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Research paper

Arduino-Powered Parking System with Real-Time Proximity Space Monitoring

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Abstract

This paper presents an innovative Arduino-based smart parking system that utilizes real-time proximity sensing to efficiently manage parking spaces. The system employs ultrasonic sensors, LCDs, LED indicators, and a Wi-Fi module to deliver accurate and intuitive feedback to drivers. When an available parking space is detected, the system automatically updates the parking status and guides the driver to the vacant spot, thereby reducing search time and fuel consumption. The system can also be integrated with cloud databases and mobile applications, enabling remote access to real-time parking data and enhancing user convenience. Automated space allocation minimizes human intervention, increases operational efficiency, and reduces costs. IoT-enabled connectivity ensures seamless data exchange for continuous monitoring and predictive analytics, optimizing overall parking management. Security is enhanced through camera-based vehicle identification, preventing unauthorized access and improving enforcement. The system's modular and scalable design makes it suitable for deployment in diverse settings such as shopping malls, office complexes, hospitals, airports, and universities.

Keywords: *Arduino; Smart Parking System; Real-Time Proximity Sensing; Ultrasonic Sensors; LCD Displays; LED Indicators.*

1. Introduction

The rapid urbanization and growing vehicle population have led to a surge in parking-related issues, causing frustration and congestion in urban areas. Traditional parking systems often rely on manual monitoring and static signage, which can be inefficient, ineffective, and costly. These systems fail to provide real-time information, leading to wasted time, fuel. To address these challenges, this project proposes the development of an innovative Arduino-powered parking system with real-time proximity space monitoring.

This intelligent system integrates cutting-edge technologies, including ultrasonic sensors, LCDs, and LED indicators, to provide accurate and intuitive feedback to drivers. By optimizing parking space utilization and reducing congestion, this system aims to revolutionize the parking experience, making it more efficient, convenient, and sustainable.

The inefficiencies of traditional parking methods have had far-reaching consequences. Studies suggest that nearly 30% of urban congestion is caused by drivers searching for parking, leading to increased air pollution and wasted time. Moreover, unauthorized and mismanaged parking further complicates the issue, causing disruptions in traffic flow.

The Arduino-powered parking system utilizes IoT-based technology to provide real-time monitoring, optimize resource allocation, and enhance security. Using Arduino microcontrollers and ultrasonic sensors, the system detects vehicle presence and displays availability on LCD screens and LED indicators. Its scalable and modular design enables seamless integration with automated payments, vehicle tracking, and mobile navigation, making it suitable for shopping malls, offices, hospitals, airports, and universities.

2. Related Works

Udo et al. (2023) propose a fuzzy-based smart car parking system utilizing Arduino to enhance parking space management through intelligent decision-making. Their method addresses the inefficiencies of traditional parking systems, which rely on static signage and manual monitoring, leading to congestion and underutilized spaces. To overcome these challenges, the system integrates fuzzy logic with RFID-based vehicle identification, weight sensors, and an Arduino microcontroller to optimize parking allocation based on vehicle weight and availability. This approach not only automates the parking process but also improves space utilization by dynamically assigning slots, ensuring efficient parking management, and reducing traffic congestion in urban areas.

Veeramanickam et al. (2022) propose an IoT-based smart parking model using Arduino UNO with FCFS priority scheduling to improve parking efficiency. Traditional systems often cause congestion due to a lack of real-time monitoring. Their model uses ultrasonic sensors, RFID technology, and cloud-based data processing to detect and allocate spaces based on arrival order. This approach ensures fair slot assignment, reduces search time, and enhances overall parking management while integrating seamlessly with smart city infrastructure.

Smith et al. (2022) present an Arduino microcontroller-based intelligent car parking system to enhance parking efficiency and reduce congestion. Traditional parking methods rely on manual monitoring, leading to space mismanagement and increased search time. Their system integrates ultrasonic sensors, RFID technology, and an Arduino microcontroller to automate space detection and vehicle identification. Real-time data processing allows for efficient slot allocation, improving parking space utilization and minimizing traffic congestion. This approach provides a cost-effective and scalable solution for modern urban parking management.
Kadhim (2018) introduces an Arduino-based smart parking management system utilizing ultrasonic sensors and IoT technologies to optimize parking efficiency. Traditional parking systems often suffer from congestion and inefficient space utilization due to the lack of real-time monitoring. This system integrates ultrasonic sensors for vehicle detection, an Arduino microcontroller for data processing, and IoT connectivity for remote access to parking status. By enabling automated slot allocation and real-time updates, the system reduces search time, enhances space utilization, and provides a scalable solution for modern urban parking management.
Sodiq and Hasbullah (2018) propose an Arduino-based parking rotation system to optimize space utilization and reduce congestion. The system uses Arduino microcontrollers, ultrasonic sensors, and a rotational mechanism to adjust parking slots based on availability. This approach minimizes search time, maximizes capacity, and improves overall parking efficiency in urban areas.
Narayana et al. (2018) present an IoT-based smart car parking system to enhance parking efficiency and reduce congestion. The system utilizes Arduino, ultrasonic sensors, and cloud connectivity to monitor parking space availability in real-time. By providing automated slot allocation and remote access through IoT integration, it minimizes search time, optimizes space utilization, and offers a scalable solution for modern urban parking management.

3. Methodology

The Arduino-powered parking system uses ultrasonic sensors, LCDs, LED indicators, and Wi-Fi modules to detect available parking spaces in real time, providing instant feedback to drivers. Unlike traditional manual parking methods that lead to inefficiencies, this system automates space allocation, reducing congestion and fuel consumption. This cost-effective and scalable solution optimizes parking management, enhances security, and contributes to a more organized urban infrastructure.

3.1. Setting up the hardware components

To begin, gather all the necessary components required for building the smart parking system. The Arduino Uno acts as the central microcontroller, while IR sensors are used to detect vehicle entry and exit. Ultrasonic sensors monitor parking slot occupancy, and a servo motor controls the parking gate. A 16x2 LCD is included to show the number of available slots in real-time, and LED indicators provide visual feedback for occupied and vacant spaces. Ensure that all components are placed on a breadboard or PCB for proper testing before final assembly.

3.2. Connecting the sensors and actuators

After setting up the components, connect the IR sensors at the entry and exit gates to detect vehicles. Position the ultrasonic sensors above each parking slot to measure distances and determine if a slot is occupied. The servo motor is installed at the entrance to open and close the gate based on parking availability. The LCD is connected to update and show the number of free slots dynamically. Additionally, LEDs are placed next to each slot, where a red LED indicates an occupied space and a green LED shows an available slot. Ensure all wiring connections are secure and organized to prevent electrical failures. Also, integrate the microcontroller (such as an Arduino) with these sensors and actuators, ensuring proper power distribution and signal connections. Use resistors where necessary to avoid voltage fluctuations and potential damage to components. Finally, test each connection with a multimeter before powering the system to ensure reliability and prevent short circuits.

3.3. Algorithm development and software implementation

The software development phase involves writing an embedded C++ program using the Arduino IDE, ensuring seamless coordination between hardware components. The algorithm begins with IR sensors detecting a vehicle at the entrance. If a parking slot is available, the servo motor activates to open the gate, allowing entry. Ultrasonic sensors continuously measure distances to update the occupancy status of each parking slot. The LCD dynamically shows the number of available slots in real time, while LED indicators change color to reflect slot occupancy—green for available and red for occupied. When a vehicle exits, the IR sensor at the exit detects movement, updating the slot count accordingly. The Arduino processes all sensor inputs and controls the display, LEDs, and servo motor based on real-time data. The Serial Monitor feature in the Arduino IDE is used for debugging and monitoring sensor outputs. The flowchart illustrating this process is given below.

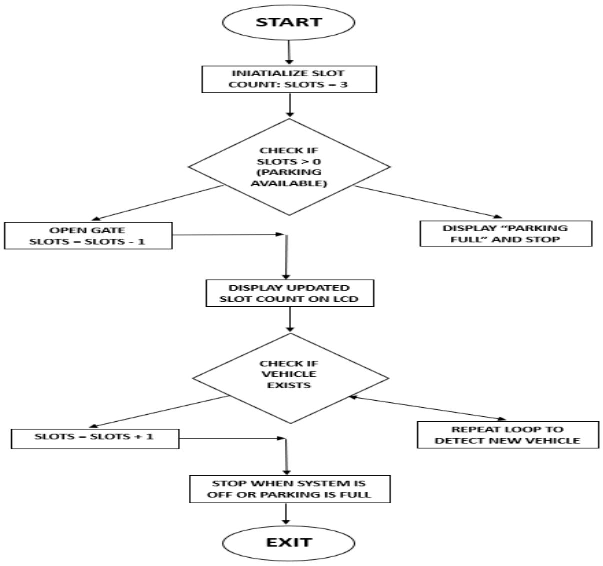

Fig. 1: Workflow Diagram of the Proposed System.

3.4. System assembly and physical mode construction

Once the electronic components are tested, they are assembled onto a miniature parking model. The model is built using foamboard, cardboard to resemble a real parking lot. As shown in Fig. 2, the IR sensors are fixed at the entrance and exit, while the ultrasonic sensors are mounted above parking slots. The LCD is positioned for clear visibility, and LED indicators are placed near each parking space. The servo motor is installed as a functional gate, ensuring smooth movement when activated. Wires are neatly arranged, and the system is powered using a 5V adapter. This stage ensures that the system is realistic, scalable, and well-organized for demonstration. To enhance durability, components are securely fixed using glue or screws, preventing displacement during operation. Proper insulation and cable management techniques are applied to avoid short circuits and maintain a tidy setup.

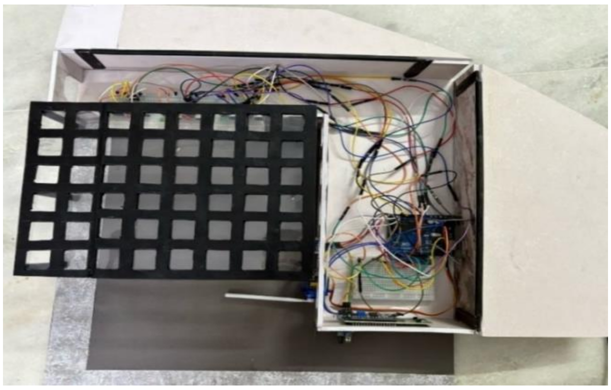

Fig. 2: Physical Model Construction.

3.5. Testing, validation, and performance analysis

The final stage involves rigorous testing to validate the system's functionality under multiple scenarios, ensuring accurate vehicle detection, slot monitoring, and gate operation. The IR sensors are tested for precise entry and exit detection, confirming their ability to detect vehicles reliably. Ultrasonic sensors are evaluated for their accuracy in identifying occupied and vacant parking slots based on real-time distance measurements. The LCD and LED indicators are checked to ensure they update dynamically, reflecting the current parking status. The servo motor's functionality is tested to confirm that the gate operates only when slots are available and remains closed when the parking lot is full. Additionally, the system's response time and accuracy are measured to ensure quick and reliable slot detection and updates. Testing is conducted in both controlled lab environments and simulated real-world conditions, with performance metrics such as detection accuracy, response time, and sensor precision recorded for evaluation.

4. Architecture and Proposed System

The architecture of the proposed Smart Parking System (figure 3)is designed to enable automated vehicle detection, real-time slot monitoring, and efficient gate control using an Arduino-based framework. The system consists of IR sensors placed at the entrance and exit to detect vehicle movement, while ultrasonic sensors are positioned above parking slots to monitor occupancy. A servo motor is used to control the entrance gate, opening and closing based on slot availability. The Arduino Uno microcontroller serves as the central processing unit, receiving input from sensors and executing decisions accordingly. A 16x2 LCD provides real-time updates on the number of available slots, while LED indicators visually represent whether a slot is occupied (Red) or vacant (Green). The entire system is powered by a 5V adapter or battery, ensuring low energy consumption and continuous operation. The components are interconnected through a structured wiring system, with proper insulation to prevent electrical faults. The LCD and LEDs are placed at strategic locations to ensure clear visibility for drivers. The entry and exit IR sensors are calibrated to detect a wide range of vehicle sizes accurately. Proper

signal filtering techniques are used to reduce noise and enhance sensor precision. The system is designed to be modular and scalable, allowing future expansion with additional sensors or IoT integration.
The functional workflow of the system begins with a vehicle approaching the parking area, triggering the entry IR sensor. If a parking slot is available, the servo motor opens the gate, and the vehicle proceeds inside. The ultrasonic sensors then detect the occupied slot and update the LCD and LEDs. If the parking lot is full, the system displays "Parking Full" and prevents entry. When a vehicle exits, the exit IR sensor detects movement, and the slot count is updated to reflect the available space. The Arduino continuously processes data from all sensors, ensuring real-time monitoring and smooth automation. Additionally, the servo motor returns to its default position once the vehicle passes through the entry point. The system can be configured to trigger an alert if a vehicle attempts to enter when no slots are available. Multiple test cases have been implemented to verify the system's accuracy in detecting parked and exiting vehicles. The response time for sensor detection and slot updates is optimized to provide real-time results. Overall, this architecture provides an efficient, cost-effective, and scalable solution for smart parking management, minimizing manual intervention and optimizing space utilization.

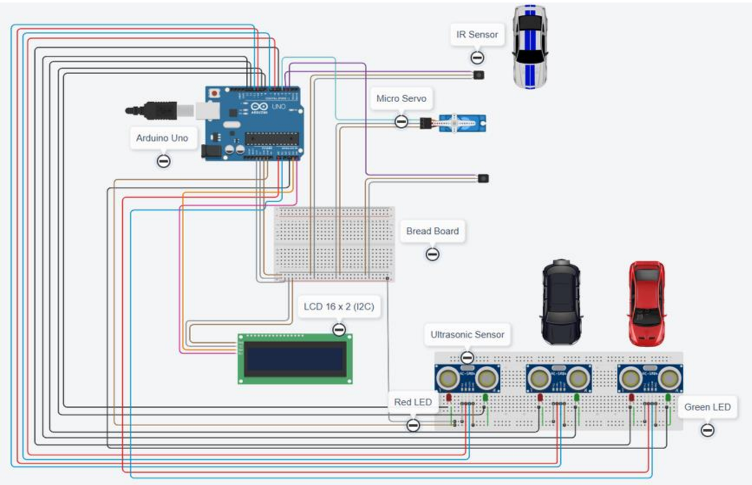

Fig. 3: Architecture Diagram.

4.1. Efficiency of the proposed system

The proposed Smart Parking System, utilizing Arduino-based automation and sensor technology, demonstrates high accuracy in detecting vehicle movement and monitoring parking slot occupancy. By integrating IR sensors for entry/exit detection and ultrasonic sensors for slot monitoring, the system can effectively track vehicle presence and dynamically update parking availability. The ability to monitor parking slot status in real time enables better space utilization and minimizes congestion. To fully evaluate the system's efficiency and address potential limitations, rigorous testing and validation are essential. This includes defining appropriate performance metrics, assessing the system under various conditions, and comparing its accuracy with traditional parking management methods. By addressing these factors, a comprehensive assessment of the proposed Smart Parking System can be conducted, ensuring a reliable foundation for future enhancements and wider implementation.
Accuracy is a key performance metric used to evaluate the overall effectiveness of the parking system. It is measured as the proportion of correctly detected vehicle movements and slot statuses out of the total number of detections made by the system.
The formula for accuracy is:

1) Accuracy of Vehicle Detection (IR Sensors):

$$\text{Accuracy of IR Sensors} = \frac{\text{TP}}{\text{TP} + \text{FN}} \text{X } 100$$

The IR sensor detected the vehicle 98 times out of 100. Therefore,

$$\frac{98}{100} \text{X } 100 = 98\ \%$$

2) Accuracy of Parking Slot Monitoring (Ultrasonic Sensors):

$$\text{Accuracy of Ultrasonic Sensors} = \frac{\text{TP}}{\text{TP+FN+FP}} \text{ X } 100$$

The Ultrasonic Sensor correctly detected 95 occupied slots out of 100. Therefore,

$$\frac{95}{100} \text{X } 100 = 95\%$$

3) Overall System Accuracy:

$$\text{Overall Accuracy} \quad = \frac{\text{Accuracy of IR Sensors+Accuracy of Ultrasonic Sensors}}{2}$$

Therefore, the overall system accuracy is:

$$\frac{\mathbf{98+95}}{\mathbf{2}} = 96.5\ \%$$

4.2. Comparison of existing and proposed systems

The Arduino-based Smart Parking System offers significant advantages over traditional parking management methods and barrier-based systems. This system is specifically designed for real-time vehicle detection and parking slot monitoring, making it ideal for automated parking solutions. One key advantage is the use of IR sensors and ultrasonic sensors, which allow for precise detection of vehicle entry, exit, and slot occupancy. The combination of these sensors ensures accurate slot availability tracking, reducing errors in parking space allocation and improving overall efficiency. The comparison of different parking management systems highlights the advantages of the Arduino-based Smart Parking System over traditional and older automated methods. The proposed system leverages IR sensors for vehicle detection and ultrasonic sensors for slot monitoring, ensuring a high detection accuracy of approximately 96.5%. Unlike traditional parking systems, which rely on manual supervision, or barrier-based systems, which depend on mechanical sensors and ticket validation, the Arduino-based solution provides real-time updates via an LCD and LED indicators, as shown in Figure 4.

In contrast, manual parking systems rely on human supervision, which can lead to delays and inaccuracies in slot monitoring. Barrier-based systems, while semi-automated, lack real-time slot tracking and depend on mechanical ticket validation, which is slower and prone to wear and tear. Additionally, the Arduino-based system is cost-effective, as it requires minimal infrastructure compared to large-scale automated parking solutions. Its ability to provide dynamic slot updates via an LCD and LED indicators enhances user convenience, ensuring a smooth parking experience. Therefore, the real-time accuracy, automation, and scalability of the Smart Parking System make it a superior choice for improving modern parking management. The compact and modular design of the Arduino system allows it to be deployed in both small and medium-scale parking lots with ease. It is also highly adaptable, enabling developers to add features like mobile app integration or cloud-based analytics in the future. Maintenance is simple due to the use of off-the-shelf components, which are easy to replace or upgrade. Overall, this system bridges the gap between affordability and intelligent automation in parking technology.

Table 1: Comparison of Existing and Proposed Systems

Parameter	Proposed System (Arduino-Based)	Traditional Parking System	Barrier-Based Parking System
Vehicle Detection	IR sensors with ~98% accuracy	Manual or ticket-based entry	Mechanical sensor-based (~90% accuracy)
Slot Monitoring	Ultrasonic sensors (~95% accuracy)	Visual/manual verification	No slot monitoring, relies on ticket validation
Real-Time Updates	LCD and LED indicators for slots	No automated display	Limited digital display (only entry/exit status)
Response Time	~500 ms (real-time)	Manual process (delayed)	~2-3 sec (barrier and ticket scanning process)
Overall Accuracy	~96.5% (IR + Ultrasonic Sensors)	Prone to human error (~85%)	~88% (mechanical sensors with occasional failures)

4.3. Final result

Fig. 4: Physical Model Showing Empty Parking Slots with Green LED Indication.

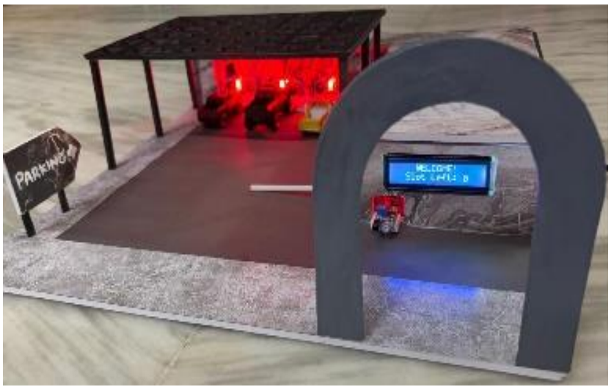

Fig. 5: Physical Model Showing Full Parking Slots with Red LED Indication.

5. Conclusion

In this study, we developed an Arduino-powered smart parking system that utilizes real-time proximity sensing to enhance parking efficiency and space utilization. The system integrates ultrasonic sensors, LCDs, LED indicators, and a Wi-Fi module to provide real-time feedback to drivers, reducing search time and congestion.

By leveraging IoT connectivity, the system ensures accurate and automated parking management, addressing the limitations of traditional parking methods. The proposed system has significant implications for smart city infrastructure, offering a cost-effective and scalable solution for urban parking challenges. By automating parking allocation and monitoring, it optimizes space utilization and enhances user convenience. The system's adaptability allows for seamless integration into shopping malls, corporate offices, airports, hospitals, and universities, making it a versatile and impactful solution for modern urban environments. Future work will focus on expanding the system's capabilities, including AI-based vehicle recognition, mobile app integration, and predictive analytics for advanced parking management. Additionally, incorporating automated payment systems and cloud-based data analysis will further enhance efficiency and user experience. Overall, the Arduino-powered smart parking system represents a significant advancement in intelligent parking solutions, demonstrating the potential of IoT and automation in revolutionizing urban mobility.

In addition, the system can be further enhanced by integrating machine learning algorithms to analyze parking patterns and predict space availability, improving overall efficiency. Implementing real-time notifications and reservation features through a mobile application can enhance user convenience and reduce last-minute parking hassles. The incorporation of solar-powered components can make the system more energy-efficient and environmentally friendly. Future research can also explore the integration of vehicle-to-infrastructure (V2I) communication to further optimize parking guidance and traffic flow. With continuous advancements in IoT and smart city technologies, this system has the potential to become a fundamental component of modern urban infrastructure, providing seamless, automated, and intelligent parking solutions.

References

[1] Hary, H., Bansal, P., & Valarmathi, B. (2017, January). Advanced CAR parking system using Arduino. In 2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 1-5). IEEE. https://doi.org/10.1109/ICACCS.2017.8014701.

[2] Nandyal, S., Sultana, S., & Anjum, S. (2017). Smart car parking system using arduino uno. International Journal of Computer Applications, 169(1), 13-18. https://doi.org/10.5120/ijca2017914425.

[3] Kadhim, M. H. (2018). Arduino smart parking manage system based on ultrasonic. Int. J. Eng. Technol, 7, 494-501.

[4] Veeramanickam, M. R. M., Venkatesh, B., Bewoor, L. A., Bhowte, Y. W., Moholkar, K., & Bangare, J. L. (2022). IoT based smart parking model using Arduino UNO with FCFS priority scheduling. Measurement: Sensors, 24, 100524. https://doi.org/10.1016/j.measen.2022.100524.

[5] Alshehri, F., Almawgani, A. H. M., Alqahtani, A., & Alqahtani, A. (2019, May). Smart parking system for monitoring cars and wrong parking. In 2019 2nd International Conference on Computer Applications & https://arxiv.org/abs/2006.01128 Information Security (ICCAIS) (pp. 1-6). IEEE. https://doi.org/10.1109/CAIS.2019.8769463.

[6] Sodiq, M., & Hasbullah, H. (2018, July). Prototype of Arduino based parking rotation system. In IOP Conference Series: Materials Science and Engineering (Vol. 384, No. 1, p. 012013). IOP Publishing. https://doi.org/10.1088/1757-899X/384/1/012013.

[7] Kannan, M., Mary, L. W., Priya, C., & Manikandan, R. (2020, March). Towards smart city through virtualized and computerized car parking system using arduino in the internet of things. In 2020 International Conference on Computer Science, Engineering and Applications (ICCSEA) (pp. 1-6). IEEE. https://doi.org/10.1109/ICCSEA49143.2020.9132876.

[8] Kabir, A. T., Nath, N. D., Hasan, F., Utshaw, R. A., & Saha, L. (2019, July). Automated Parking System with Fee Management Using Arduino. In 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-6). IEEE. https://doi.org/10.1109/ICCCNT45670.2019.8944642.

[9] Bhorge, S., Jadhav, Y., Kalamkar, K., & Katepallewar, P. (2024, April). Arduino Uno-based Adaptive Parking System. In 2024 International Conference on Inventive Computation Technologies (ICICT) (pp. 1861-1864). IEEE. https://doi.org/10.1109/ICICT60155.2024.10544537.

[10] Suresh, M., Kumar, P. S., & Sundararajan, T. V. P. (2015, March). IoT-based airport parking system. In 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS) (pp. 1-5). IEEE. https://doi.org/10.1109/ICIIECS.2015.7193216.

[11] Hameed R, Qadeer W, Wachs M, Azizi O, Solomatnikov A, et. al. Understanding Sources of Inefficiency in General-Purpose Chips. ACM SIGARCH Computer Architecture News.2010;38:37-47. https://doi.org/10.1145/1816038.1815968.