Asynchronous Bioplausible Neuron for Spiking Neural Networks for Event-Based Vision

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Robotics & Computer Vision has endless applications

Industrial Robots

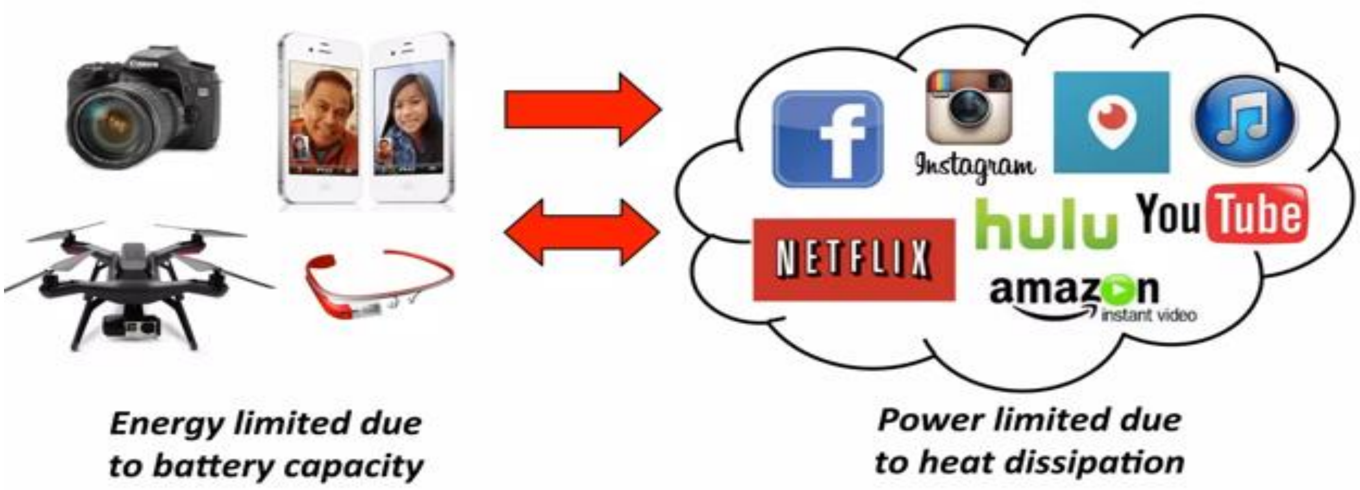
Agricultural Drones

YOLO: Real-time segmentation. Surveillance

AR/VR for surgeries

82% of all internet traffic is video.

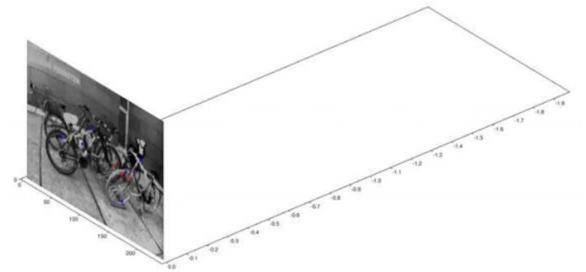
Over 500 hours of video are uploaded to YouTube every minute.



- The average battery life of a drone is 20-30 minutes per charge.
- Processing and storing video data on social media platforms generate significant heat and limit power usage.

Why are standard cameras incapable?

- Standard Camera Produces frames at around 30 FPS speed



Standard Camera

Gehrig et al., Asynchronous, Photometric Feature Tracking using Events and Frames, ECCV’18, Oral Talk

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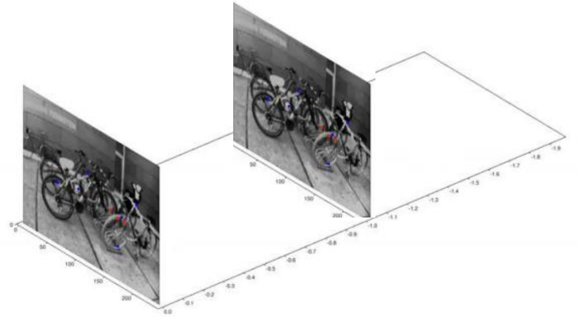

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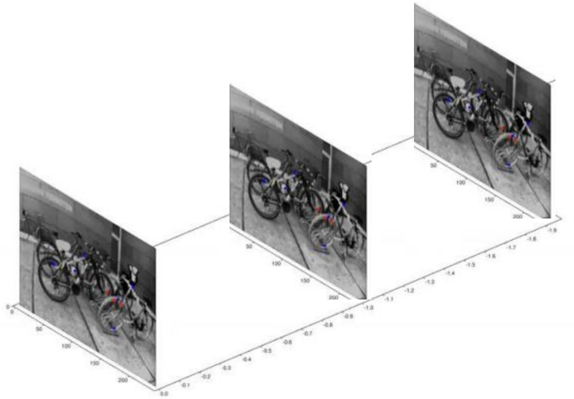

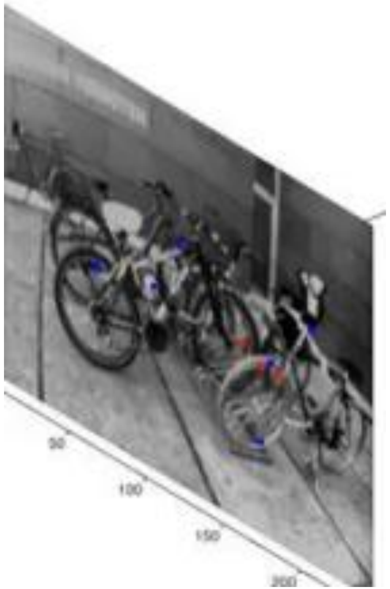

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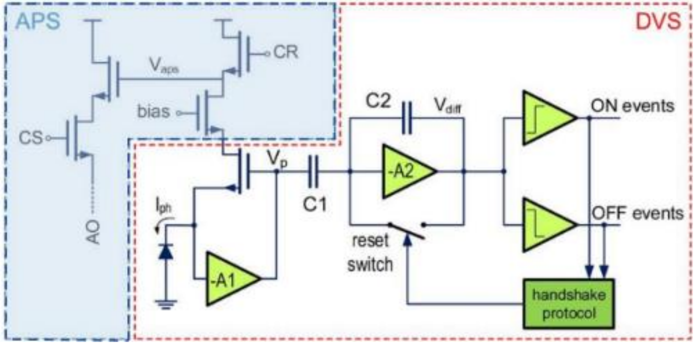
Could Event Camera be the alternative solution?

- Traditional Camera - captures a series of frames at a fixed frame rate
- Event camera – captures individual pixels' intensity changes, asynchronously. Output is a stream of events.

Event-Based Vision Camera



Brandli et al., A 240x180 130 dB 3 μs Latency Global Shutter Spatiotemporal Vision Sensor, IEEE J. Solid-State Circuits, 2014

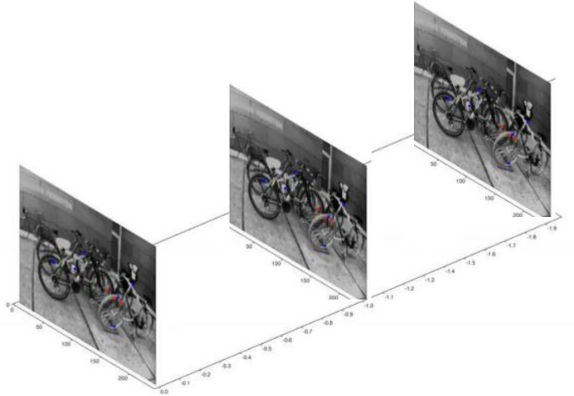
Can Event Camera tackle this problem?

RGB Camera :

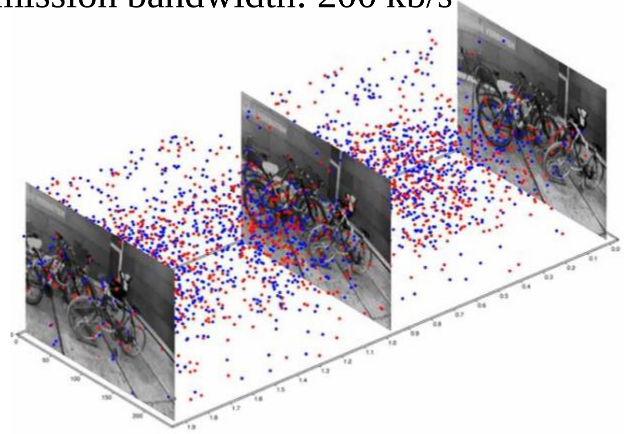
- Temporal resolution: 33000 µs or 30 FPS
- High dynamic range: 120 dB
- High Latency

Event Camera :

- Temporal resolution: 1 µs
- High dynamic range: 84 dB
- Low power: 20mW
- Low transmission bandwidth: 200 kb/s



Standard Camera

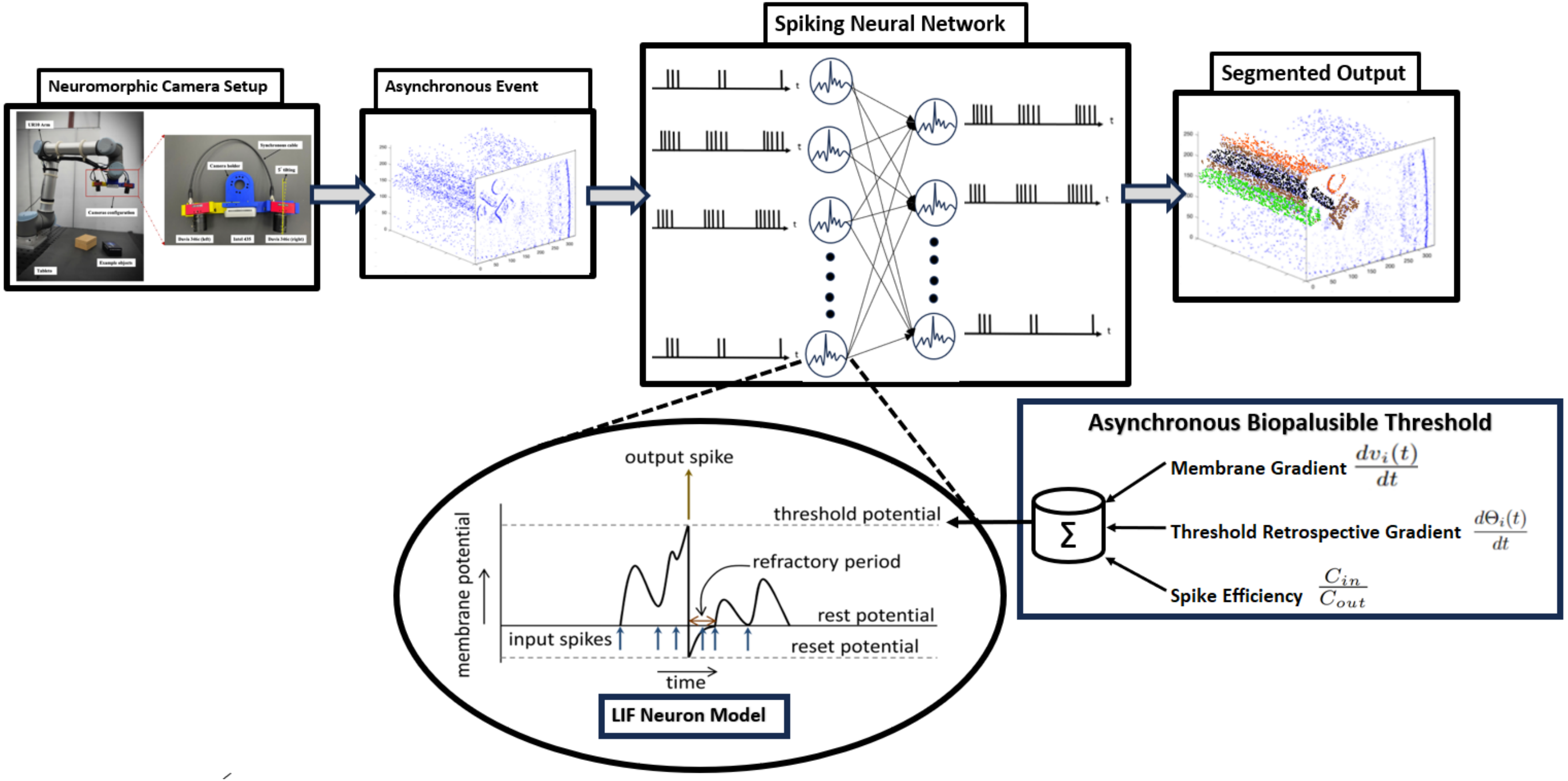


Event-Based Vision Camera

Gehrig et al., Asynchronous, Photometric Feature Tracking using Events and Frames, ECCV’18, Oral Talk

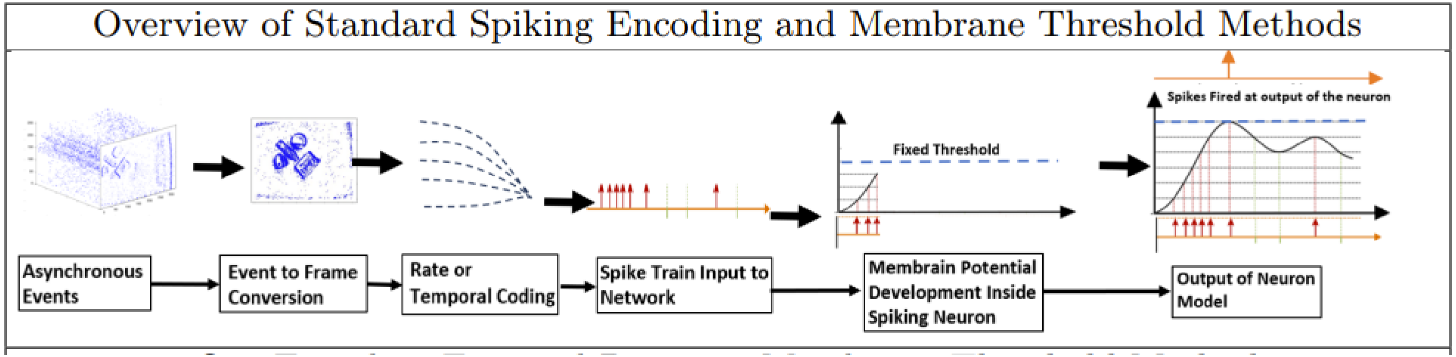
Experimental Set Up

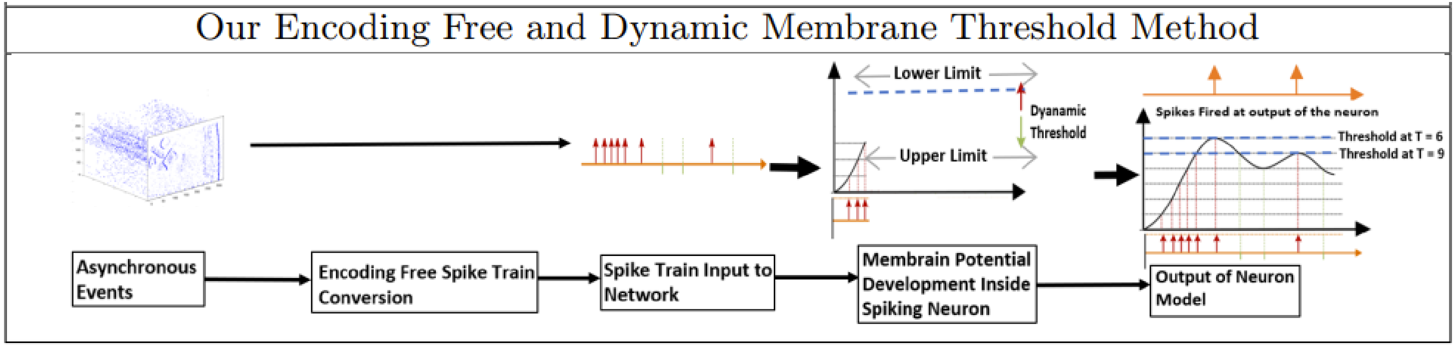
- Two event cameras (Davies346) separated by depth camera (Intel D435) structure mounted on Robotic arm (UR10).
- Objects cluttered on the flat wooden platform in low and bright light conditions.



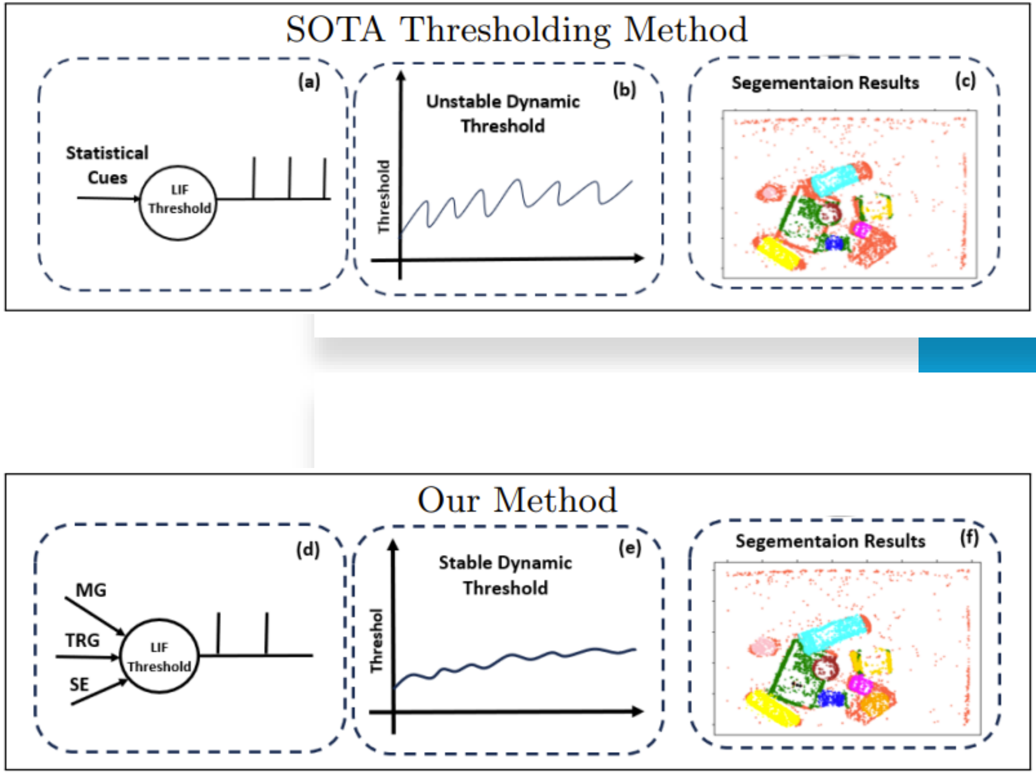
Neuromorphic Camera Setup
Asynchronous Event
Spiking Neural Network
Segmented Output
output spike
threshold potential
refractory period
membrane potential
rest potential
input spikes
reset potential
time
LIF Neuron Model
Asynchronous Biopalusible Threshold
Membrane Gradient $\frac{dv_i(t)}{dt}$
Threshold Retrospective Gradient $\frac{d\Theta_i(t)}{dt}$
Spike Efficiency $\frac{C_{in}}{C_{out}}$
Σ

Comparative Visualization of SNNs approaches





Comparative Visualization of Thresholding Method



Generalisation Capabilities (using LIF and SRM)

- Classification and Event-wise Segmentation Accuracy across Various Datasets and Models

Method	Classification								Segmentation			
	N-MNIST		DVS128		CIFAR10		N-ImageNet		ESD-1		ESD-2	
	SRM	LIF	SRM	LIF	SRM	LIF	SRM	LIF	SRM	LIF	SRM	LIF
Spiking RBM [30]	92.1	93.16	87.38	90.21	83.04	86.25	39.47	40.19	48.95	51.05	45.2	50.31
Spiking MLP (BP) [31]	94.52	97.66	90.72	93.4	86.23	90.06	41.15	43.36	49.53	54	45.5	52.42
Spiking MLP (STDP) [13]	93.47	95	90.8	92.01	87.5	91.7	44.53	45.55	52.63	58.84	46.7	49.44
Spiking MLP (STBP) [38]	97.13	98.89	92.54	93.64	86.23	91.73	46.12	47.16	55.82	63.09	49.07	51.37
DT1 [18]	99.05	99.4	95.01	96.88	89.17	92.65	48.52	47.73	57.55	61.45	50.13	54.59
DT2 [21]	98.13	98.24	92.54	95.54	89.38	91.47	47.02	48.83	58.28	64.3	53.49	56.5
BDETT [11]	99.15	99.45	94.09	96.05	91.61	93.5	48.93	49.51	61.02	65.39	51.36	55.46
ABN (Ours)	**99.23**	**99.48**	**95.64**	**98.74**	**93.5**	**94.74**	**56.73**	**57.04**	**61.56**	**67.29**	**56.23**	**58.04**

Power Consumption Comparison

Method	Model	MAC	AC	Power (W)
Calabrese [8]	CNN	285	**0**	0.541
Baldwin [4]	CNN	963	**0**	1.56
Asude [3]	Hybrid	235	81	0.404
Asude [3]	SNN	0.6	123	0.053
BDETT [3]	SNN	0.7	115	0.046
Ours	SNN	**0.4**	105	**0.038**

- We evaluate SNNs' energy efficiency by calculating the total number of accumulate (AC) operations, which are mainly sparse due to the binary nature of spikes. Using 7 nm CMOS technology data, one 32-bit AC operation consumes 0.38 pJ. We use this to estimate power usage across different SNN methods. AC operations are quantified by multiplying the architecture-based count by the average spiking activity, giving us a ratio of total spikes to total neurons in each layer.

Conclusion

- The Asynchronous Bioplausible Neuron (ABN) method introduces innovative components that enhance neuron model functionality: Membrane Gradient (MG) for directional control of membrane potential, Threshold Retrospective Gradient (TRG) for independent and controlled spike burst suppression, and Spike Efficiency (SE) for improved processing efficiency using asynchronous event data.
- **Validation Across Conditions:** ABN has been effectively tested on various datasets including N-MNIST, ESD-1, ESD-2, DVS128-Gesture, N-ImageNet, and CIFAR-10 DVS, proving its versatility in object segmentation and image classification.
- **Efficiency Studies:** ABN includes studies on neuron firing stability and efficiency, along with a comparison of its power consumption against leading methods, highlighting its potential for energy-efficient applications.

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- Excellence
- Integrity
- Collaboration
- People-centricity
- Pace and Agility

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47 UG, PG, PhD Programs

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4,099 Total Students *1

56%	44%
Females	Males

71%	29 %
UAE National	Int'l.

74%	26%
UG	PG

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459 Researcher s

Innovation & Enterprise

315+ Issued Patents (Highest in the UAE)

700+ Invention Disclosures

19 Startups

Graduates

8,413 KU Alumni *2

73%	27%
UAE Nationals	Int'l.

70 Nationalitie s

*1 Data as for academic year 2023/24
*2 graduates of 2018-2024

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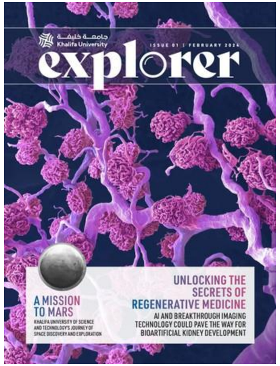

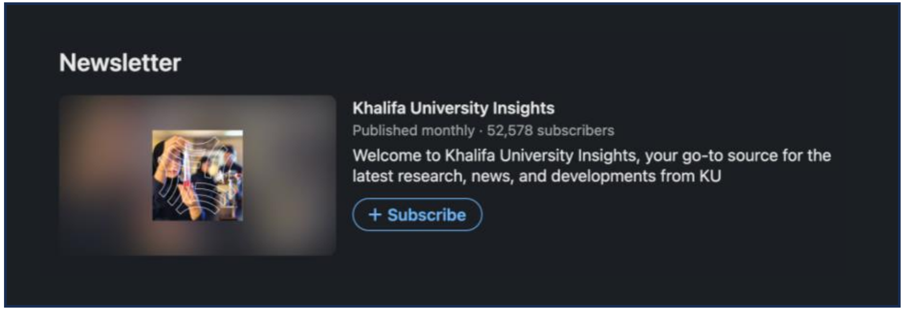

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