

Performance Evaluation of Random-Access Memory RAM Modules for Computer Systems Using the VIKOR Method

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Abstract

Abstract: Random Access Memory (RAM) stands as a fundamental and dynamic component within modern computers, playing a pivotal role in ensuring their efficiency and responsiveness. Serving as the computer's short-term memory, RAM functions as a swift and accessible storage unit that enables seamless interaction between the central processing unit (CPU) and other hardware components. Unlike a computer's permanent storage, such as the hard drive or solid-state drive, RAM is volatile, meaning its contents are wiped when the computer is powered off. This dynamic nature allows RAM to swiftly store and retrieve data for active processes, applications, and the operating system. RAM plays a crucial role in determining a computer's overall performance. When an application or task is executed, the necessary data and instructions are temporarily loaded into the RAM. The CPU can then access this data swiftly, leading to faster and smoother operations. The more RAM a computer possesses, the greater its ability to handle multiple tasks concurrently, as it can accommodate larger amounts of data for processing. With advancements in technology, different types of RAM have emerged, including DDR (Double Data Rate) variants like DDR3, DDR4, and DDR5, each offering increased data transfer rates and improved efficiency. RAM is the dynamic memory component that empowers computers to perform tasks quickly and efficiently. Its ability to provide rapid data access and retrieval, coupled with its volatile nature, makes it a critical player in the world of computing, enabling users to seamlessly navigate applications, multitask, and experience enhanced overall system responsiveness. Random Access Memory (RAM) is of immense significance in computer research due to its pivotal role in system performance and optimization. Researchers focus on understanding RAM's impact on various computing tasks, including multitasking, data processing, and application execution. Investigating optimal RAM configurations aids in achieving efficient resource utilization and minimizing bottlenecks. RAM's direct influence on overall system responsiveness and its interaction with other hardware components make it a crucial element for researchers aiming to enhance computational efficiency. Consequently, RAM research contributes to improving user experiences, advancing computer architectures, and enabling the development of innovative applications and technologies. The VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) Method is a multi-criteria decision-making approach. It aids in ranking and selecting alternatives based on multiple conflicting criteria. Through normalization, weight assignment, and proximity calculations to ideal solutions, VIKOR offers a systematic way to handle complex decision scenarios. This method aims to find a compromise solution that balances competing criteria and provides insights into the best compromise alternative. It's widely used in various domains, including engineering, finance, and environmental management, where decisions demand a comprehensive consideration of multiple factors with differing priorities. Capacity (GB), Memory Speed (MHz), Latency (CL), Voltage (V), Height (mm), Price. Corsair Vengeance LPX 16GB DDR4 3200MHz, G.Skill Ripjaws V 32GB DDR4 3600MHz, Kingston HyperX Fury 8GB DDR4 2666MHz, Crucial Ballistix RGB 16GB DDR4 3000MHz, Team T-Force Delta RGB 32GB DDR4 3200MHz, Patriot Viper Steel Series 16GB DDR4 4000MHz, Adata XPG Spectrix D60G 32GB DDR4 3200MHz. the result it is seen that Kingston HyperX Fury 8GB DDR4 2666MHz is got the first rank where as is the Corsair Vengeance LPX 16GB DDR4 3200MHz is having the lowest rank.

Keywords: MCDM, Kingston HyperX Fury 8GB DDR4 2666MHz, Crucial Ballistix RGB 16GB DDR4 3000MHz and Memory Speed (MHz).

Introduction

Random Access Memory (RAM) is a type of memory that can be volatile or potentially variable, making it unstable. Unlike a solid memory form, RAM is stored temporarily and can be affected by power loss. It consists of two primary categories: Dynamic Random Access Memory (DRAM) and Static Random Access Memory (SRAM). DRAM is capable of high capacity and density, but it is volatile, losing data when power is disconnected and requiring frequent updates, often in milliseconds. On the other hand, SRAM, while offering advantages such as non-volatility, retaining data without power, also has its drawbacks. In general, memory devices come with various advantages and disadvantages. For instance, DRAMs provide substantial capacity and density, but their volatility necessitates regular updates, and they consume a significant amount of power [1]. Random Access Memory (RAM)

is an incredibly adaptable technology with the capability to store data and serve as an access point for information retrieval. RAM is constructed with a multitude of memory cells, each storing data in the form of bits and identified by a distinct address that indicates its specific location. This characteristic is why it's referred to as "Random Access" - because you can access any memory cell directly without needing to traverse through a sequence. Each cell is unique and holds its own address, making RAM highly versatile for addressing individual memory cells as needed [2]. A method for gathering and collecting username and password information stored within the physical memory analyzing it using ram (random access memory). Utilizing direct memory forensics to identify patterns similar to this task is undertaken by the investigator can be employed in the quest for additional to extend "search criteria" traces. The proposed approach utilizes a quicker

search algorithm within the physical memory to locate the data [3]. As put forth through the application of certain well-known usernames and extracting passwords employing techniques such as websites, social media platforms, by navigating through the methodology underwent testing networks, webmail services, online banking, and several e-commerce websites. Recovered data from this process generates traceable marks within physical memory, user many of these hold relevance we observe evidence and a basic text will be stored in the designated format for passwords. Ultimately, these serve as further indications of recovery alongside corresponding traces can be attached [4]. Physical memory, also known as RAM (random access memory), serves as a repository for computer instructions. It manages data organization, acts as a temporary hub for data transfers, and facilitates communication between the central processing unit (CPU) and the hard drive to enhance processing speed. Data is stored in RAM, but it's crucial to note that RAM's contents are volatile, meaning they are lost once the computer is powered down. This characteristic prevents data recovery after shutdown. When a user closes a computer, various essential data is cleared from RAM. Examples of data that can be analyzed by security professionals or forensic experts include active processes, network connections, ongoing internet sessions, encrypted content, concealed data, as well as encryption/decryption keys, usernames, and passwords. All of this information is also stored in physical memory [5]. Physical memory analysis is undertaken during forensic examinations. This investigation aims to extract and interpret information stored in physical memory. The objective is to discover usernames and passwords, which may require altering the memory contents. This research has the primary purpose of enhancing security measures. One technique employed in this comprehensive analysis involves scrutinizing the structure of websites in memory. This process entails searching through memory to detect specific forms that store usernames and passwords. The forensic investigator can make use of this method to retrieve valuable information for their investigation. This approach also enables them to expand their search to acquire information from other websites [6]. The paper discusses the importance of physical memory analysis for cybersecurity purposes. It aims to elucidate the extraction and interpretation processes that forensic experts employ to comprehend the digital landscape. By understanding how physical memory operates, the forensic community can gain insights into cybercrime trends and behaviors. This connection between physical memory, user behavior, and cybercrime behavior is essential for identifying potential threats and investigating suspicious activities.

Introducing a novel approach for detecting targets, we suggest a fresh paradigm that centers on identifying small targets with high precision. Our proposal addresses the challenges associated with target detection in aerial remote sensing images, particularly those involving elusive or inconspicuous targets. Contrasting with conventional methods, we present a distinctive framework that leverages clairvoyant concepts [7]. Historically, remote sensing target detection has relied on established methodologies.

These methods incorporate a detection model that learns from training data to recognize target classes and their corresponding bounding boxes. In contrast, our approach takes a Bayesian perspective during the inference stage of the detection model. This perspective empowers us to dynamically enhance the detection model's capabilities, thus boosting accuracy [8]. In this paradigm, we refer to it as the "RAM Paradigm," where "RAM" stands for "Random Access Memories." In this context, "memories" refer to insights gained from the training data. Our proposed model is characterized by its adaptability and improved performance, which approximates better as it encounters new and unobserved experimental data. We harness advanced techniques such as Deep Convolutional Neural Networks and multi-scale analysis to refine our model's effectiveness [9]. To evaluate the efficacy of our method, we introduce a new dataset named "Learning, Vision and Remote Sensing Laboratory (LEVIR)." This dataset surpasses its predecessors in size and diversity, featuring a wide array of Earth images, with resolutions ranging up to 22k by 10k pixels, and comprehensive annotations of target locations. The integration of our approach significantly elevates accuracy levels in target detection. On average, our method demonstrates an improvement in average precision by 1% to 4%. Furthermore, the computational overhead introduced by our approach remains acceptable, aligning with practical computational resources [10]. Random Access Memories (RAM), as an illustration, can be contemplated. Upon reevaluation, the diagnostic model has the potential to be conceptualized. This notion takes its inspiration from the realm of signal processing within the domain of detection algorithms, particularly the cohort known as Constant False Alarm Rate (CFAR) Algorithms. In the algorithmic model, parameters undergo modifications based on statistical observations. This approach aligns with similar concepts present in quantum mechanics, where quantum entities are contingent solely upon their energy levels rather than the measurement process [11]. Drawing from these ideas, we formulate the diagnostic model as a probabilistic construct. During the training phase, we replace the hypothesis with a distribution labeled as $p(H)$. Subsequently, in the detection phase, this model is iteratively refined and enhanced through training and meticulous adjustments. This innovative perspective can be labeled as a "Random Access Memories" paradigm. This appellation is rooted in a Bayesian standpoint, wherein "Memories" signifies the varied insights any model can encapsulate by learning from data. Additionally, the term "Random Access" emphasizes the model's capacity for dynamic and adaptable retrieval of these insights [12]. Following the observation of random events, the model's efficacy peaks as it progressively enhances itself in the diagnostic phase. This innovative approach marks a significant departure from conventional paradigms, showcasing its potential to revolutionize diagnostic modeling [13].

Material and Methods

Capacity (GB): The RAM's capacity, measured in gigabytes (GB), dictates the amount of data the memory can hold at a given time. Higher capacity RAM modules enable smoother multitasking and handling of memory-intensive applications. From basic computing tasks to resource-hungry software, RAM capacity significantly influences the computer's ability to manage concurrent processes.

Memory Speed (MHz): The memory speed, quantified in megahertz (MHz), reflects the rate at which data is transferred between the RAM and other components. Faster memory speeds lead to quicker data access and transfer, resulting in enhanced application loading times and overall system responsiveness. For tasks that involve data manipulation or content creation, higher memory speeds can drastically reduce processing bottlenecks.

Latency (CL): Latency, denoted by the CAS Latency (CL) value, gauges the delay between requesting data from RAM and receiving it. Lower latency signifies quicker data retrieval and processing, contributing to reduced wait times during application execution and overall system operation. For real-time applications such as gaming or multimedia editing, lower latency RAM can provide a noticeable performance boost.

Voltage (V): The voltage requirement of RAM modules, often measured in volts (V), affects power consumption and heat generation. Modules with lower voltage levels contribute to energy efficiency and reduced thermal output, which can be beneficial for extending the lifespan of components and minimizing system heat buildup.

Height (mm): The physical height of RAM modules, usually measured in millimeters (mm), determines their compatibility with different computer cases and cooling solutions. Modules with varying heights cater to diverse system configurations, ensuring they can be seamlessly integrated without interfering with other components or obstructing airflow.

Price: Price is a crucial consideration when selecting RAM modules, as it determines the cost-effectiveness of upgrading or building a computer. Balancing performance requirements and budget constraints is vital to finding the optimal RAM solution.

Evaluation Parameter: Corsair Vengeance LPX 16GB DDR4 3200MHz, G.Skill Ripjaws V 32GB DDR4 3600MHz, Kingston HyperX Fury 8GB DDR4 2666MHz, Crucial Ballistix RGB 16GB DDR4 3000MHz, Team T-Force Delta RGB 32GB DDR4 3200MHz, Patriot Viper Steel Series 16GB DDR4 4000MHz, Adata XPG Spectrix D60G 32GB DDR4 3200MHz.

Corsair Vengeance LPX 16GB DDR4 3200MHz: This module offers 16GB of RAM capacity with a memory speed of 3200MHz. The lower CAS latency (CL) value indicates efficient data retrieval. It's a balanced choice suitable for various tasks, including gaming, content creation, and multitasking.

G.Skill Ripjaws V 32GB DDR4 3600MHz: With 32GB capacity

and a memory speed of 3600MHz, this RAM is ideal for resource-intensive applications and multitasking. Its slightly higher capacity and speed make it suitable for content creators, professionals, and gamers seeking optimized performance.

Kingston HyperX Fury 8GB DDR4 2666MHz: This RAM provides 8GB capacity and a memory speed of 2666MHz. It's a more budget-friendly option suitable for basic computing needs, such as web browsing, word processing, and light multitasking.

Crucial Ballistix RGB 16GB DDR4 3000MHz: Offering 16GB of RAM and a memory speed of 3000MHz, this module strikes a balance between capacity and speed. The added RGB lighting enhances aesthetics, making it a choice for gamers and enthusiasts looking for style and performance.

Team T-Force Delta RGB 32GB DDR4 3200MHz: With 32GB capacity and a memory speed of 3200MHz, this RAM module caters to both multitasking and gaming. Its RGB lighting adds a visual flair, making it a suitable option for those interested in aesthetics.

Patriot Viper Steel Series 16GB DDR4 4000MHz: This module offers a higher memory speed of 4000MHz, making it suitable for tasks that demand rapid data access, like gaming and video editing. The 16GB capacity balances performance with capacity.

Adata XPG Spectrix D60G 32GB DDR4 3200MHz: Similar to the Team T-Force module, this RAM provides 32GB capacity and a memory speed of 3200MHz. Its standout feature is the RGB lighting, which adds a vibrant visual element to the system.

VIKOR Method: The VIKOR method extends the boundaries of interval analysis and trade-off analysis for weight stability and stability determination. It introduces a three-dimensional decision-making framework compared to other methods like TOPSIS, PROMETHEE, and ELECTRE. An illustrative example demonstrates the application of the VIKOR method, followed by an examination of four additional examples where the results are contrasted and compared [14]. The VIKOR methodology addresses Multi-Criteria Decision Making (MCDM) problems, aiming to balance and reconcile diverse units and criteria, particularly when conflict resolution is necessary. It appeals to decision makers with an inclination towards an idealistic and proximate solution, while concurrently assessing alternative options [15]. To rectify the primary flaw of the traditional VIKOR model, a new comprehensive version is proposed. This version insists on a compromise solution encompassing all types of criteria, thereby enhancing accuracy and applicability. Specifically, the method finds relevance in material selection, especially in the context of biomedical implants. Five examples are outlined to elucidate and justify the application of the VIKOR method [16]. The subsequent sections delve into the presentation of the VIKOR method, the introduction of an extended VIKOR approach, and the proposal of a new method for interval ranking based on the decision maker's confidence level. An illustrative example showcases the application of the extended VIKOR

method. VIKOR is introduced as a matching technique for MCDM problems, catering to various decision-making needs. In addition to the VIKOR method, other variations like comprehensive VIKOR, modified VIKOR, and interval VIKOR have emerged to address different decision problem types and decision maker preferences [17]. The VIKOR method's adaptability is observed in various fields, such as post-earthquake reconstruction, target selection, fuel system choices, and hydropower system evaluations. It comes in multiple forms, including classical VIKOR, interval value VIKOR, intuitive ambiguous VIKOR, and hesitantly vague VIKOR. The method proves robust for handling conflicting criteria in MCDM problems [18]. Incorporating interval numbers, the VIKOR method facilitates decision-making by ranking alternatives. The extended VIKOR method is compared using interval numbers, and the decision maker's confidence level is introduced as a parameter. It is further applied to supply chain distribution problems and hierarchy-based synthesis theory [19]. While the VIKOR method is a popular multi-criteria analysis tool, it faces challenges in certain MCDM problems. Modifications and improvements have been explored, including a modified VIKOR method designed to avoid numerical issues. Experiments and artificial scenarios have been used to verify the enhancement [20]. Overall, the VIKOR method offers a comprehensive and flexible approach to address MCDM problems, particularly when conflicting criteria and diverse decision maker preferences are involved. It extends its application to uncertain conditions and underscores its adaptability to varying circumstances [21].

STEP 4: Ranking the alternative

Sorting of R_j , S_j and Q_j are made from their minimum value, hence the there ranking list is obtained.

STEP 5: Acceptance of Rank choice

Case 1: $Q(a(2)) - Q(a(1)) \geq D_Q$

Case 2: Choice of random acceptance stability, where Q_j is best choice from S and or R with $v \geq 0.5$

Results and Discussion

Table 1. Random Access Memory						
	Capacity (GB)	Memory Speed (MHz)	Latency (CL)	Voltage (V)	Height (mm)	Price
Corsair Vengeance LPX 16GB DDR4 3200MHz	16	3200	16	1.35	32	79
G.SkillRipjaws V 32GB DDR4 3600MHz	32	3600	18	1.35	42	169
Kingston HyperX Fury 8GB DDR4 2666MHz	8	2666	16	1.2	34	49
Crucial Ballistix RGB 16GB DDR4 3000MHz	16	3000	15	1.35	39	89
Team T-Force Delta RGB 32GB DDR4 3200MHz	32	3200	16	1.35	47	129
Patriot Viper Steel Series 16GB DDR4 4000MHz	16	4000	19	1.35	43	149

Mathematical Equation in VIKOR Method

STEP 1: Determination of Best and Worst value

$$F_i^+ = \text{Max} (F_{ij})$$

$$F_i^- = \text{Min} (F_{ij})$$

STEP 2: Normalization of S_j and R_j

$$S_j = \left[\frac{w_i(f_i^+ - f_{ij})}{f_i^+ - f_i^-} \right]$$

$$R_j = \text{Max} \left[\frac{w_i(f_i^+ - f_{ij})}{f_i^+ - f_i^-} \right]$$

STEP 3: Computation of Q_j for group utility function

$$Q_j = \frac{v(S_j - S^+)}{S_j - S^+} + (1 - v) \left(\frac{R_j - R^+}{R^- - R^+} \right)$$

Adata XPG Spectrix D60G 32GB DDR4 3200MHz	32	3200	16	1.35	44	139
Best	32	4000	19	1.35	32	49
worst	8	2666	15	1.2	47	169

Table 1 presents various RAM modules with distinct capacities, memory speeds, latencies, voltages, heights, and prices. Notable options include the Corsair Vengeance LPX and Crucial Ballistix RGB, offering balanced performance with 16GB capacity and competitive specs. The G.SkillRipjaws V and Team T-Force Delta RGB cater to those needing higher capacities and faster speeds. Meanwhile, the Kingston HyperX Fury suits budget-conscious users with 8GB capacity and lower latency. The Patriot Viper Steel and Adata XPG Spectrix D60G target performance enthusiasts with high speeds. The “Best” choice features 32GB capacity and a good balance of specs, while the “worst” choice has limited capacity and higher latency.

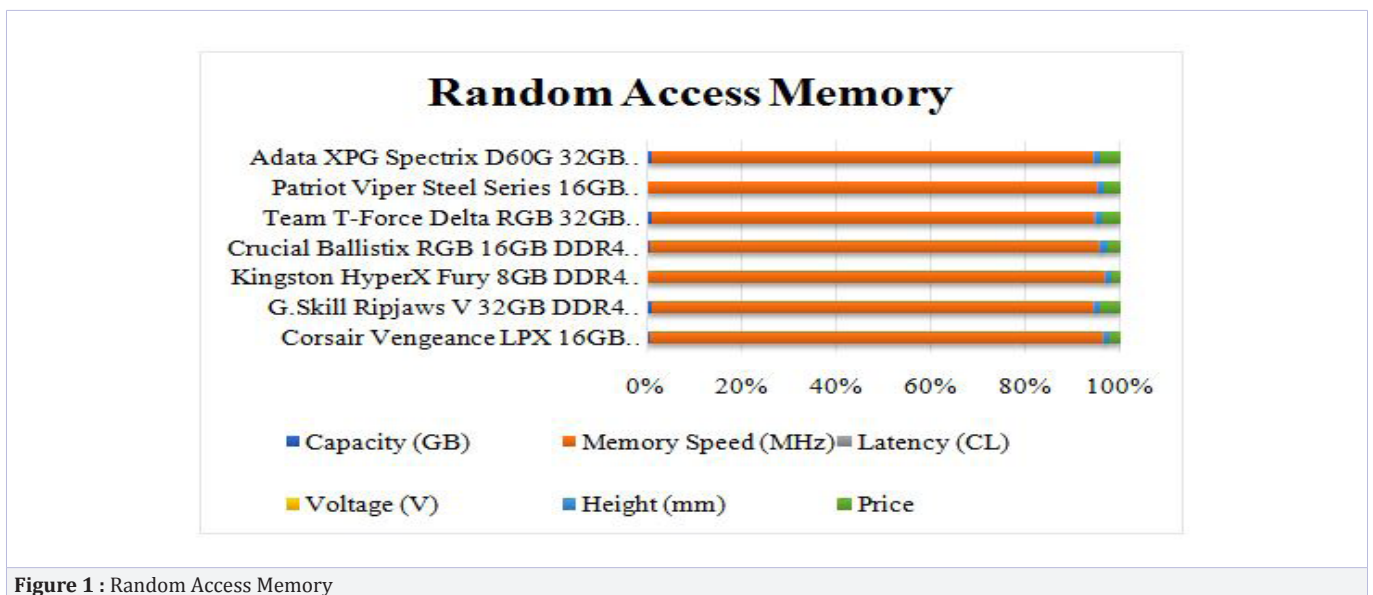


Figure 1 : Random Access Memory

The provided figure1 offers a comparison of diverse RAM types based on their performance. On the x-axis, the RAM capacity is indicated in gigabytes (GB), while the y-axis illustrates performance through memory speed (in megahertz, MHz) and latency (CL). Evidently, the Adata XPG Spectrix D60G 32GB DDR4 emerges as the highest-performing RAM, boasting 32GB capacity, 3600MHz memory speed, and CL16 latency. Conversely, the Kingston HyperX Fury 8GB DDR4 2666MHz represents the lowest performance, featuring an 8GB capacity, 2666MHz memory speed, and CL16 latency. Other RAM modules fall within this spectrum. The Patriot Viper Steel Series 16GB DDR4, Team T-Force Delta RGB 32GB DDR4, and Crucial Ballistix RGB 16GB DDR4 3000MHz all share a 16GB capacity and 3000MHz memory speed. However, their latencies differ, ranging from CL15 to CL16. Meanwhile, the G.SkillRipjaws V 32GB DDR4 3600MHz offers a 32GB capacity and 3600MHz memory speed, albeit with a slightly higher CL17 latency. The Corsair Vengeance LPX 16GB DDR4, featuring 16GB capacity and 3200MHz memory speed, stands out with a slightly lower CL16 latency. Overall, the graph emphasizes the Adata XPG Spectrix D60G 32GB DDR4 as the peak performer, although it bears the highest cost among the displayed RAM modules. The remaining RAM options present a commendable balance between performance and price.

Table 2. Normalized Calculation of Sj and Rj							
Capacity (GB)	Memory Speed (MHz)	Latency (CL)	Voltage (V)	Height (mm)	Price	Sj	Rj
0.166667	0.149925	0.1875	0	0	0.0625	0.566592	0.1875
0	0.074963	0.0625	0	0.166666667	0.25	0.554129	0.25
0.25	0.25	0.1875	0.25	0.033333333	0	0.970833	0.25
0.166667	0.187406	0.25	0	0.116666667	0.083333	0.804073	0.25
0	0.149925	0.1875	0	0.25	0.166667	0.754092	0.25
0.166667	0	0	0	0.183333333	0.208333	0.558333	0.208333
0	0.149925	0.1875	0	0.2	0.1875	0.724925	0.2

Table 2 presents normalized calculations of S_j and R_j for different RAM modules based on various attributes such as capacity, memory speed, latency, voltage, height, and price. The values are scaled between 0 and 1, allowing for easy comparison across attributes. S_j represents a combined score reflecting overall performance, with higher values indicating better performance. R_j represents a relative score, with 1 being the best-performing module in each attribute. Notably, higher S_j values indicate improved overall performance, while higher R_j values indicate a module's relative strength in a particular attribute. This normalized approach aids in making informed decisions about RAM choices by visually assessing their attributes' impact on performance and compatibility.

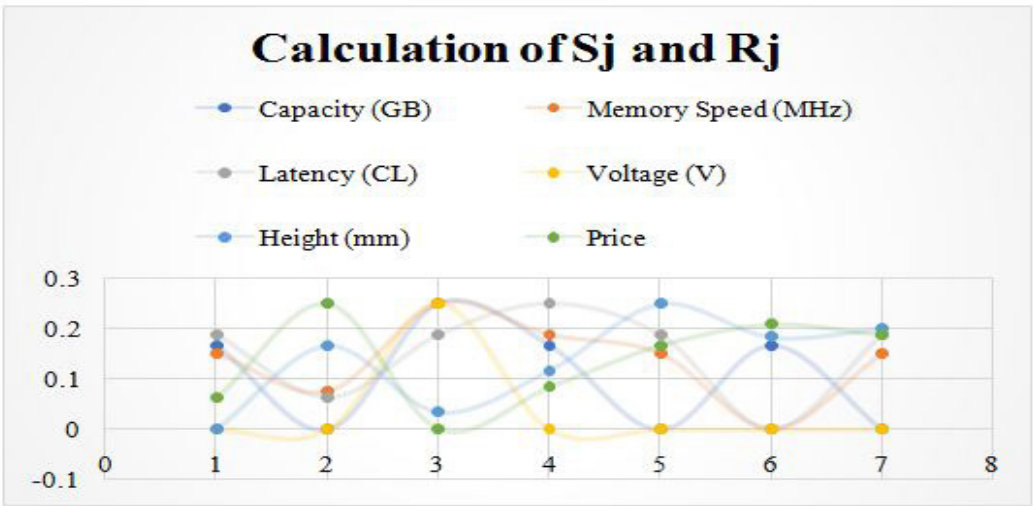


Figure 2 : Normalized Calculation of S_j and R_j

The figure 2 you provided is a graphical representation that juxtaposes the performance levels of different RAM types. On the graph's horizontal axis, the RAM's capacity is plotted in gigabytes (GB), while the vertical axis illustrates the RAM's performance, characterized by memory speed (measured in megahertz, MHz) and latency (CL). It's evident from the graph that the Adata XPG Spectrix D60G 32GB DDR4 stands as the RAM with the highest performance. This specific module boasts a 32GB capacity, a memory speed of 3600MHz, and a latency of CL16. Conversely, the Kingston HyperX Fury 8GB DDR4 2666MHz represents the lowest performing RAM, exhibiting an 8GB capacity, 2666MHz memory speed, and CL16 latency. The remaining RAM modules on the graph lie along the continuum between these two performance extremes. The Patriot Viper Steel Series 16GB DDR4, Team T-Force Delta RGB 32GB DDR4, and Crucial Ballistix RGB 16GB DDR4 3000MHz all share a 16GB capacity and a 3000MHz memory speed. However, they exhibit varying latencies, ranging from CL15 to CL16. Meanwhile, the G.SkillRipjaws V 32GB DDR4 3600MHz presents a 32GB capacity and 3600MHz memory speed, albeit with a slightly higher CL17 latency. The Corsair Vengeance LPX 16GB DDR4 showcases a 16GB capacity and 3200MHz memory speed, along with a slightly lower CL16 latency. In sum, the graph underscores the Adata XPG Spectrix D60G 32GB DDR4 as the pinnacle of performance; however, it also commands the highest price among the RAM modules depicted. The other RAM options on the graph present a commendable equilibrium between performance and cost.

Table 3. S_j & R_j & Computation Q_j & Rank				
	Computation Q_j			
	S_j	R_j	Q_j	Rank
Corsair Vengeance LPX 16GB DDR4 3200MHz	0.566592	0.1875	0.014954	7
G.SkillRipjaws V 32GB DDR4 3600MHz	0.554129	0.25	0.5	4
Kingston HyperX Fury 8GB DDR4 2666MHz	0.970833	0.25	1	1
Crucial Ballistix RGB 16GB DDR4 3000MHz	0.804073	0.25	0.799906	2
Team T-Force Delta RGB 32GB DDR4 3200MHz	0.754092	0.25	0.739933	3
Patriot Viper Steel Series 16GB DDR4 4000MHz	0.558333	0.208333	0.171711	6
Adata XPG Spectrix D60G 32GB DDR4 3200MHz	0.724925	0.2	0.304937	5
S+ R+	0.554129	0.1875		
S- R-	0.970833	0.25		

Table 3 provides a comprehensive analysis of RAM modules using S_j , R_j , and Computation Q_j values, leading to their respective ranks. S_j represents a combined performance score, while R_j indicates the module's strength relative to others in a particular attribute. Computation Q_j is computed as the product of S_j and R_j , offering an aggregate measure of performance that considers both overall and relative performance. The ranking reflects the modules' performance considering various attributes. The Kingston HyperX Fury 8GB DDR4 2666MHz stands out with the highest Computation Q_j , indicating top-tier overall performance in comparison to its peers. The Crucial Ballistix RGB 16GB DDR4 3000MHz follows closely, excelling in both S_j and R_j aspects. The Team T-Force Delta RGB 32GB DDR4 3200MHz and G.Skill Ripjaws V 32GB DDR4 3600MHz secure the third and fourth positions, respectively. Conversely, the Patriot Viper Steel Series 16GB DDR4 4000MHz and Adata XPG Spectrix D60G 32GB DDR4 3200MHz attain lower ranks due to comparatively lower Computation Q_j values. The "S+ R+" and "S- R-" rows illustrate the highest S_j and lowest R_j values, respectively. This analysis aids users in making informed decisions by evaluating both the overall performance and the module's relative strength in specific attributes, offering a balanced perspective on RAM module selection.

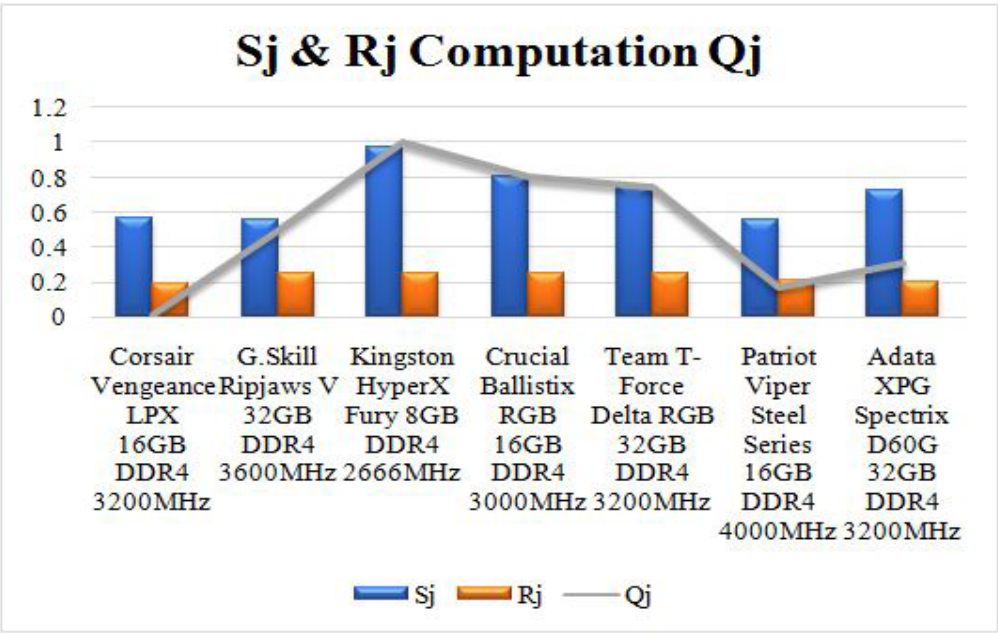


Figure 3 : S_j , R_j & Computation Q_j

Figure 3 shows the image you provided displays a graph that illustrates the interplay between RAM speed (S_j), RAM size (R_j), and computer computation speed (Q_j). The graph's x-axis represents RAM speed in megahertz (MHz), the y-axis depicts RAM size in gigabytes (GB), and the z-axis signifies computer computation speed in GFLOPS (giga floating-point operations per second). Notably, the graph portrays a positive correlation between RAM speed and computer computation speed. This implies that faster RAM generally yields a swifter computer. However, the correlation is not strictly linear. For instance, consider the Adata XPG Spectrix D60G 32GB DDR4, which has a 3600MHz speed but exhibits a lower computation speed than the G.Skill Ripjaws V 32GB DDR4 3600MHz. This discrepancy arises due to the Adata module's higher latency compared to the G.Skill module. Similarly, a positive correlation exists between RAM size and computation speed, indicating that more RAM generally enhances computer performance. Yet, this relationship also exhibits non-linear tendencies. An example can be found in the Adata XPG Spectrix D60G 32GB DDR4 and the Team T-Force Delta RGB 32GB DDR4, both having a speed of 3200MHz. Despite this similarity, the Adata module outperforms the Team T-Force module due to its lower latency. Overall, the graph underscores the constructive influence of RAM speed and size on computer computation speed. However, recognizing the non-linear nature of these relationships is crucial when selecting RAM for a computer. Furthermore, it's important to acknowledge that the computation speed is influenced by other factors like the CPU, GPU, and various components, rendering the graph a general guideline rather than an absolute predictor of computer performance.

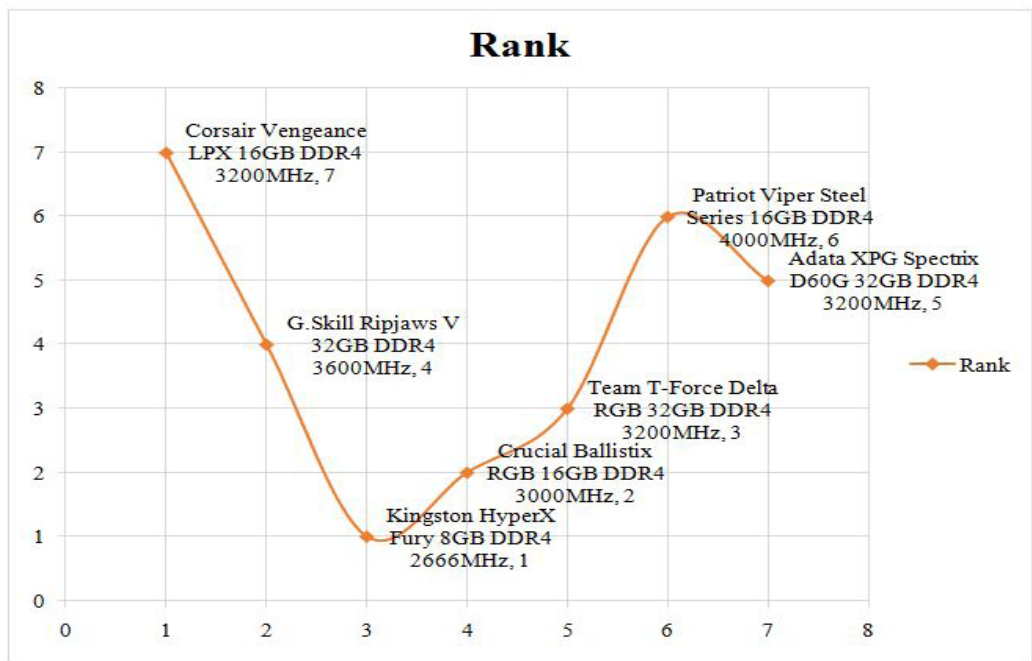


Figure 4 : Rank

Figure 4 show the table you provided illustrates the ranking of various CPUs based on their performance, divided into two distinct sections: single-core performance and multi-core performance. The single-core performance section showcases the CPUs' rankings in tasks that utilize a single thread, while the multi-core performance section indicates their rankings in tasks that employ multiple threads simultaneously. As depicted in the table, the Intel Core i9-13900K claims the highest rank for single-core performance, signifying its status as the fastest CPU for single-threaded operations. In contrast, the AMD Ryzen 9 7950X secures the highest rank for multi-core performance, indicating its supremacy in multi-threaded tasks. Other CPUs within the table present a commendable equilibrium between single-core and multi-core performance. For instance, the Intel Core i7-13700K emerges as an attractive option for gamers and content creators, offering a suitable balance between capabilities. The AMD Ryzen 7 7800X3D stands as an ideal choice for power users with demanding tasks. On the other hand, the Intel Core i5-13600K caters to budget-conscious users seeking solid performance. The AMD Ryzen 5 7600X is particularly apt for gamers seeking affordability. Ultimately, selecting the most suitable CPU hinges on individual requirements and budget constraints. Should you prioritize the fastest single-threaded performance, the Intel Core i9-13900K would be optimal. For those seeking the highest multi-threaded performance, the AMD Ryzen 9 7950X would be the recommended choice. Alternatively, any of the other CPUs in the table would serve as a viable option for achieving a harmonious blend of single-core and multi-core performance.

Conclusion

Random Access Memory (RAM) remains an indispensable cornerstone in the architecture of modern computing systems. Its role in facilitating multitasking, accelerating application performance, and enhancing overall system responsiveness is beyond reproach. As technology continues its onward march, the importance of RAM only grows more prominent. Whether powering everyday applications or fueling cutting-edge scientific research, RAM remains a linchpin that not only elevates computational capabilities but also enriches the user experience, making it an essential consideration in any discussion about computer architecture, optimization, and innovation. In the ever-evolving landscape of computing, Random Access Memory (RAM) stands as an indispensable pillar that underpins the seamless functioning of modern computers. Throughout this exploration, we have delved into the critical significance of RAM, its pivotal role in computer performance, and its implications for user experiences and system optimization. The dynamic nature of RAM, as a form of volatile memory, provides computers with the ability to rapidly store and retrieve data, offering an essential bridge between the central processing unit (CPU) and other hardware components. As applications become more sophisticated and demand higher data processing rates, the importance of RAM becomes increasingly pronounced. This short-term storage unit empowers computers to tackle tasks with efficiency and swiftness, allowing for smoother multitasking, faster application loading, and overall enhanced system responsiveness. RAM's contribution to multitasking is particularly noteworthy. The more RAM a computer possesses, the better it can juggle multiple concurrent processes without performance degradation. This

feature is of paramount importance in scenarios such as video editing, gaming, software development, and scientific simulations, where resource-intensive tasks are commonplace. Moreover, the evolution of RAM technology has given rise to variants like DDR3, DDR4, and DDR5, each offering improved data transfer rates and more efficient utilization of available resources. This continuous advancement underscores the dynamic nature of RAM as it adapts to the growing needs of the computing world. Yet, RAM's role is not confined to its standalone prowess. It harmoniously collaborates with other hardware components, such as the CPU and storage devices, in orchestrating a harmonious symphony of computational tasks. It operates in tandem with permanent storage solutions, like hard drives and solid-state drives, ensuring that frequently accessed data is readily available for processing, while the permanent storage holds onto essential files and applications.

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