Heterogeneous thread-based parallel software for scalable industrial machinery

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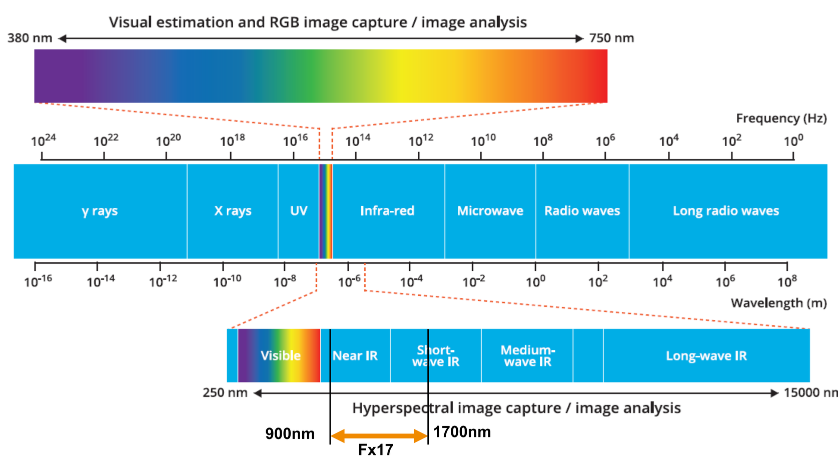
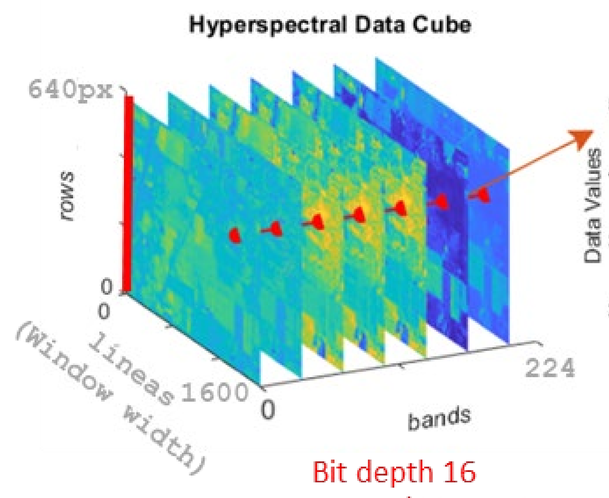
Introduction

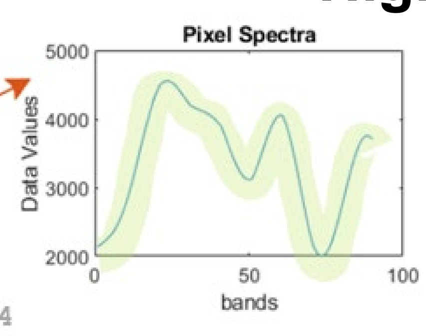
Light incident on a material is reflected with different intensities at different wavelengths. Using hyperspectral cameras, for each pixel, the reflectance data values of the 224 bands form a spectrum. Spectra patterns are built for different materials. By analyzing and comparing the spectra with the patterns we are able classify unknown materials.

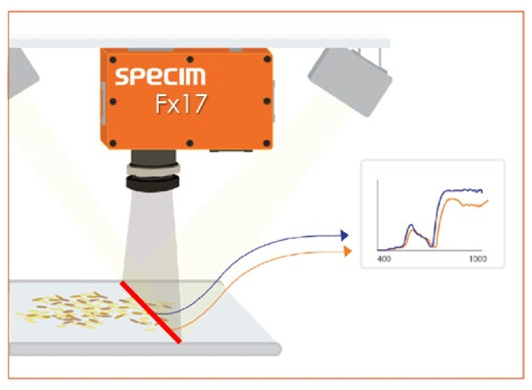


Some of the problems are: Sensor noise. High sensitivity to light variations. Wide dynamic range of spectra. Good resolution depends on light intensity. Signal must be pre-processed to improve results. Size of the hypercube
High computational cost.



Bit depth 16
438 MBytes / hipercubo





Instalation & Requeriments

We start from a ROS (Robot Operating System) and a HSI (HyperSpectral Imaging) classification algorithm for plastic / packaging card.

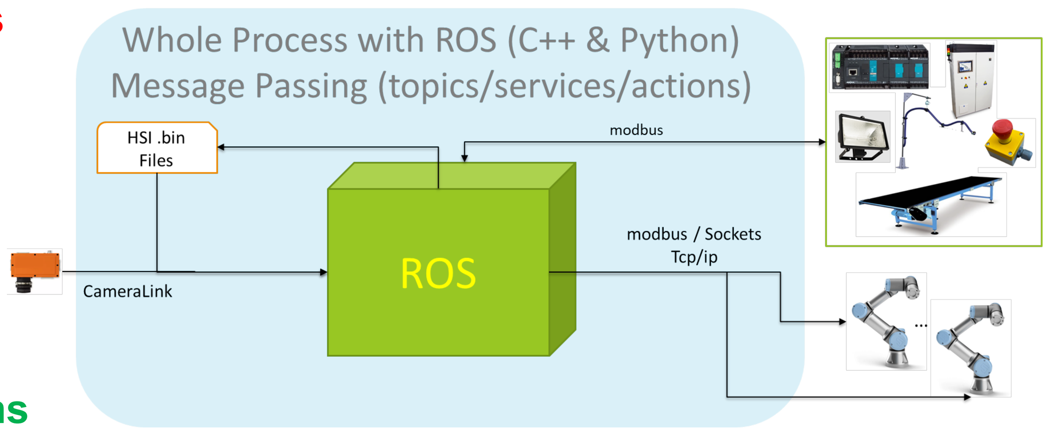
Excessive communication and computations for each frame at 670Hz cause failures in tracking picks at 25 m/min.

-Require: Only hyperspectral vision and multiple robots.

Window Size (Hypercube)
640px x 1600 lines x 224 Bands
at 25 m/min : 4,146 s - 1,729 m

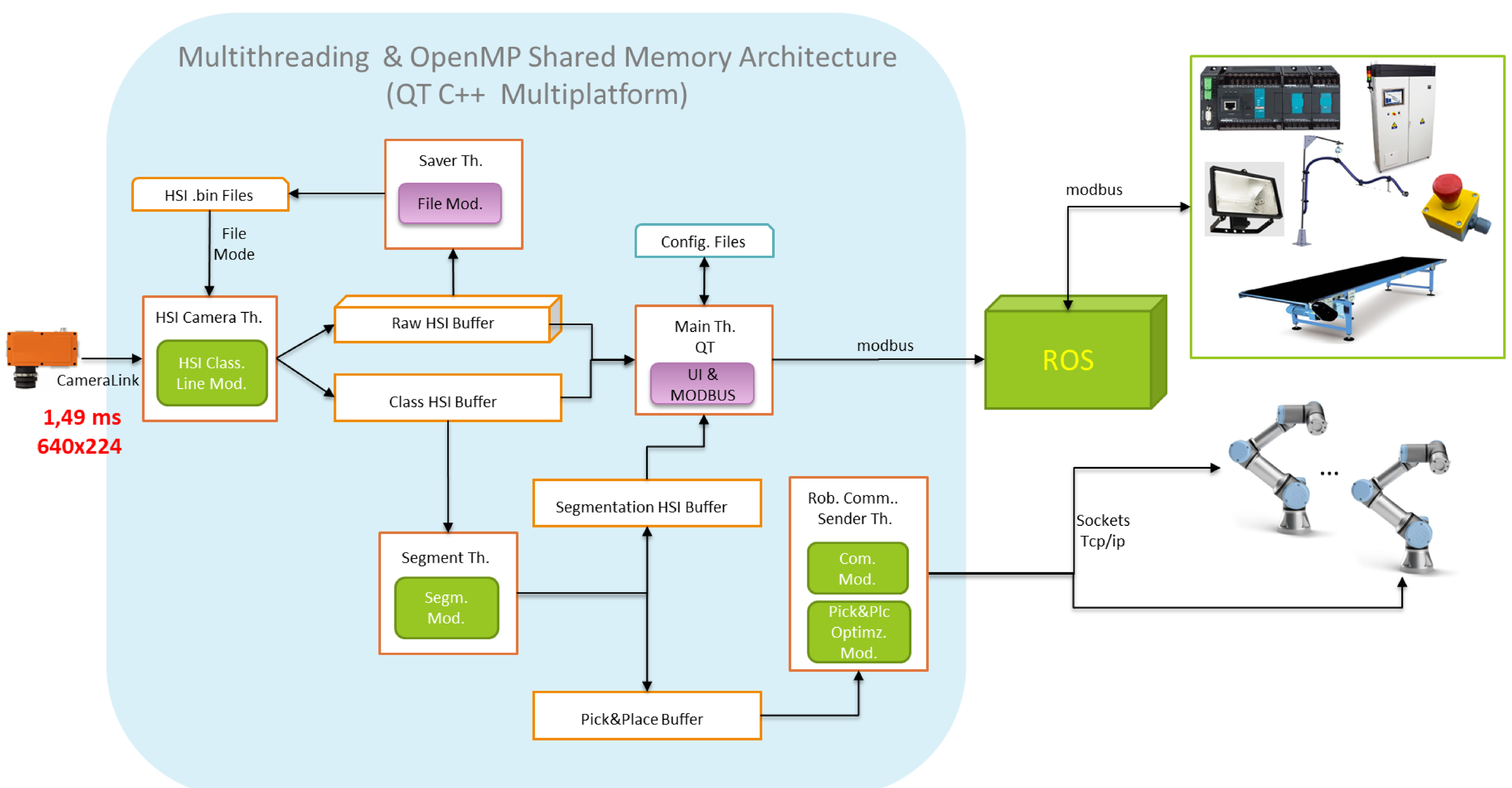
Using the same conveyor belt, to reach 670Hz for full frame (max for Fx17)

Conveyor Speed : 43,28 m/min
Time to compute 1 frame: 1,49 ms
Time to compute 1 window: 2,38 s

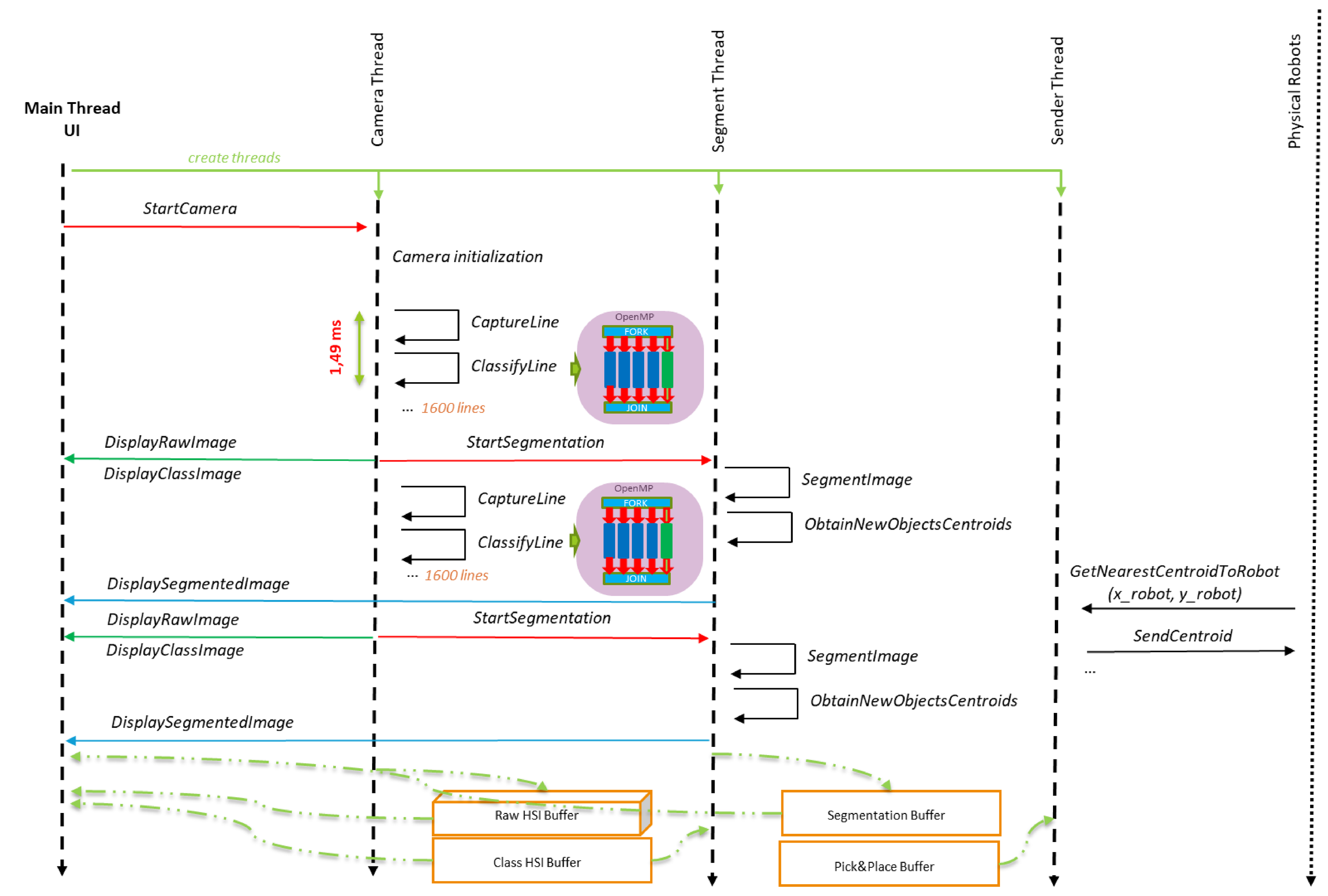


The proposed solution

- To use a shared memory architecture to control the entire process, from acquisition to delivery to the robots.
- To use multithreading for heterogeneous tasks and OpenMP for homogeneous tasks.
- Power supply, lighting and conveyor control over ROS.

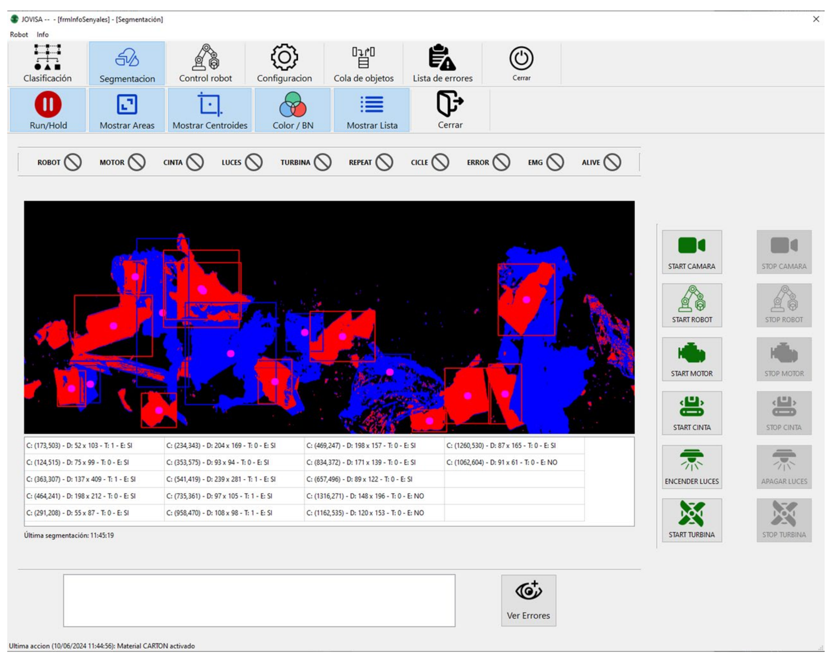


Parallel Software Skeleton



Results

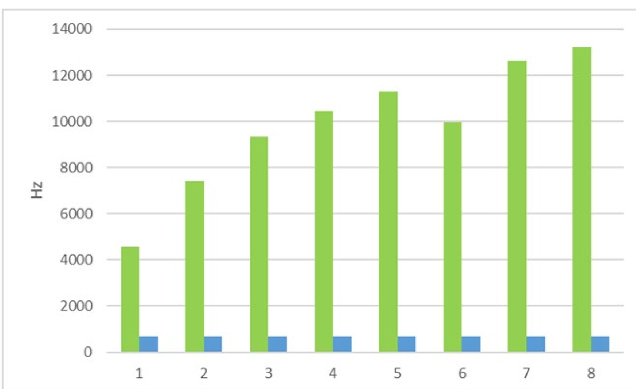
With OpenMP threads we can classify each frame up to 8.8 times the maximum frequency of the camera. This leaves time to implement much more complex classification algorithms. Even without OpemMP a 1600 lines window can be processed up to 51 times per second.



NO-OPENMP	ms			Hz			Cam.
	max	min	promedio	max	min	promedio	670 Hz
Captura	0,716	0,053	**0,060**				
Classify	2,433	0,183	**0,219**	411	5464	**4565**	
Capture&Classify	2,505	0,237	**0,279**	399	4219	**3584**	**5,3 x**
Total Segment (1600 lines)	38,332	16,156	**19,537**	26	62	**51**	
Total Sement Line	0,024	0,010	**0,012**	41741	99034	**81894**	**122,2 x**

OPENMP	ms			Hz			Cam.
	max	min	promedio	max	min	promedio	670 Hz
Captura	1,597	0,056	**0,063**				
Classify	1,404	0,088	**0,107**	712	11364	**9319**	
Capture&Classify	1,931	0,148	**0,170**	518	6757	**5873**	**8,8 x**
Total Segment (1600 lines)	38,332	16,156	**19,537**	26	62	**51**	
Total Sement Line	0,024	0,010	**0,012**	41741	99034	**81894**	**122,2 x**

# threads	1	2	3	4	5	6	7	8
ms	0,22	0,14	0,11	0,10	0,09	0,10	0,08	0,08
Hz	4565	7407	9319	10458	11305	9984	12625	13220
Times (x) Cam 670Hz	6,8	11,1	13,9	15,6	16,9	14,9	18,8	19,7



450 Mbytes of memory is use for a double hypercube buffer and three window buffers. Heterogeneous tasks use 4 threads, while OpenMP tasks use 3 threads.

This resources consumption allows cost-effective systems with 8 cores to process an industrial recycling plant.

Conclusion & Future Work

- Include RGB computations and industrial threads (OPC)
- New classification algorithms (SAM, Ratios, PCA, ad-hoc)
- Include Deep Learning in segmentation tasks
- Build an open access materials database.

Acknowledgment

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