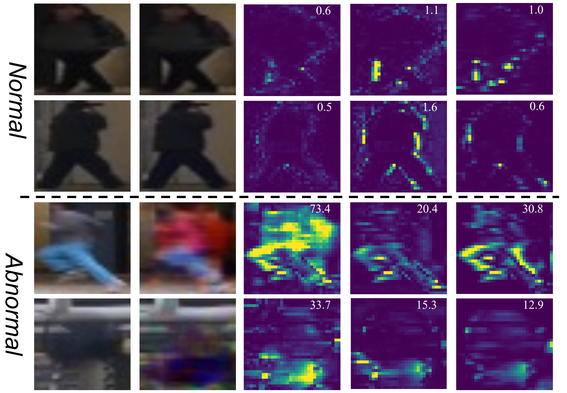
	Method	UCSD Ped2	CUHK Avenue	SHTech
Recon.	Conv-AE [11]	90.0	70.2	-
	ConvLSTM-AE [32]	88.1	77.0	-
	GMFC-VAE [7]	92.2	83.4	-
	MemAE [8]	94.1	83.3	71.2
	MNAD-R [39]	90.2	82.8	69.8
Pred.	Frame-Pred. [26]	95.4	85.1	72.8
	Conv-VRNN [31]	96.1	85.8	-
	MNAD-P [39]	97.0	88.5	70.5
	VEC [50]	97.3	90.2	74.8
Hybrid	ST-AE [53]	91.2	80.9	-
	AMC [37]	96.2	86.9	-
	AnoPCN [49]	96.8	86.2	73.6
	HF^2-VAD w/o FP	98.8	86.8	73.1
	HF^2-VAD w/o FR	94.5	90.2	76.0
	HF^2-VAD	**99.3**	**91.1**	**76.2**

- Qualitative comparisons



Abnormal event: kid running.

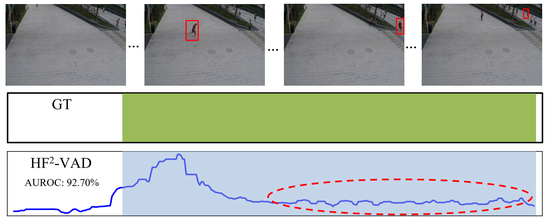
Detailed Visualization



Ablation study

	Memory-augmented Reconstruction Models	Prediction Models		AUROC
		VAE	CVAE	
Flow	✓			96.27
	✓			97.75
	✓			98.81
Frame		✓		89.96
			✓	94.48
Hybrid	✓		✓	96.91
	✓		✓	98.28
	✓		✓	**99.31**

Failure case



Fail when objects are far away from camera.