Technische Universität Berlin

EINSTEIN CENTER Digital Future

Event-based Robot Vision

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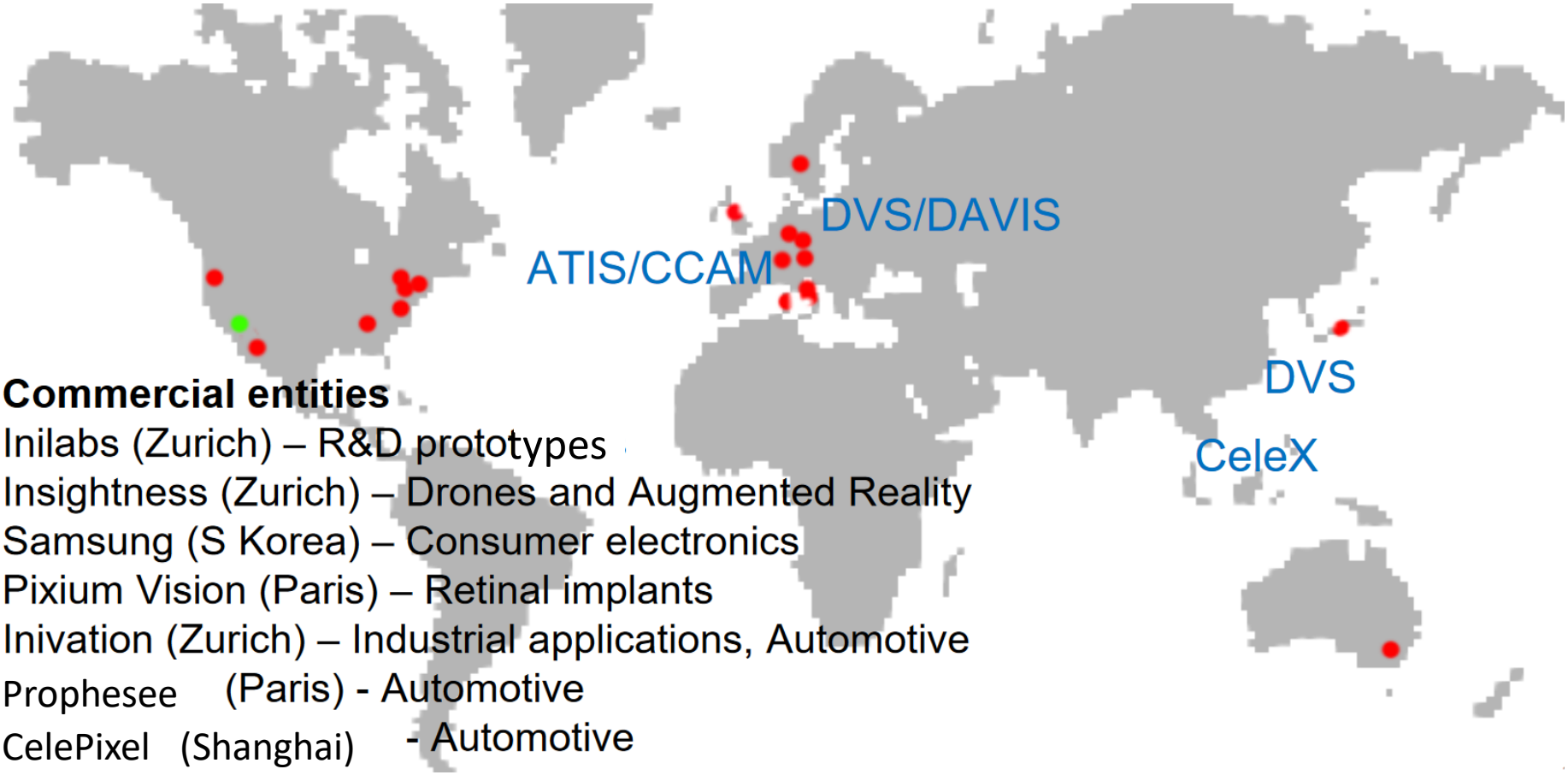
Hardware companies developing cameras



Commercial entities

Inilabs (Zurich) – R&D prototypes
Insightness (Zurich) – Drones and Augmented Reality
Samsung (S Korea) – Consumer electronics
Pixium Vision (Paris) – Retinal implants
Inivation (Zurich) – Industrial applications, Automotive
Prophesee (Paris) - Automotive
CelePixel (Shanghai) - Automotive

Credit: Tobi Delbruck, ICRA Workshop 2017. Video: https://youtu.be/kisqhMqbWTU

Actual Event-based Cameras

Comparison of commercial or prototype event cameras. Values are approximate since there is no standard measurement testbed.

	Supplier	iniVation			Prophesee				Samsung			CelePixel		Insightness
	Camera model	DVS128	DAVIS240	DAVIS346	ATIS	Gen3 CD	Gen3 ATIS	Gen 4 CD	DVS-Gen2	DVS-Gen3	DVS-Gen4	CeleX-IV	CeleX-V	Rino 3
Sensor specifications	Year, Reference	2008 [2]	2014 [4]	2017	2011 [3]	2017 [66]	2017 [66]	2020 [67]	2017 [5]	2018 [68]	2020 [39]	2017 [69]	2019 [70]	2018 [71]
	Resolution (pixels)	128 × 128	240 × 180	346 × 260	304 × 240	640 × 480	480 × 360	1280 × 720	640 × 480	640 × 480	1280 × 960	768 × 640	1280 × 800	320 × 262
	Latency (µs)	12μs @ 1klux	12μs @ 1klux	20	3	40 - 200	40 - 200	20 - 150	65 - 410	50	150	10	8	125μs @ 10lux
	Dynamic range (dB)	120	120	120	143	> 120	> 120	> 124	90	90	100	90	120	> 100
	Min. contrast sensitivity (%)	17	11	14.3 - 22.5	13	12	12	11	9	15	20	30	10	15
	Power consumption (mW)	23	5 - 14	10 - 170	50 - 175	36 - 95	25 - 87	32 - 84	27 - 50	40	130	-	400	20-70
	Chip size (mm^2)	6.3 × 6	5 × 5	8 × 6	9.9 × 8.2	9.6 × 7.2	9.6 × 7.2	6.22 × 3.5	8 × 5.8	8 × 5.8	8.4 × 7.6	15.5 × 15.8	14.3 × 11.6	5.3 × 5.3
	Pixel size (µm^2)	40 × 40	18.5 × 18.5	18.5 × 18.5	30 × 30	15 × 15	20 × 20	4.86 × 4.86	9 × 9	9 × 9	4.95 × 4.95	18 × 18	9.8 × 9.8	13 × 13
	Fill factor (%)	8.1	22	22	20	25	20	> 77	11	12	22	8.5	8	22
	Supply voltage (V)	3.3	1.8 & 3.3	1.8 & 3.3	1.8 & 3.3	1.8	1.8	1.1 & 2.5	1.2 & 2.8	1.2 & 2.8		1.8 & 3.3	1.2 & 2.5	1.8 & 3.3
	Stationary noise (ev/pix/s) at 25C	0.05	0.1	0.1	-	0.1	0.1	0.1	0.03	0.03		0.15	0.2	0.1
	CMOS technology (nm)	350	180	180	180	180	180	90	90	90	65/28	180	65	180
		2P4M	1P6M MIM	1P6M MIM	1P6M	1P6M CIS	1P6M CIS	BI CIS	1P5M BSI			1P6M CIS	CIS	1P6M CIS
	Grayscale output	no	yes	yes	yes	no	yes	no	no	no	no	yes	yes	yes
	Grayscale dynamic range (dB)	NA	55	56.7	130	NA	> 100	NA	NA	NA	NA	90	120	50
	Max. frame rate (fps)	NA	35	40	NA	NA	NA	NA	NA	NA	NA	50	100	30
Camera	Max. Bandwidth (Meps)	1	12	12	-	66	66	1066	300	600	1200	200	140	20
	Interface	USB 2	USB 2	USB 3		USB 3	USB 3	USB 3	USB 2	USB 3	USB 3			USB 2
	IMU output	no	1 kHz	1 kHz	no	1 kHz	1 kHz	no	no	1 kHz	no	no	no	1 kHz

DVXplorer

Event camera hardware is getting mature

Gallego et al., *Event-based Vision: A Survey*, TPAMI 2020, Table I.

References

- Gallego et al., *Event-based Vision: A Survey*, TPAMI 2020, Section 2.5
- Delbruck, The Slow but Steady Rise of the Event Camera, EETimes 2020
- The List of Event-based Vision Resources has sections on devices & manufacturers and companies working on these cameras:
  - **iniVation**: https://inivation.com and SynSense
  - **iniLabs**: https://inilabs.com
  - **Samsung Electronics** (SmartThings Vision product)
  - **Prophesee** www.prophesee.ai (with Sony as 2020 partner)
  - **Insightness** https://www.insightness.com
    (now **Sony Advanced Visual Sensing**)
  - **CelePixel** https://www.celepixel.com
    (acquired by **Will Semiconductors** in 2020, **Omnivision**)

There are many prototype event cameras that have not been commercialized. There may be more companies "under the radar" working on event-based vision technologies. Check out the partners of the above companies.