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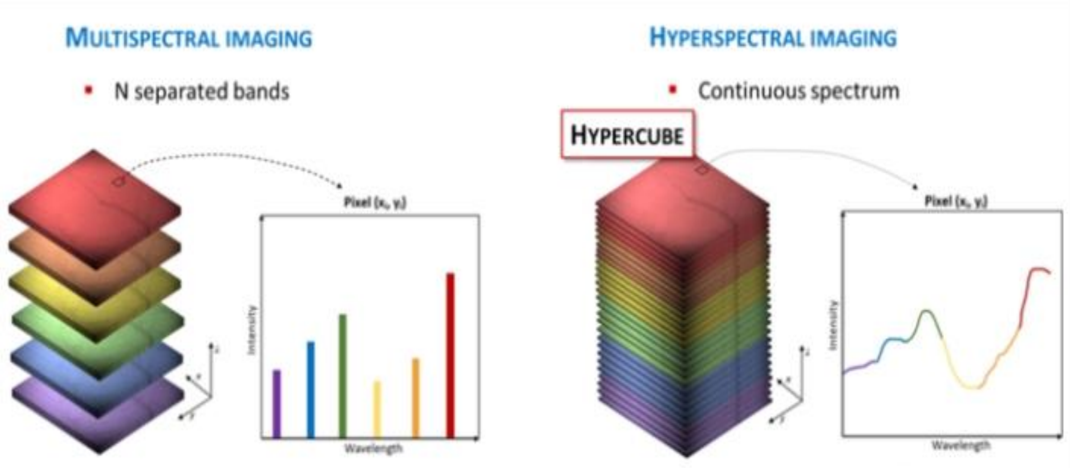
Analysis of a super-resolution algorithm applied to hyperspectral imaging for its implementation in an embedded system

INTRODUCTION

Super-resolution algorithms can be applied to hyperspectral imaging to enhance the spatial resolution of hyperspectral data. This may be limited due to the physical characteristics of the imaging system, such as the size of the sensor pixels. Super-resolution algorithms can overcome this limitation by fusing multiple low-resolution hyperspectral images to produce a higher resolution image.

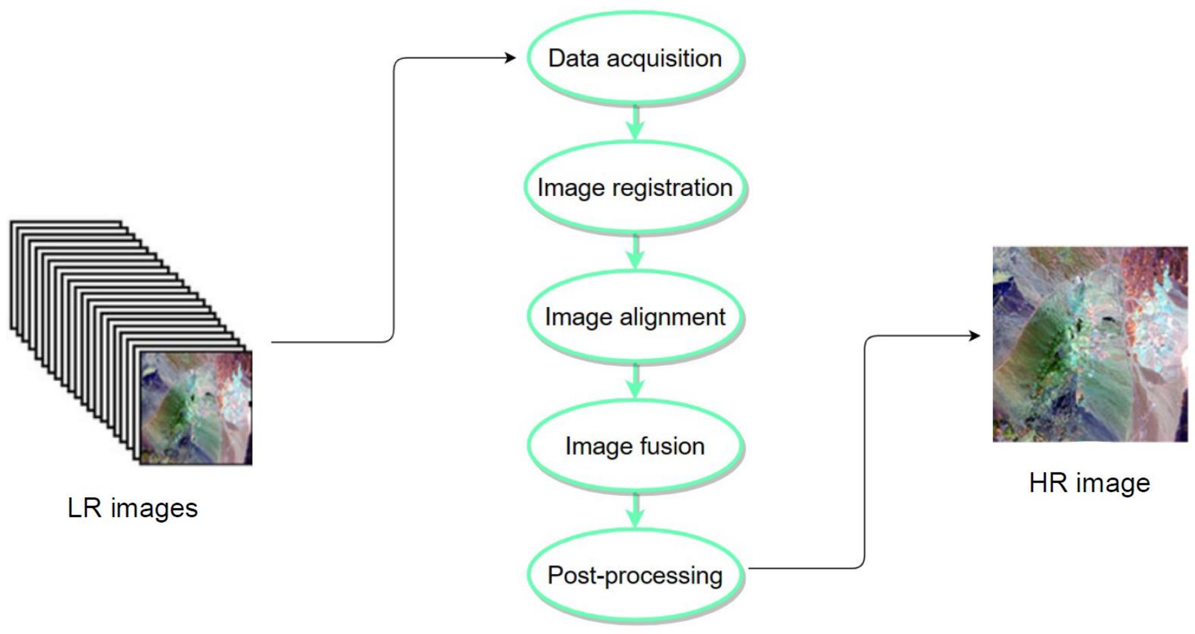


OBJECTIVES

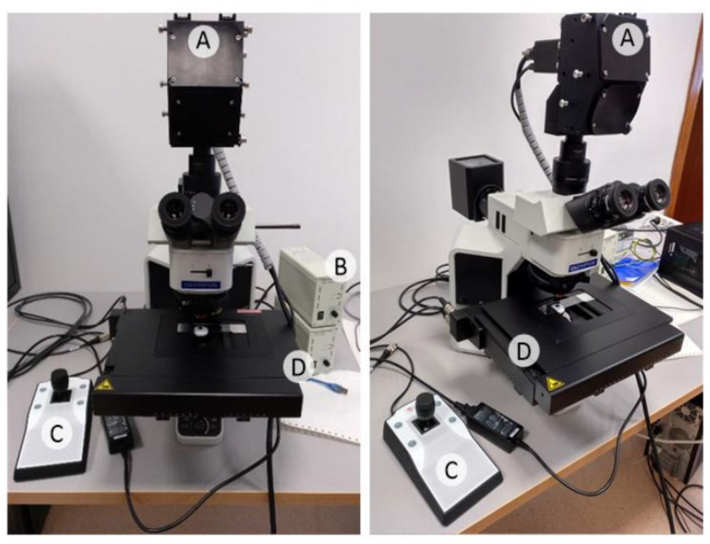
The main objective of this Final Degree Project is the analysis of the current version of a super-resolution algorithm [1] regarding its properties for implementation in an embedded real-time system. This work also considers the automation of different recording techniques of hyperspectral images for the subsequent verification of the hyperspectral super-resolution algorithm.

METHODOLOGY

Multi-image super-resolution is a class of super-resolution algorithms that utilize multiple low-resolution images of the same scene to generate a high-resolution image with improved spatial resolution.



Staring spectral arrays and push-broom scanners are the most used instruments to capture HS images [2]. Following up on this, the three necessary subsystems in every HS acquisition system could be simplified as: lenses, that focus the scene; image sensor, that records the HS data; and light source, that illuminates the scene [3].



As evaluation metrics, the choice of SSIM, PSNR and SAM is based on their utility and relevance in the evaluation of image quality in the context of super-resolution algorithms.

Regarding processing platforms, to obtain the results has been used a commercial computer with a CPU Intel(R) Core(TM) i7-6700HQ running at 2.6 GHz and 24 Gigabytes of RAM installed. The MATLAB® version used was 2021b, and the algorithm was implemented in C language.

REFERENCES

[1] Urbina Ortega, C., Quevedo Gutiérrez, E., Quintana, L., Ortega, S., Fabelo, H., Santos Falcón, L., & Marrero Callico, G. (2023). Towards Real-Time Hyperspectral Multi-Image Super-Resolution Reconstruction Applied to Histological Samples. Sensors, 23(4). https://doi.org/10.3390/s23041863

[2] Lu, G.; Fei, B. Medical hyperspectral imaging: A review. J. Biomed. Opt. 2014, 19, 1–24.

[3] Ortega, S.; Halicek, M.; Fabelo, H.; Camacho, R.; Plaza, M.d.l.L.; Godtliebsen, F.; Callicó, G.M.; Fei, B. Hyperspectral imaging for the detection of glioblastoma tumor cells in h&e slides using convolutional neural networks. Sensors, 2020, 20, 1911.

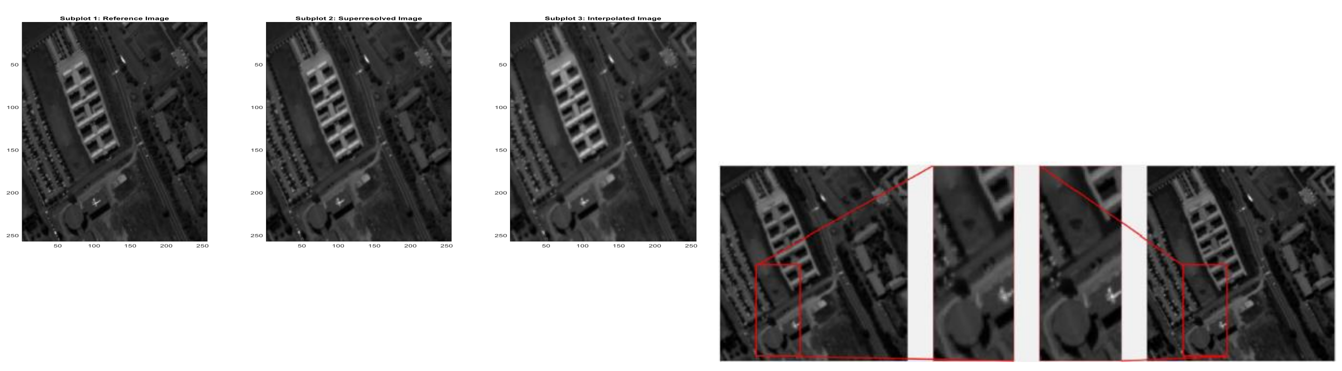
RESULTS

First, the algorithm was tested in some sequences. Using the Spectral Angle Mapper (SAM) metric the results for the super-resolved image and interpolated image can be appreciated. Values closer to zero mean better image quality. Moreover, it is represented the gain of the proposed super-resolution algorithm with respect to the bilinear interpolation.

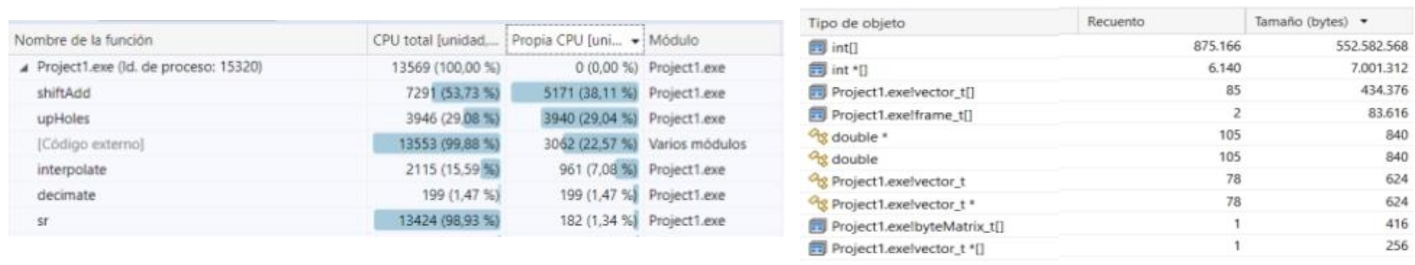
Next, results are shown for the sequence of Pavia University. F represents the position of the selected frame within the sequence, and N denotes the number of frames that have been combined in the sequence under study.

F	N	samSRvsREF	samINTvsREF	benefitFromSR (%)
3	80	0.0672	0.0754	10.7907

From left to right, the reference, the super-resolved, and the interpolated image are represented. Then, the interpolated is compared with the super-resolved with zoom.



Moreover, the parameters of real-time characterization and optimization of their values are considered. Analysis have been carried out with respect to CPU and memory program.



Respect to super-resolution algorithm implementation in an embedded system, the chosen one is the following:

The Rock 5 Model B with 8GB RAM is a single board computer powered by the Rockchip RK3588 SoC (System on a Chip). Since the Rockchip RK3588 is a high-performance SoC with advanced graphics capabilities, it might be able to handle hyperspectral image processing. Compared to the used above:

Processor	Intel Core i7-6700HQ	Rockchip RK3588
Market (main)	Desktop	Single-board computer
ISA	x86-64 (64 bit)	ARMv8-A (64-bit)
Microarchitecture	Skylake	Cortex-A76, Cortex-A55
Cores	4	8
Threads	8	8
Frequency	2,6 GHz	1,8 GHz
Memory RAM	24 GB	8 GB
Memory type	DDR4-2133	LPDDR4
GPU integrated graphics	Intel HD Graphics 530	ARM Mali-G610MC4
GPU execution units	24	4
GPU base clock	350 MHz	600 MHz
GPU FP32 floating point	403,2 GFLOPS	610,6 GFLOPS
Socket	LGA1151	SoC

CONCLUSION AND FUTURE LINES OF RESEARCH

The analysis suggests that this algorithm is a promising avenue for improving image quality and spatial resolution. However, careful attention must be given to hardware design, optimization techniques, energy efficiency, and the specific requirements of the application to ensure successful integration and optimal performance within the limitations of an embedded system.

In the case concerned, as future lines of research, for example, bottlenecks that have been found in the analysis can be solved, look for ways to reduce memory load and look for ways to improve the quality of super-resolved images… Regarding its implementation in Rock 5 Model B 8GB, could be analysed and optimized the existing algorithm to take full advantage of the hardware capabilities, explore techniques to improve performance…