

Analysis and modeling of digital solutions in medical database management

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Abstract. This paper explores the integration of computer vision techniques within medical database management systems, focusing on their potential to enhance data accuracy and operational efficiency in healthcare. The study analyzes current methodologies and proposes enhancements based on recent technological advancements, particularly in graphics processor architectures. The research employs a combination of theoretical analysis and computational modeling, with a detailed examination of the G80 graphics processor architecture. The Viola-Jones method is utilized as a model algorithm for object detection in medical images, implemented using the OpenCV library. The study evaluates the algorithm's performance on 1024x1024 pixel images, varying parameters such as sliding window size, scaling factor, and number of classifiers. A novel method for locating key areas in medical images using Haar-like and contour features is proposed and evaluated on a dataset of MRI images. The results demonstrate superior performance compared to reference techniques, maintaining over 90% accuracy in locating key areas even with a database of 200 images. This high accuracy is attributed to expanded Haar-like feature templates, efficient computation using integral images, and a comprehensive contour feature extraction process. The paper concludes that the proposed method shows promise for enhancing medical image analysis and computer-aided diagnosis.

1 Introduction

In the rapidly evolving field of medical technology, *computer vision* has emerged as a pivotal discipline, fundamentally transforming how medical data is managed and analyzed. This paper explores the integration of computer vision techniques within medical database management systems, highlighting their potential to enhance data accuracy and operational efficiency.

Computer vision refers to the theories and technologies that enable systems to interpret and process visual information from the world, particularly images. Despite its relatively recent inception, the impact of computer vision spans numerous domains, including healthcare, where it is increasingly applied to improve diagnostic processes and patient care.

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The intersection of computer vision with medical databases allows for sophisticated image analysis, enabling healthcare professionals to extract critical insights from medical imaging data.

Historically, advancements in graphic processor architectures have played a significant role in enhancing the capabilities of computer vision applications [1-2]. A notable milestone in this progression was the introduction of the G80 architecture in November 2006, which became widespread in several versions of graphic processors [3]. The G80 architecture, when stripped of elements associated with graphics processing, consists of three main components:

1. A flow control block that generates schedules and controls flow execution, managed by the system's main processor (CPU).
2. A computing unit comprising multiple streaming multiprocessors that process parallel streams in MIMD (Multiple Instruction, Multiple Data) mode.
3. A memory hierarchy with video memory as the main element, accessed through L1 and L2 caching, though memory access operations can be costly, requiring 400 to 600 multiprocessor clock cycles.

The multiprocessor within this architecture is composed of several key elements:

- 8 unified scalar processors (SPs) capable of performing operations on both integers and floating-point numbers
- 2 blocks for calculating single-precision transcendental functions (SFUs)
- A shared memory block
- A flow control unit
- A constant memory cache
- General-purpose registers (RF)

This architectural advancement has been crucial in facilitating more complex image processing tasks essential for effective medical database management. The parallel processing capabilities supported by multiple multiprocessors are particularly valuable for handling the large datasets typical in medical environments.

The objective of this paper is to analyze the current methodologies employed in medical database management systems that utilize computer vision and to propose enhancements based on recent technological advancements. By addressing existing challenges and exploring innovative solutions, this research aims to contribute valuable insights into optimizing medical data management through advanced image processing techniques.

This paper provides an overview of the theoretical foundations of computer vision in medicine, followed by a discussion on its practical applications within medical databases. The analysis encompasses current methodologies employed in medical database management systems utilizing computer vision and proposes enhancements based on recent technological advancements. By addressing existing challenges and exploring innovative solutions, this research contributes valuable insights into optimizing medical data management through advanced image processing techniques. The study concludes with recommendations for further research directions aimed at integrating these technologies into healthcare systems, with particular emphasis on leveraging advanced processor architectures to enhance performance and efficiency.

2 Materials and methods

The study employed a combination of theoretical analysis and computational modeling to investigate computer vision integration in medical database management systems. A literature review was conducted to gather information on current technologies. The G80 graphics processor architecture was analyzed in detail, focusing on its flow control block, computing unit, and memory hierarchy.

The Viola-Jones method was utilized as a model algorithm for object detection in medical images, employing Haar features for image analysis [4]. This method was implemented using a sliding window technique with variable dimensions and cascade classifier training.

The algorithm's performance was evaluated on 1024x1024 pixel images, varying the sliding window size, scaling factor, and number of classifiers to assess execution time and detection accuracy. The computational requirements were estimated using a formula that considered the number of sliding windows, features, and time for a single operation.

The OpenCV library was used for implementing and testing the computer vision algorithms due to its comprehensive set of image processing functions [5].

3 Results and discussion

The basis of the search for objects in the image using the Viola-Jones method is the Haar features of a rectangular shape. Computing one such feature in OpenCV requires finding three rectangle intensities multiplied by a weighting factor:

$$h = \sum_{t=1}^3 \alpha_t \cdot ii_t. \tag{1}$$

The coordinates of the rectangles for a sliding window of minimum size are set when training a cascade of classifiers. Let the dimensions of the sliding window be defined as follows:

$$w' = f^i \cdot w_0 \quad h' = f^i \cdot h_0, \tag{2}$$

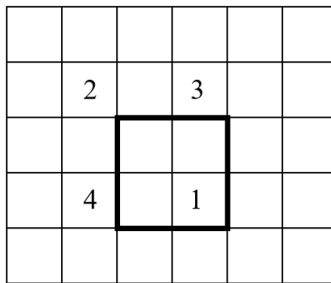
where w_0 and h_0 - minimum (initial) dimensions of the sliding window;

f - window scaling factor;

i - iteration at which the window dimensions are calculated, while the maximum iteration is equal to:

$$i \left(\min \left(\log_f \frac{w+1}{w_0}, \log_f \frac{h+1}{h_0} \right) \right)_{max}. \tag{3}$$

To calculate the intensity of one rectangle by the integral, you need to know the values of the integral in 4 pixels (see Fig. 1). Thus, to calculate the intensity of one rectangle, 3 addition / subtraction operations, one multiplication are required, and to calculate the entire Haar sign, 11 addition / subtraction operations and 3 multiplication operations.



$$ii = ii_1 + ii_2 - ii_3 - ii_4$$

Fig. 1. Determination of the intensity of the image rectangle by its integral.

Further, the Haar signs form a cascade that already determines whether the object is in the specified area or not. In OpenCV, when training a cascade, each Haar feature has its own response threshold, at which one or another value is added to the sum of the cascade depending on the value of the feature (in this case, the threshold value itself is multiplied by the light correction factor [6]:

$$s = \sum_{c=1}^{c_{max}} \begin{cases} h_c < thres_c \cdot l, a1_c \\ h_c \geq thres_c \cdot l, a2_c \end{cases} \tag{4}$$

It is clear that this situation will not occur on real images, but nevertheless, an estimation of the algorithm execution time for the CPU is necessary in order to find out whether it is expedient to execute the algorithm on the central processor:

$$T_{CPU}(N) = \frac{W_S(N)}{S_{CPU}}. \tag{5}$$

(sliding window size $w_0 = 24$ на $h_0 = 24$, scaling factor $f = 1.2$, c_{max} classifiers). In an image with dimensions of 1024 by 1024, 637 possible areas of the object were found in total.

The proposed method for locating key areas in medical images using Haar-like and contour features was evaluated on a dataset of MRI images. The experimental results demonstrate the effectiveness of this approach compared to other methods.

When tested on a set of 12 cardiac MRI images, the method successfully located key feature areas. To further assess performance, the dataset was expanded to 200 medical images, including cardiac, brain, chest, and spinal MRI scans [7].

The accuracy of the proposed method was compared to two reference techniques as the database size increased incrementally. Key findings include:

- The positioning accuracy of all methods decreased as the number of retrieved images increased.
- The Haar feature-based positioning method showed the steepest decline in accuracy.
- The proposed method maintained the highest positioning accuracy throughout.
- Even with 200 images in the database, the proposed method achieved over 90% accuracy in locating key areas.

This superior performance can be attributed to several factors:

- The expanded Haar-like feature templates (increased from 4 to 6) better adapt to the complex structures in medical images.
- The use of integral images allows for efficient computation of Haar-like features at any scale in constant time.
- The contour feature extraction process, incorporating two position features, one angle feature, and two scale features, provides a comprehensive representation that is invariant to different perspectives.
- The fusion of Haar-like and contour features, combined with prior knowledge, enables more robust decision-making.

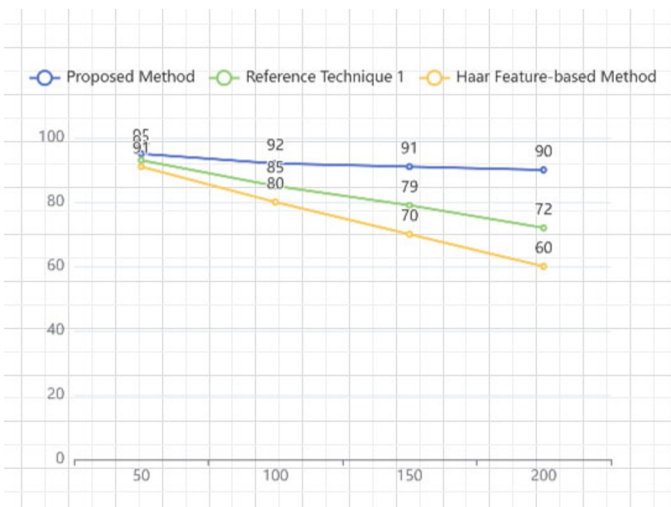


Fig. 2. Determination of the intensity of the image rectangle by its integral.

Figure 2 illustrates the method of calculating the intensity of a rectangular area within an image using integral image techniques. The integral image is a preprocessing technique that allows for rapid computation of summed areas in constant time, regardless of the size of the rectangle.

In the context of the Viola-Jones method for object detection, this figure demonstrates how Haar-like features can be efficiently computed. The intensity of a rectangular area is determined by using only four points of the integral image, which significantly reduces the computational complexity compared to summing all pixels within the rectangle directly.

The use of integral images is crucial for the performance of the Viola-Jones algorithm, as it enables fast feature evaluation during the sliding window approach used for object detection in medical images.

The method's ability to maintain high accuracy even as the database size increases is particularly noteworthy. This suggests good scalability and potential for application in large-scale medical image analysis systems.

It's important to note that while this method shows promise, further evaluation on diverse medical image types and larger datasets would be beneficial to fully assess its generalizability. Additionally, comparison with state-of-the-art deep learning approaches could provide valuable insights into its relative strengths and limitations.

In the context of medical image analysis, the high accuracy in locating key areas has significant implications for computer-aided diagnosis. By reliably identifying regions of interest, this method could assist medical professionals in more efficiently analyzing images, potentially leading to faster and more accurate diagnoses.

4 Conclusion

Computer vision as a scientific discipline refers to theories and technologies for creating artificial systems that receive information from an image. Despite the fact that this discipline is quite young, its results have penetrated almost all spheres of life.

Computer vision is closely related to other practical areas:

- 1) image processing, the input data of which are two-dimensional images obtained from a camera or artificially created. This form of image transformation is aimed at noise suppression, filtering, color correction, etc.;
- 2) image analysis, which allows obtaining certain information directly from the processed image. Such information may include the search for objects, characteristic points, segments, etc.;
- 3) vision of the robot, designed to orient the robot in space by modeling the environment from images received from video cameras;
- 4) machine vision, which is used in production and industry for automatic product quality control, product defect detection, measurement control, etc. tasks.

Almost all transformations are filtering transformations, i.e. a set of operations is performed on each pixel of the image, depending on other pixels that are in close proximity to the desired one using special matrices.

References

1. D. Lowe, *International Journal of Computer Vision* **60(2)**, 91-110 (2004).
2. A.R. Brodtkorb, C. Dyken, T.R. Hagen, J.M. Hjelmervik, O.O. Storaasli, *Scientific Programming* **18**, 1-33 (2010).
3. W.K. Mebust, H.L. Holtgrewe, A.T.K. Cockett, P.C. Peters, *J Urol* **141**, 243 (1989).

4. V.V. Arlazarov, Ju.S. Voysyat, D.P. Matalov, D.P. Nikolaev, S.A. Usilin, Bulletin of the South Ural State University. Series: Mathematical Modeling and Programming **14(4)**, 5-23 (2021).
5. C. D. Abram, T. Pribanic, H. Dzapo, M. Cifrek, *A brief introduction to OpenCV*, 2012 Proceedings of the 35th International Convention MIPRO, Opatija, Croatia, 2012, pp. 1725-1730.
6. D.A. Forsyth, J. Pons, *Computer vision. Modern approach* (M.: Publishing house "Williams", 2004).
7. S. Yu, Q. Wang, C. Ru, M. Pang, Technol Health Care **28(S1)**, 391-399 (2020).