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REVISTA COLOMBIANA DE COMPUTACIÓN

Monitoring of Green Areas in the University of Guadalajara through Image Processing in an HPC Environment

Monitoreo de zonas verdes en la Universidad de Guadalajara mediante procesamiento de imágenes en un entorno *HPC*

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Abstract. Evaluation and monitoring of vegetation in urban areas is used for the management of natural resources and urban planning. This information has become more important than ever due to climate change. This work proposes the use of drones or Unmanned Aerial Vehicle (UAV) to make these vegetation inventory and process the acquired images using the photogrammetry software OpenDroneMap (ODM) in a high performance computer under Singularity and Snakemake. These tools can generate a big image map of the interested zone which can be used to study the future condition and health of vegetation.

Keywords: Aerial photogrammetry, drones, UAV, containers, Singularity, Docker, High Performance Computing, OpenDroneMap, Snakemake.

Resumen. La evaluación y el monitoreo de la vegetación en las zonas urbanas se utilizan para la gestión de los recursos naturales y la planificación urbana. Esta información se ha vuelto más importante que nunca debido al cambio climático. Este trabajo propone el uso de drones o vehículos aéreos no tripulados (*UAV*, en su acrónimo en inglés) para realizar estos inventarios de vegetación y procesar las imágenes adquiridas utilizando el software de fotogrametría *OpenDroneMap* (*ODM*) en un computador de alto rendimiento con *Singularity* y *Snakemake*. Estas herramientas pueden generar un gran mapa de imágenes de la zona interesada que puede utilizarse para estudiar el estado futuro y la salud de la vegetación.

Palabras claves: Fotogrametría aérea, drones, vehículos aéreos no tripulados, contenedores, *Singularity*, *Docker*, Computación de Alto Rendimiento, *OpenDroneMap*, *Snakemake*.

1 Introduction

Trees and green areas are essential for an urban environment, they can be present in streets, yards, and parks and represents many benefits in the sociocultural or economics fields; for example, they can reduce air pollution, reduce energy consumption (reduce temperature) and improving the quality of life (improve aesthetic environment) (Carreiro, Song, & Wu, 2008). They serve as vital lungs, purifying the air we breathe, while also acting as natural air conditioners, tempering the sweltering heat of urban landscapes. Moreover, they elevate the aesthetic appeal of our surroundings, enriching our lives in profound ways.

However, these areas are being reduced because of the increase of urbanization and bad planning. Also, the vegetation can be vulnerable to pests, diseases, and environmental stresses (Tahar, Ahmad, & Wan Mohd Akib, 2011). To inherit a sustainable environment for future generations, it is necessary to create programs to manage and protect green areas. As a result, it is important to be able to evaluate and monitor the health of trees in order to ensure their long-term survival.

Yet, recognizing the need to bequeath a sustainable environment to future generations, it is up to us to champion the cause of green spaces. Initiating comprehensive programs aimed at their management and protection becomes not only an option, but a necessity. Central to this effort is the ability to systematically assess and monitor tree health, ensuring their resilience and longevity in the face of growing challenges.

Traditionally, the evaluation and monitoring of trees has been carried out manually implying intensive time consumption and labor. The use of Unmanned Aerial Vehicles (UAV) or drones has revolutionized this field allowing the collection of detailed aerial trees´s images at a low cost with reduced supervision and providing a continuous monitoring of a dynamic environment. This technology is ideal to study small areas such as campuses, parks, urban areas, etc. (Micheletti, Chandler, & Lane, 2015). Complementarily this technology has been used for ecology studies such as preparation of vegetation, study forest swaps, etc. (Han, Jung, & Kwon, 2017).

In the realm of modern technology, photogrammetry tools emerge as indispensable assets, wielding the power to transform ordinary images into intricate, high-resolution maps that serve as the bedrock for a myriad of data processes (e.g. AgiSoft PhotoScan, visual SFM). However, they are designed to work in a local computer or require a subscription/license for use in a cluster, presenting a barrier to entry for those looking to utilize the full capabilities.

We utilized the open-source software OpenDroneMap (ODM) as our photogrammetry tool to generate accurate 2D or 3D image maps, facilitating the measurement of green spaces, tree management, problem identification, and future intervention planning (OpenDroneMap, 2018). In this work, we focus on generating a 2D image called orthophoto. It is available in a container called Docker which can be converted to other technologies, such as Singularity, Apttainer, Sarus, etc.

Another important tool to consider is Snakemake, this tool is workflow manager and open source (Köster, et al., 2017). It can be used to automatize, reproduce and scalable the process which is frequently used in bioinformatics studies (Mölder, et al., 2021). It seamlessly integrates with container technologies like Singularity and interfaces with Slurm for enhanced functionality.

Processing spatial resolution model (data) results are high computationally demanding; in power, file size, data storage and processing time, the use of a supercomputer can drastically reduce the processing time, and it can be optimized more using a graphics card (GPU) (La Salandra, et al., 2021). On the other hand, the use of container technology or a workflow manager can help to replicate, reproduce and scalable the results in any architecture or on other computer centers. In this work we use Singularity which is most widely used in HPC (Liu & Guitart, 2021).

It is possible to create a methodology for image processing of urban green areas using drones (UAV), open source software such as ODM with Singularity and Snakemake using the supercomputer Leo Atrox. The result produces an accurate map of the green areas and the methodology can be extended to inspect other areas such as parks, colleges, campuses, schools, etc.

2 Methodology

In our effort to capture the images of the area of the trees that we wanted to analyze, the DJI drone was used, which is equipped with the integrated Hasselblad camera model L2S-20c and GPS, which was able to capture with fidelity, stunning visual images and also get precise geospatial accuracy. To process the images, the open source OpenDroneMap command line toolkit version 3.1.0 available in Docker was used (OpenDroneMap, 2018). However, recognizing the computational demands of image processing, the ODM installation was converted to a Singularity 3.6.4 container; in order to take advantage of the potential processing power of the Leo Atrox supercomputer, we used workflow manager Snakemake 7.28.3 which is compatible with Singularity (Köster, et al., 2017). The resolutions of the images used were ultra, medium, and low. Figure 1 illustrates the image processing workflow using container and Snakemake environment.

For image processing, only two computing nodes were utilized: one consisting solely of a CPU (Central Processing Unit), and the other featuring a GPU (Graphics Processing Unit). Both nodes, the CPU and GPU, are equipped with two Intel(R) Xeon(R) Gold 6154 processors, each boasting 16 cores. The CPU node is configured with 188 GB of RAM, while the GPU node boasts 196 GB of RAM, complemented by a Nvidia P100 GPU with 12 GB of VRAM. For further clarity, refer to Figure 2 for a visual representation of the node configuration.

The survey area and flight path are illustrated in Figure 3. The output consisted of 177 color RGB images, each with a resolution of 5280x2970 pixels and captured from an altitude of 1569 meters above sea level. The polygon covered an area of 114,609 square meters, with a ground sample distance (GSD) of 0.5 cm.

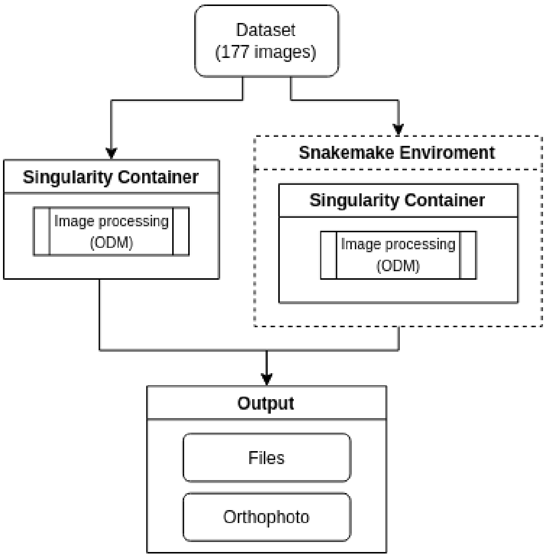

Figure 1. Workflow image processing with ODM with singularity and the Snakemake environment

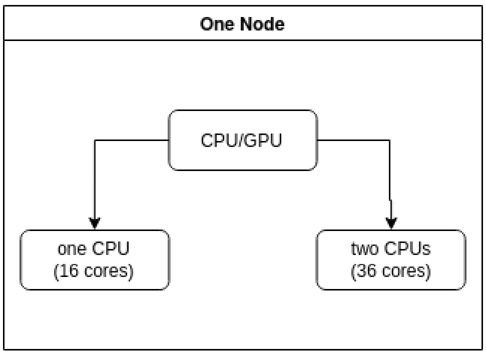

Figure 2. Workflow how were processed the images using CPU and GPU. The CPU was implemented with a Snakemake and without it

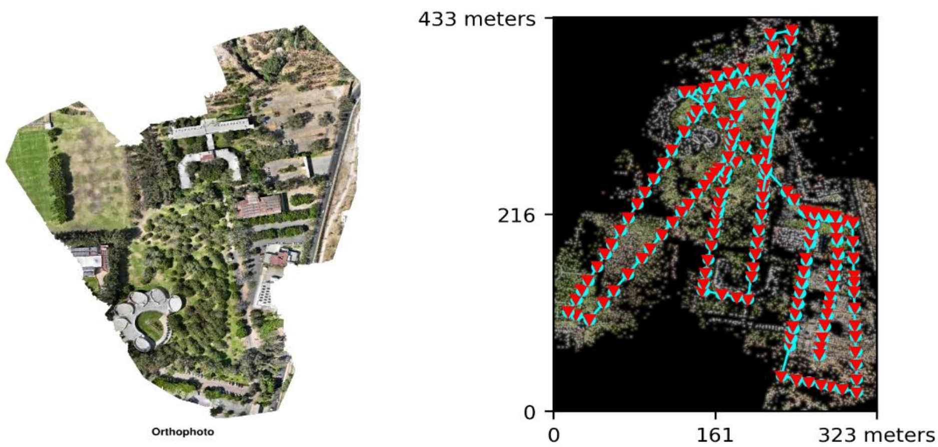

Figure 3. On the left we can see the flight path, on the right the orthophoto. Both were taken with an altitude of 1569 meters at sea level measurement

3 Results

3.1 Data

From the 177 images, we obtained a total dataset size of 2.4 GB, with an average file size of 15 MB. The output consisted of between 1220 and 1320 files, with the total size increasing proportionally with resolution. Surprisingly, the size of the orthophoto is larger at lower resolutions, as illustrated in Table 1 for further details.

Table 1. Output of number of files, their total size and the orthophoto size

Resolution	Size of total files (Gb)	Number of files	Orthophoto (Mb)
Ultra	46.57	1339	72.14
Medium	9.81	1175	151.10
Low	9.80	1212	505.61

3.2 Processing time

The performance was measured in time, which was computed with ODM. In high resolution, it is evident that utilizing the GPU outperforms both Snakemake and CPU processing, whether using 18 or 36 cores. On average, the GPU processing is 48% faster than Snakemake and 20% faster than CPU processing. Refer to Figure 4 for a visual representation of these results.

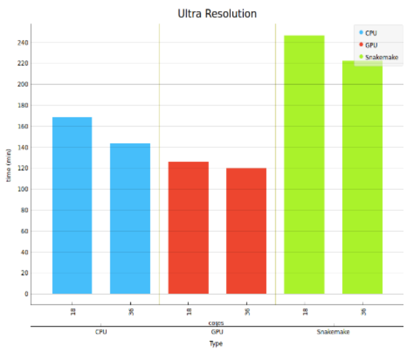

Figure 4. Workflow for processing images using CPU and GPU. The CPU was implemented with a Snakemake and without it

In medium resolution, the difference in performance between CPU and GPU is minimal. This pattern mirrors the findings observed in the low-resolution processing, as depicted in Figure 5 and Figure 6.

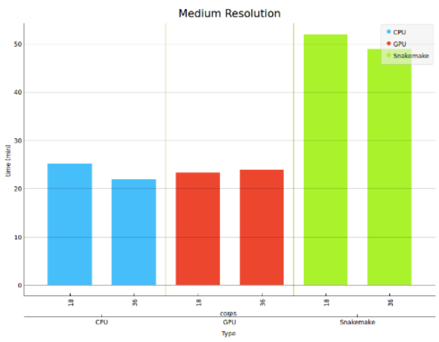

Figure 5. Medium resolution using CPU, GPU and CPU + Snakemake

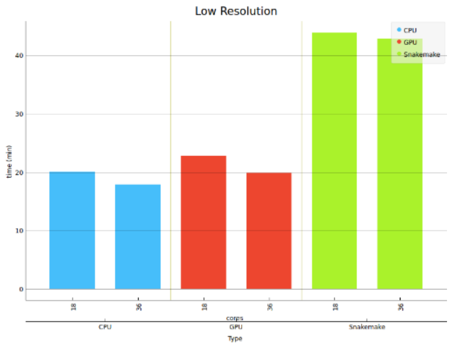

Figure 6. Low resolution using CPU, GPU and CPU + Snakemake

3.3 Cores

The impact of core usage on processing time is evident. A comparison of image processing using 18 cores versus 36 cores, utilizing CPU alone, GPU alone, or managed by Snakemake, is presented in Table 2.

Table 2. Comparison using 18 and 36 cores using only CPU, GPU or Snakemake

Time processing (%)	Ultra	Medium	Low
CPU	15	10	13
GPU	5	13	-2
Snakemake	10	2	6

3.4 Resolutions

The difference in the time of processing between low and medium using CPU or GPU resolution is 10% in GPU and 20% GPU (Figure 7).

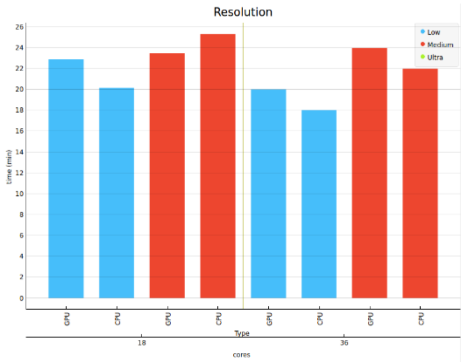

Figure 7. Low and Medium resolution using CPU and GPU

4 Discussion

The output of the size of total files is similar between low resolution and medium, but in high resolution it is 4.7 bigger. On the other hand, the size of the orthophoto increases when it is low resolution. The difference between low versus high is 7 times and low versus high is 3.3.

Independent of the type of resolution, processing data (CPU or GPU) or number of cores to use, Snakemake increases the processing time by around 40%. Using more cores improves the performance using CPU or GPU. In general, memory does not play a significant role. But, it requires more memory when there are more images for processing.

The time of processing images in low resolution is 19% faster than medium in CPU and 9.5 using a GPU. It is important to note the use of GPUs to reduce time in the time of processing but the advantage versus CPUs is around 10%. In term, performance CPU is a better option.

Comparative analysis of output sizes across different resolutions —low, medium, and high— reveals intriguing insights within the context of high performance computing. For both low and medium resolutions, the cumulative size of total files showcases a degree of parity. However, in the case of high-resolution data, a substantial amplification of 4.7 fold magnification is observed. Conversely, the size of orthophotos demonstrates a contrasting pattern. Specifically, while low-resolution orthophotos see an expansion in size, the difference between low and high resolutions manifests at a significant factor of 7, and similarly, at 3.3 between low and medium resolutions.

Irrespective of resolution type, data processing methods (CPU or GPU), or the utilization of cores, it is noteworthy that Snakemake consistently results in an approximate 40% augmentation in processing time. Remarkably, the integration of additional cores presents a performance enhancement across both CPU and GPU operations. It's imperative to emphasize that while memory may not exert a profound influence on processing efficiency in general, its significance becomes apparent when dealing with an elevated volume of images.

In terms of time efficiency, image processing at lower resolutions demonstrates a 19% reduction in processing time compared to medium resolution when utilizing CPU, and a 9.5% advantage when employing GPU acceleration.

Significantly, the utilization of GPUs for hastening processing times presents a noticeable advantage, albeit within the confines of a marginal 10% margin as compared to CPU capabilities. Hence, considering performance dynamics holistically, CPUs emerge as the more compelling choice.

5 Conclusion

Leveraging supercomputing capabilities ensures fast and efficient data processing, allowing for timely identification of areas requiring attention and proactive interventions to mitigate hazards. The advantages of our approach are manifold. Firstly, the rapid processing afforded by supercomputing ensures quick assessments of woodland health and identification of potential risks. This real-time insight empowers decision-makers to take prompt action, safeguarding precious ecosystems from harm. Moreover, our methodology facilitates the creation of highly accurate 3D models, providing a comprehensive understanding of terrain and vegetation dynamics.

Crucially, our process remains cost-effective, thanks to our strategic utilization of open-source solutions and supercomputing resources. By harnessing the power of community-driven software and tapping into the computational might of supercomputers, we have maximized efficiency while minimizing overhead costs, ensuring that our environmental initiatives are both impactful and sustainable.

The results of orthophoto have the enough quality for a preview for evaluating and monitoring woodland in urban areas. The use of drones for collecting aerial images provides a quick and efficient means of acquiring data about the woodland. Enabling the evaluation of woodland health and the identification of areas of risk.

This study demonstrates the effectiveness of a UAV-based workflow integrated with supercomputing resources for rapid and accurate woodland evaluation and monitoring in urban environments. The proposed approach offers several key advantages:

- Fast data processing: Leveraging supercomputing capabilities facilitates efficient orthophoto generation, enabling timely identification of areas requiring intervention for hazard mitigation.
- High-fidelity 3D models: The process ensures the production of highly accurate 3D models, crucial for a comprehensive understanding of woodland structure and potential risks.
- Cost-effective solution: By employing open-source software and optimizing processing through supercomputing resources, the approach remains cost-effective.

While Snakemake serves as a valuable tool for automation, exploring alternative workflow managers may yield additional efficiency gains. Additionally, employing medium resolution for initial data visualization presents advantages in processing time compared to low resolution, all while maintaining final orthophoto quality.

Overall, the results of this study emphasize the advantages of incorporating GPUs and CPUs into the workflow of UAV aerial image processing. The utilization of GPUs offers improved reduction of computational time, and enhanced performance in 2D reconstruction image. However, the choice between CPUs and GPUs should be tailored to the specific requirements of the project, for example the cost of using a GPU with many cores could be higher than using only a CPU with the same cores.

Future research in this field could explore the utilization of additional compute nodes for image processing, as well as the integration of 2D and 3D images for monitoring the health and risk of green areas.

The process presented in this study offers several advantages. Firstly, it is quick, enabling timely assessments of woodland health and risk identification. Secondly, it is accurate, providing precise 3D models for a comprehensive understanding of the woodland. Lastly, it is cost-effective, utilizing open-source software and leveraging the computational power of supercomputers for efficient data processing.

By improving the understanding and management of woodland, this approach holds the potential to reduce the risk of accidents caused by woodland and promote the sustainable use of urban woodland resources. The speed, accuracy, and cost-effectiveness of our process make it a promising tool for enhancing woodland management practices, improving safety, and supporting the preservation of urban ecosystems.

To conclude the presented workflow offers a fast, accurate, and cost-effective approach for woodland evaluation and monitoring in urban settings. This method has the potential to enhance woodland management practices, improve safety, and promote the sustainable use of urban green spaces. Further research and implementation can contribute significantly to effective urban woodland management strategies and the overall preservation of urban ecosystems.

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