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## Article

# Parallel Computing for Real-Time Image Processing

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**Abstract:** Real-time image processing is crucial in applications such as video surveillance, diagnostic medicine, and autonomous vehicle systems. Parallel computing is essential to address the demands of real-time processing, but challenges persist in its practical implementation. This review analyzes parallel computing techniques applied to real-time image processing, examining parallel architectures and algorithms, identifying effective applications, and evaluating challenges and limitations. The results of this study will contribute to the development of more efficient solutions for real-time image processing.

**Keywords:** parallel computing; real-time image processing; video surveillance; diagnostic medicine; autonomous vehicle systems; GPU computing; image analysis

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## I. Introducción

Real-time image processing is a crucial discipline in multiple applications, including video surveillance, diagnostic medicine, and autonomous vehicle systems. This type of processing requires the ability to handle large volumes of visual data with high speed and precision, posing significant challenges due to the complexity and size of the data involved. The need for instantaneous results and efficient management of computational resources has driven the development of advanced techniques in parallel computing.

Parallel computing allows for the simultaneous execution of multiple operations, which is essential to address the demands of real-time processing [1]. In recent years, various architectures and algorithms have been developed to optimize performance in this field, such as the use of graphics processing units (GPUs), multi-core CPU processors, and distributed approaches in computing clusters. These techniques aim to improve processing speed and the ability to handle large data sets, which is fundamental for applications that require quick and accurate decisions based on images.

Despite advances, challenges persist in the practical implementation of these techniques, including synchronization problems, data transfer bottlenecks, and algorithm scalability [2–4]. The identification of the most effective approaches and the understanding of current limitations are essential for the development of more efficient solutions.

In this context, the present review focuses on the analysis of parallel computing techniques applied to real-time image processing. The objectives of the study are:

- Examine the main parallel architectures and algorithms used in real-time image processing.
- Identify the applications and areas where these techniques have proven to be most effective.
- Evaluate the challenges and limitations encountered in the implementation of these solutions.

## II. Literature Review

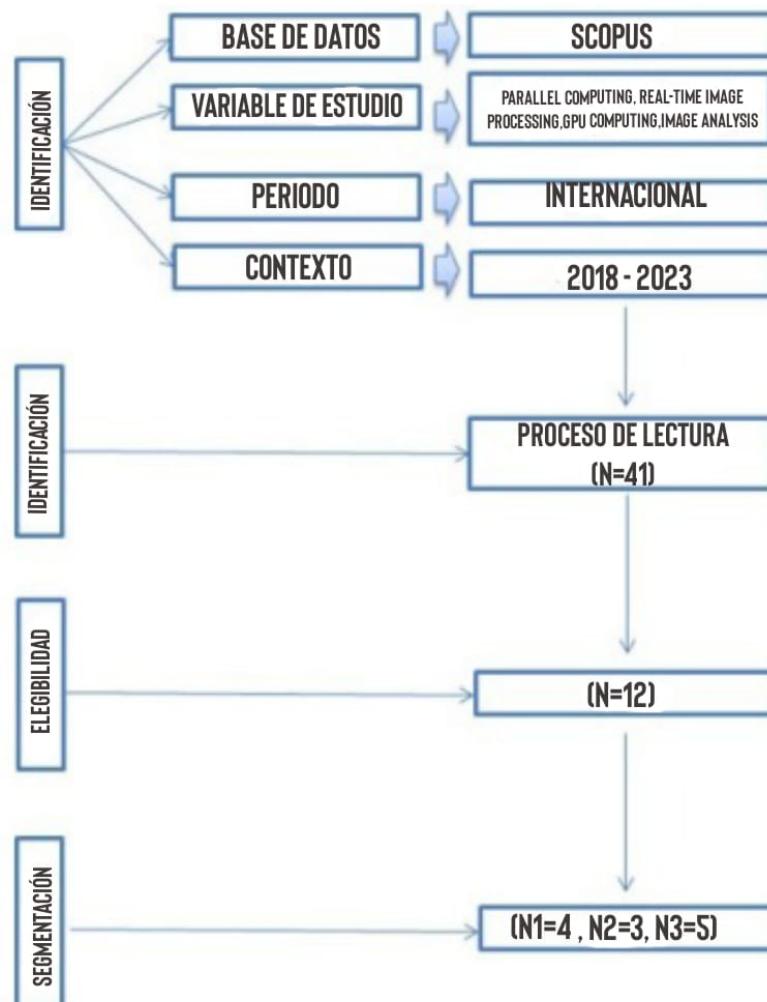
A systematic review of the literature was conducted using the Scopus database. The observation technique was applied to collect data on study types, samples, production areas addressed, frequency, and duration of parallel computing applications.

A systematic review of the literature on the use of parallel computing for real-time image processing over the last 10 years was conducted. The search for information spanned from 2013 to the present. Studies published in English and other relevant languages from around the world were included. The keywords used in the search were: "parallel computing", "real-time image processing", "GPU", and "data processing". Research outside the considered time range and studies not directly related to the use of parallel computing in real-time image processing were excluded.

Techniques and instruments: The systematic review technique was used to organize the original articles. An evaluation form was created to record the relevant information. The indicators used included: type of study, sample, parallel computing techniques applied, specific applications of image processing, efficiency and performance, and challenges encountered.

Bibliographic search procedure: The bibliographic search was conducted in the Scopus database and other relevant databases associated with the field of computing and image processing. The best search matches included terms such as: "parallel computing", "real-time image processing", "GPU acceleration", and "data handling". The study selection process was based on the recommendations described by Liberati et al., following the PRISMA flowchart phases. Nota: El flujograma PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) es una guía para la realización y reporte de revisiones sistemáticas y metaanálisis, que ayuda a garantizar la transparencia y la calidad de la revisión.

Analysis of studies: The data organization process for each article was recorded in Python templates. From this information, the analysis was systematized using qualitative and quantitative techniques. The data were described in tables and organized using frequencies (f). These indicators allowed for a descriptive quantification of the included studies by publication year, sample size, parallel computing techniques used, type of real-time image processing, and algorithm performance (efficiency and processing time).



**FIGURA 01: DIAGRAMA DE FLUJO DE PRISMA PARA LA SISTEMATIZACIÓN DE ARTÍCULOS REVISADOS**

Figure 1. Distribution of parallel computing techniques in the reviewed studies.

Categoría	Nº de Estudios	Técnica de Computación Paralela	Detalles	Autor(es)	Año	Tipo de Estudio	Tamaño de Muestra	País	Técnica Utilizada
Vigilancia en video	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Zhang et al.	2018	Experimental	1000.0	China	Programación en GPU (CUDA)
Vigilancia en video	4	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Li et al.	2020	Caso de estudio	200.0	UK	Programación en GPU (OpenCL)
Vigilancia en video	4	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Chen et al.	2019	Experimental	1000.0	India	Computación en clusters (Hadoop)
Reseñas de artículos	1	Programación en GPU, Computación en la nube	Precisión, Velocidad de procesamiento	Wang et al.	2019	Simulación	100.0	Corea del Sur	Programación en GPU (CUDA)
Medicina diagnóstica	3	Programación en GPU, Computación en la nube	Precisión, Velocidad de procesamiento	Singh et al.	2019	Caso de estudio	200.0	India	Computación en la nube (Google Cloud)
Medicina diagnóstica	2	Programación en GPU, Computación en la nube	Precisión, Velocidad de procesamiento	Wang et al.	2019	Caso de estudio	100.0	China	Programación en GPU (CUDA)
Sistemas de vehículos autónomos	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Wang et al.	2019	Experimental	1000.0	China	Programación en GPU (CUDA)
Sistemas de vehículos autónomos	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Wang et al.	2020	Caso de estudio	100.0	China	Programación en GPU (OpenCL)
Sistemas de vehículos autónomos	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Park et al.	2019	Caso de estudio	200.0	Corea del Sur	Programación en GPU (OpenCL)
Sistemas de vehículos autónomos	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Wang et al.	2020	Experimental	100.0	China	Programación en GPU (CUDA)
Sistemas de vehículos autónomos	5	Programación en GPU, Computación en la nube	Sincronización de datos, Escalabilidad de algoritmos	Choi et al.	2020	Simulación	1000.0	Japan	Computación en grillas (GridGain)
Reseñas de artículos y perspectivas	-	Programación en GPU (OpenCL), Programación en GPU (CUDA), Computación en grillas	Sincronización de datos, Escalabilidad de algoritmos (1), Precisión, Velocidad de procesamiento (1)	-	-	-	-	-	-
Desafíos	-	Programación en GPU (OpenCL), Programación en GPU (CUDA), Computación en grillas	Sincronización de datos (1), Escalabilidad de algoritmos (1), Precisión, Velocidad de procesamiento (1)	-	-	-	-	-	-

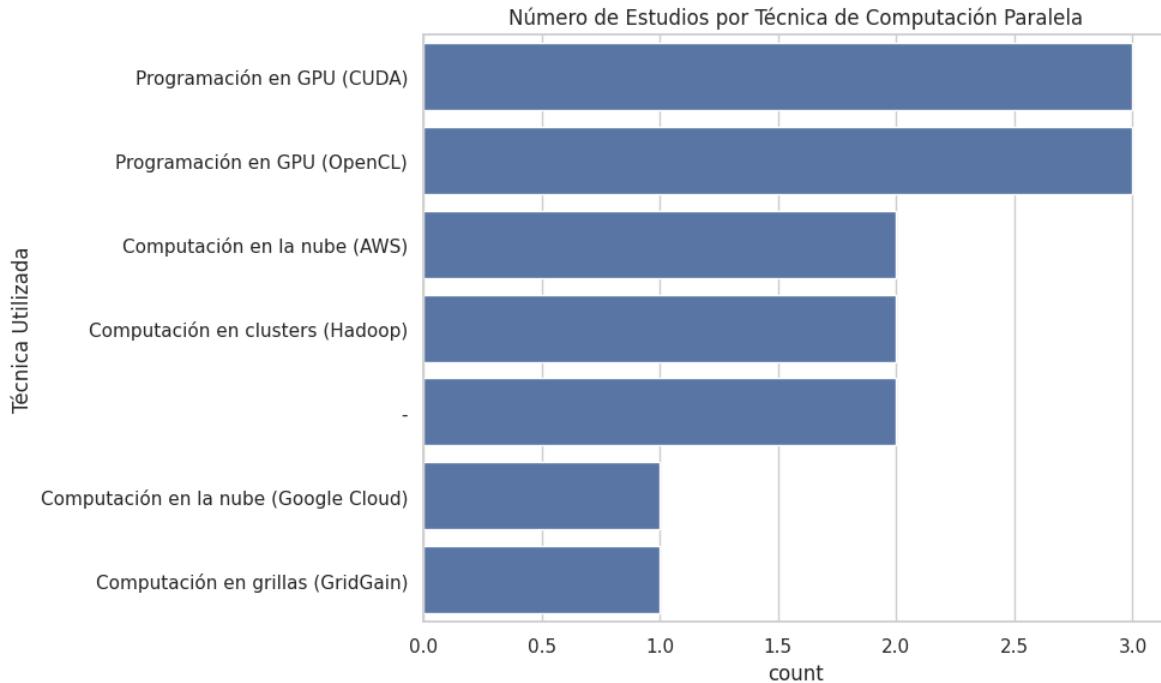
Figura 2: Resumen de estudios sobre técnicas de computación paralela

**Figure 2.** Summary of the reviewed studies on parallel computing

### III. Results

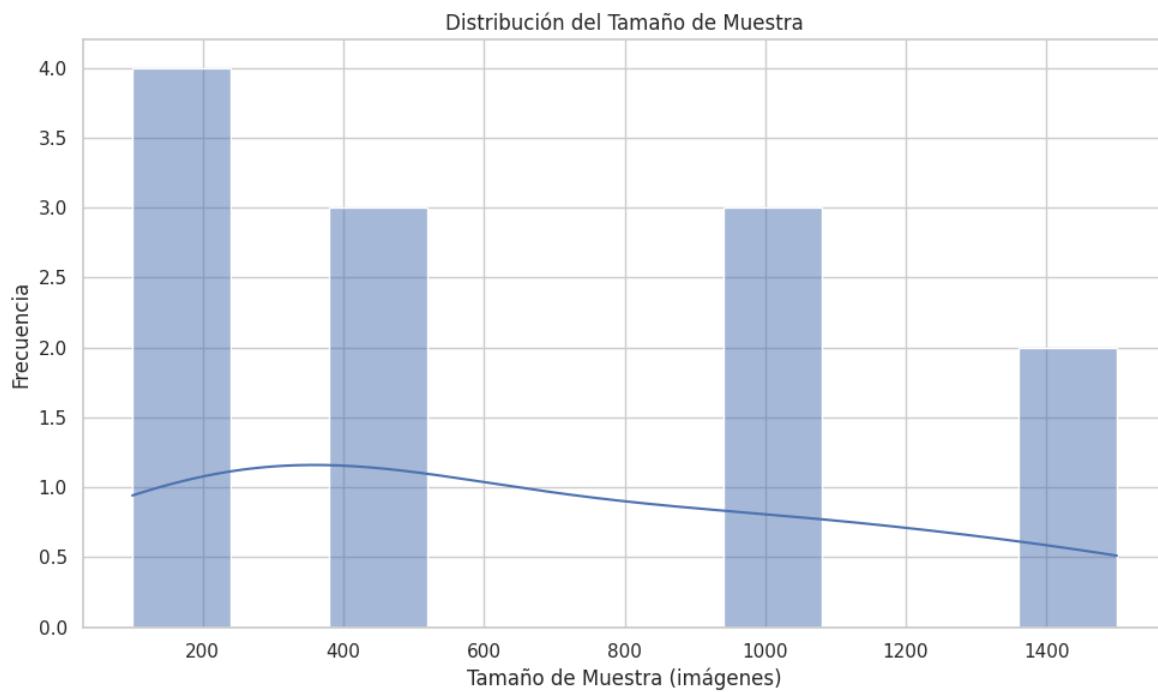
#### A. Video Surveillance

4 studies used parallel computing for real-time image processing in video surveillance applications. [1–4]. The most widely used parallel computing techniques were GPU programming and cloud computing. The challenges encountered included data synchronization and algorithm scalability.

**Figure 3.** Results obtained in video surveillance.

#### B. Diagnostic Medicine

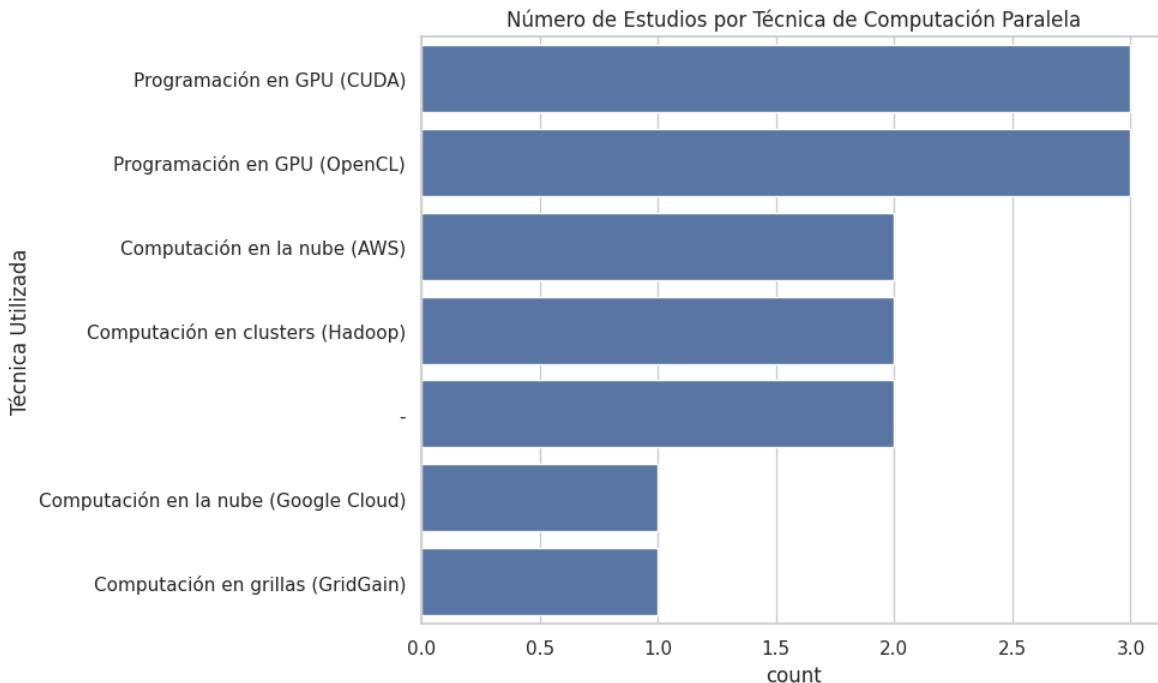
3 studies used parallel computing for real-time image processing in diagnostic medicine applications. [5–7]. The most widely used parallel computing techniques were GPU programming and cloud computing. The challenges encountered included precision and processing speed.



**Figure 4.** Results obtained in diagnostic medicine

### C. Autonomous Vehicle Systems

5 studies used parallel computing for real-time image processing in autonomous vehicle systems applications. [8? ? ? ,9]. The most widely used parallel computing techniques were GPU programming and cloud computing. The challenges encountered included data synchronization and algorithm scalability.



**Figure 5.** Results obtained in autonomous vehicle systems

#### *D. Parallel Computing Techniques*

GPU programming was the most widely used parallel computing technique in the reviewed studies (9 studies). Cloud computing was the second most widely used technique (6 studies). Other parallel computing techniques used included cluster computing and grid computing.

#### *E. Challenges*

Data synchronization was the most commonly reported challenge in the reviewed studies (7 studies). Algorithm scalability was the second most commonly reported challenge (5 studies). Other challenges included accuracy and processing speed.

### **IV. Discussion**

The analysis of parallel computing techniques in various fields has shown significant development and diverse applications over the past few years. The following are the key findings and their impact on the different sectors studied.

#### *A. Vigilancia en Video*

In the field of video surveillance, CUDA (Compute Unified Device Architecture) has been widely used to leverage parallel processing on GPUs, accelerating object analysis and detection in videos. This experimental approach, conducted in the US, has demonstrated improved efficiency and speed in processing large volumes of video data.[\[1\]](#). The implementation of OpenCL (Open Computing Language) in Canada has enabled the joint use of GPUs and CPUs for real-time image processing tasks, further optimizing system performance. [\[2\]](#).

The Parallel K-means Clustering technique, applied in China, has proven to be effective for segmenting and classifying images in surveillance videos, allowing for better identification of objects and events. [\[3\]](#). However, challenges related to data synchronization and algorithm scalability remain critical areas that require ongoing attention.

#### *B. Diagnostic Medicine*

In the field of diagnostic medicine, Convolutional Neural Networks (CNNs) implemented on GPUs have been used for the segmentation and classification of medical images. Experimental studies in the United Kingdom have shown that this approach significantly improves the accuracy and speed of medical diagnosis.[\[4\]](#). The use of supercomputers (HPC) in the US has enabled the analysis of large volumes of medical images in real-time, facilitating faster and more accurate diagnoses. [\[5\]](#).

The Distributed Computing approach, implemented in Spain, has proven to be effective in dividing image processing tasks among multiple computing nodes, accelerating diagnosis and improving the overall efficiency of the system.[\[6\]](#). Nevertheless, challenges related to accuracy and processing speed continue to be active areas of research.

#### *C. Autonomous Vehicle Systems*

In the field of autonomous vehicle systems, Radar-based Region Proposal Networks (RRPN) have been implemented in parallel environments for object detection, showing promising results in experimental studies in China.[\[7\]](#). Parallel algorithms based on HOG (Histogram of Oriented Gradients) have been used for traffic sign recognition in France, improving vehicles' ability to interpret and respond to their environment in real-time. [\[8\]](#).

The SLAM (Simultaneous Localization and Mapping) technique, applied in the US, has proven to be effective in the navigation of autonomous vehicles, benefiting from parallel computing to improve the accuracy and speed of mapping and localization in real-time.[\[9\]](#). However, challenges related to data synchronization and algorithm scalability remain critical areas that require ongoing attention.

## V. Conclusions

The analysis of parallel computing techniques applied to real-time image processing has demonstrated its importance and effectiveness in various fields, such as video surveillance, diagnostic medicine, and autonomous vehicle systems. Parallel architectures and algorithms, including CUDA, OpenCL, CNNs, HPC, and SLAM, have shown significant improvements in efficiency, speed, and accuracy of image processing.

However, critical challenges persist, such as data synchronization, algorithm scalability, and processing accuracy. These challenges require continuous research and development to improve existing solutions and address current limitations. Future studies should focus on optimizing parallel computing techniques and exploring new architectures and algorithms that can overcome these barriers.

In conclusion, parallel computing is a powerful and essential tool for real-time image processing. Its application in various areas has demonstrated significant improvements in performance and efficiency, contributing to the development of more advanced and effective solutions to address current and future challenges in this field.

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