FACULTY OF ENGINEERING AND ARCHITECTURE
DEPARTMENT OF YOURDEPARTMENT

# Smart Tool Cabinet

GRADUATION PROJECT

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# ABSTRACT

The Smart Tool Cabinet project presents an innovative solution utilizing a C# Windows Forms application integrated with image processing techniques to revolutionize tool management and status control within industrial and workshop settings. This multifaceted system aimed to enhance efficiency, security, and accessibility in handling diverse tool inventories. The core of this project involved a user-centric C# Windows Forms application that acted as the central interface for administrators and technicians. The application streamlined tool management through a comprehensive database that cataloged tool specifications, maintenance history, and current locations within the cabinet. Leveraging intuitive design principles, the interface prioritized ease of navigation and user interaction. Moreover, the implementation incorporated cutting-edge image processing capabilities to monitor tool status within the cabinet. Utilizing cameras or optical sensors, the system captured real-time images of tool compartments, employing image recognition algorithms to detect tool presence, absence, or misplacement. This innovative approach enabled automated tracking and alerts for discrepancies in the tool inventory, ensuring swift and accurate status control.

# ÖZET

Akıllı Alet Dolabı projesi, endüstriyel ve atölye ortamlarında alet yönetimi ve durum kontrolünde devrim yaratmak için görüntü işleme teknikleriyle entegre edilmiş bir C# Windows Forms uygulaması kullanan yenilikçi bir çözüm sunmaktadır. Bu çok yönlü sistem, çeşitli alet envanterlerinin işlenmesinde verimliliği, güvenliği ve erişilebilirliği artırmayı amaçlamıştır. Bu projenin özü, yöneticiler ve teknisyenler için merkezi arayüz görevi gören kullanıcı merkezli bir C# Windows Forms uygulamasını içeriyor. Uygulama, alet özelliklerini, bakım geçmişini ve kabin içindeki mevcut konumları kataloglayan kapsamlı bir veritabanı aracılığıyla alet yönetimini kolaylaştırıyor. Sezgisel tasarım ilkelerinden yararlanan arayüz, gezinme kolaylığı ve kullanıcı etkileşimine öncelik veriyor. Ayrıca uygulama, kabin içindeki alet durumunu izlemek için sensörler ve aletlerin fiziksel durumunun kontrolü için kameralar kullanıyor, Bu yenilikçi yaklaşım, takım envanterindeki düzeni sağlıyor.

# ACKNOWLEDGMENTS

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# TABLE OF CONTENTS



# LIST OF FIGURES

# I. INTRODUCTION

The "Smart Tool Cabinet" project aimed to develop an advanced system for effective tool management and organization within industrial and workshop environments. This project leveraged a C# Windows Forms application, integrated with image processing techniques, RFID, Arduino, and micro switchs, to create a sophisticated tool management solution. The primary goal was to enhance the efficiency and accuracy of tool usage, reduce the incidence of misplaced tools, and streamline the workflow for technicians and engineers.

The software provided an intuitive interface for administrators, allowing real-time monitoring of tool inventory, classification of different tools, and tracking of tool usage. The integration of RFID and barcode scanning technologies enabled precise identification and assignment of tools to specific storage locations. This technological synergy facilitated rapid and accurate tool tracking, ensuring optimal organization and minimizing tool misplacement.

Furthermore, the project incorporated image processing techniques to monitor the status of tools within the cabinet. By utilizing cameras and optical sensors, real-time images of tool compartments were captured and analyzed using image recognition algorithms. This innovative approach allowed for automated tracking of tool presence, absence, or misplacement, providing immediate alerts for any discrepancies in the tool inventory.

In addition to the primary functionalities, the project also focused on tool condition monitoring. Given the unavoidable and irreversible nature of tool wear, a tool condition monitoring (TCM) system was developed to proactively schedule maintenance and prevent catastrophic failures. The TCM system utilized image processing to directly measure tool wear, providing a reliable and automatic characterization of tool condition without the need for expert knowledge.

This project not only aimed to address current challenges in tool management but also sought to set a new standard in the field by integrating multiple advanced technologies into a cohesive system. The "Smart Tool Cabinet" project demonstrated the potential for significant improvements in operational efficiency, security, and accessibility in industrial tool management.

## II. LITERATURE REVIEW AND METHODOLOGY

An extensive literature review was conducted to gather insights and knowledge on tool management systems, user interface design, and the basics of C# programming. This review provided valuable information that significantly influenced the design and operational features of the Smart Tool Cabinet project. Various studies have explored the monitoring of tool wear and the life of turning tools. Rehorn et al. provided a comprehensive review of sensors and signal processing methodologies used for tool condition monitoring in turning, drilling, and milling processes. Their work highlighted the importance of accurate tool monitoring to enhance manufacturing efficiency and reduce downtime. Cakir and Isik investigated variations in cutting forces when turning AISI 1050 steel using coated and uncoated tungsten carbide ISO P25 tools. Their study utilized a tool life and condition monitoring system to track these variations, emphasizing the critical role of monitoring in maintaining tool performance and quality. Kim et al. developed a magnetic jig for fixing a camera and lighting system to measure flank wear on a 4-fluted end mill. They compared the signal-to-noise ratio of measurements using a microscope and a CCD camera with a novel jig, demonstrating improvements in measurement accuracy. Kerr et al. employed four different texture analysis techniques—histogram-based processing, grey level co-occurrence technique, frequency domain analysis, and fractal method—to analyze the texture of worn regions on turning and milling inserts. They found that frequency domain analysis provided the best results due to its position and illumination invariance. Jackson et al. proposed a novel edge detection algorithm utilizing neural networks for tool wear detection. They used scanning electron microscopic images of flank wear on a 4-fluted high-speed steel milling cutter, highlighting the potential of advanced algorithms in improving wear detection accuracy. Atli et al. introduced a new measure called DEFROL (deviation from linearity) to classify sharp and dull drilling tools based on their images. However, their focus on point angle changes and linearity deviation did not fully address flank wear, which is a standard measure of tool life. Makki et al. captured real-time images of drill bits at 100 rpm and processed these images using edge detection and segmentation techniques to determine tool wear and tool run-out. Although their technique was effective for lip portion wear, it did not measure flank wear or tool run-out perpendicular to the image plane. The insights gained from these studies provided a solid foundation for developing the Smart Tool Cabinet project. By integrating RFID, Arduino, micro switch, and image processing technologies, the project aimed to create a comprehensive tool management system that addressed the limitations and challenges identified in the existing literature. This integration not only enhanced tool tracking and management but also introduced innovative methods for monitoring tool condition and wear, contributing to the advancement of industrial tool management practices.

The methodology for the Smart Tool Cabinet project was structured into several key phases, each focusing on different aspects of the system's development and implementation. The primary areas included technical learning, interface design, sensor selection, communication setup, tool cabinet usage, and RFID integration.

**Technical Learning:**

The initial phase involved gaining proficiency in C# programming, a crucial skill for building the application. This phase included understanding the programming language's syntax, data structures, and core principles, which laid a strong foundation for the project's coding stage.

**Interface Design:**

A detailed flowchart was created to map out the stages of the user interface, illustrating how users would interact with the application. This included designing navigation routes and primary features. An initial design for the welcome screen was developed, focusing on user engagement and guidance.

**Sensor Selection:**

The sensors for the project were selected based on sensitivity, response time, and compatibility with Arduino. These sensors provided the necessary precision to detect the status of tools in the cabinet drawers, ideal for real-time data transfer. Factors such as energy consumption and cost were also considered during the selection process.

**Arduino and Windows Forms Interface Communication:**

Arduino was used as the central control unit. A serial communication protocol established a connection between Arduino and the Windows Forms-based interface. This connection enabled data transfer from sensors to the interface and user inputs to Arduino. A C# library facilitated data exchange over the serial port, with code blocks designed for real-time data processing and user selection management.

**Tool Cabinet Usage:**

Two drawers of an existing instrument cabinet in a laboratory environment were utilized. These drawers were equipped with sensors to monitor the position and condition of each tool. The drawers were chosen based on tool size and usage frequency. The cabinet was integrated with the interface to automate tool tracking and facilitate user selection.

**RFID Integration:**

A preliminary study was conducted to integrate the RFID system found in school cards into the project. This integration provided a faster and more reliable identification system for tools in the cabinet. The RFID system controlled user access to specific tools using school cards and automatically recorded tool usage. This integration improved the security and efficiency of the tool cabinet.

**Image Processing:**

The project utilized image processing for quality control. The basic steps included image acquisition, pre-processing, feature extraction, analysis, visualization, and output. Features such as color conversion, filtering, edge detection, morphological processes, segmentation, feature extraction, image restoration, object recognition, image registration, and image synthesis were used to monitor tool status.

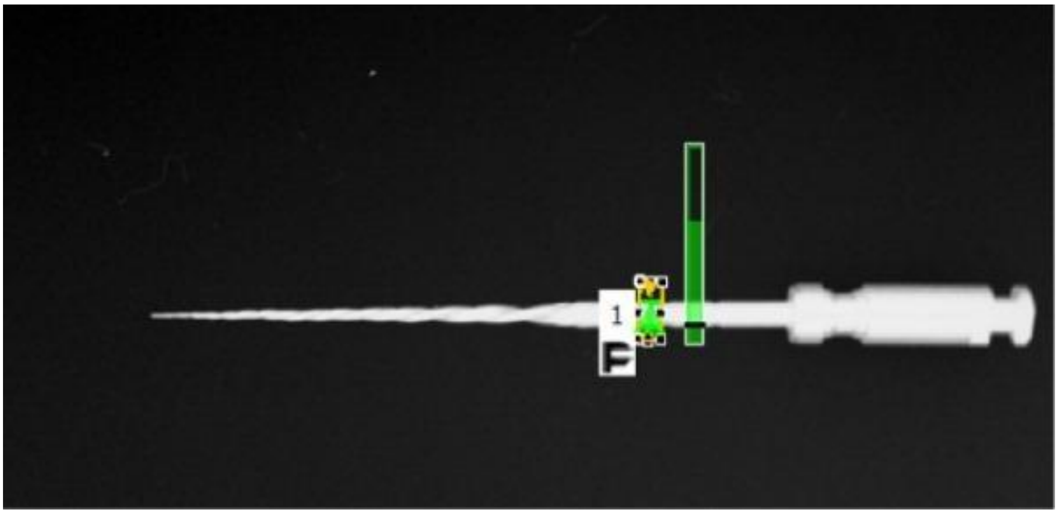

Figure 1:Camera view of the product illuminated with back light for needle tip diameter measurement

**Equipment:**

Key components included Arduino microcontrollers and micro switchs. Arduino, known for its versatility and ease of programming, served as the central control unit, interfacing with multiple micro switchs. These sensors, selected for their precision and responsiveness, provided real-time data essential for accurate analysis.

**Camera and Lighting:**

A Logitech C310 HD 720P camera was used for image processing due to its low cost and focusing feature. Proper lighting was crucial for achieving desired results, with backlight illumination chosen to highlight the edges and corners of objects.

**Software:**

C# and Windows Forms Application were chosen as foundational technologies for software development. OpenCV, an open-source image processing library, was utilized for image processing tasks. The library includes components for image processing algorithms, machine learning commands, I/O operations, and basic data structures and image drawing.

In summary, the methodology encompassed comprehensive planning, technical learning, and integration of multiple advanced technologies. Each phase was carefully executed to ensure the successful development and implementation of the Smart Tool Cabinet project.

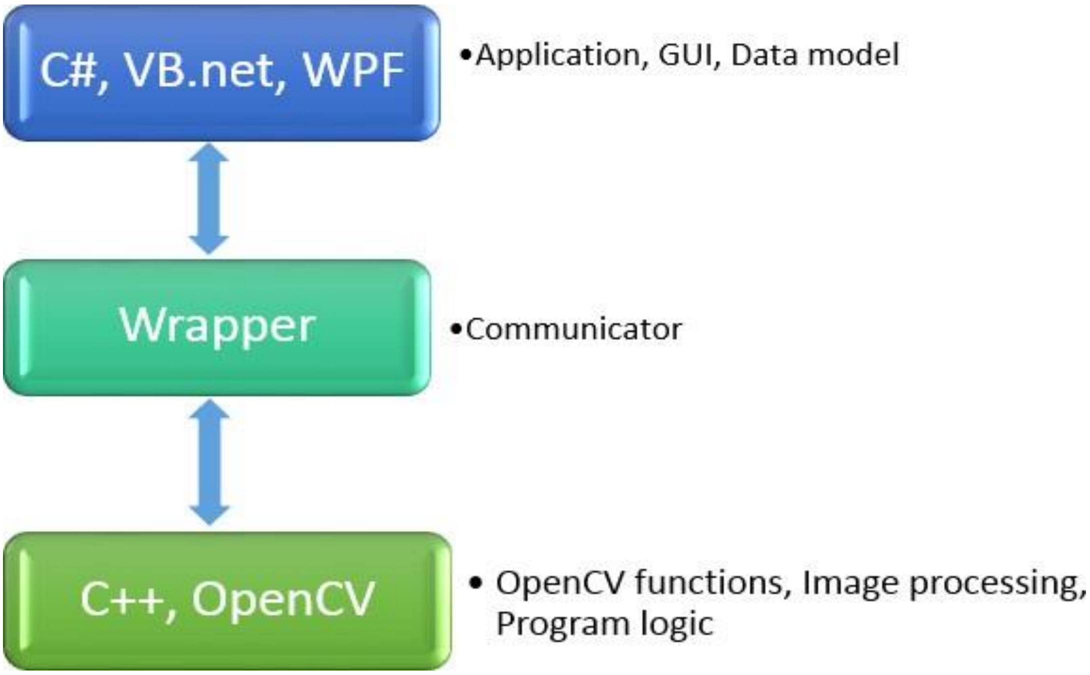


Figure 2: Working logic of wrappers

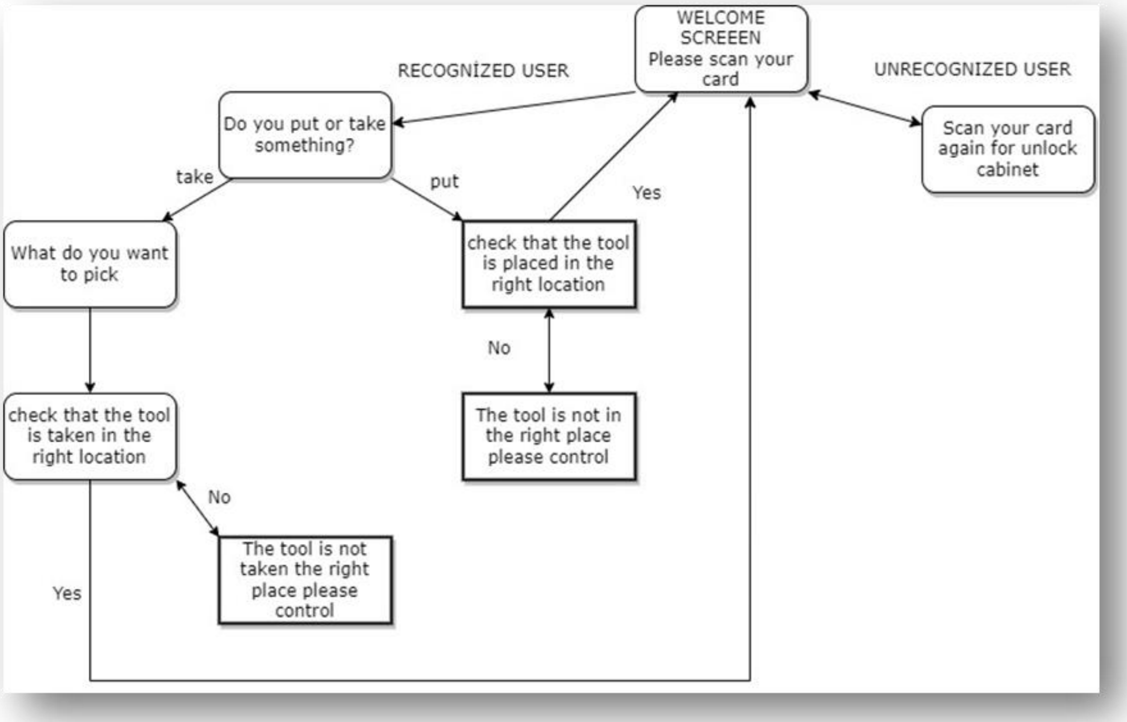


Figure 3: Flow chart for stages of the interface

# III. SUMMARY AND CONCLUSION

The "Smart Tool Cabinet" project was developed to address the inefficiencies and challenges associated with tool management in industrial and workshop settings. Utilizing a combination of advanced technologies including C# Windows Forms applications, RFID, Arduino, pressure sensors, and sophisticated image processing techniques, the project aimed to enhance tool tracking, condition monitoring, and overall operational efficiency.

The project began with an in-depth study and mastery of C# programming. This foundational knowledge was critical for developing a robust and user-friendly application that could seamlessly integrate various hardware and software components.The user interface was meticulously designed to provide an intuitive and engaging experience. Detailed flowcharts mapped user interactions, ensuring easy navigation and functionality. The interface featured real-time monitoring capabilities, visual representations of tools, and integration with RFID technology for efficient tool identification and management.Carefully chosen sensors provided the necessary precision and responsiveness to monitor the status of tools within the cabinet. These sensors, compatible with Arduino, enabled real-time data transfer and accurate condition assessment. The integration with Arduino facilitated effective communication between the hardware components and the software interface.The RFID system enhanced the project's efficiency by allowing quick and reliable tool identification. This system-controlled access to tools, recorded usage data, and ensured that tools were properly tracked and maintained.

Image processing played a crucial role in monitoring tool conditions. Using the OpenCV library, the project implemented various image processing techniques such as edge detection, feature extraction, and object recognition. These techniques allowed for precise monitoring of tool wear and automated condition assessments, thereby reducing the reliance on manual inspections.The project utilized a Logitech C310 HD 720P camera for capturing high-quality images of the tools. Proper lighting was ensured using a backlight system to highlight tool edges and features. The setup facilitated accurate image analysis and real-time condition monitoring.

The combination of C# and Windows Forms enabled the creation of a powerful, versatile, and user-friendly software solution. The application integrated various libraries and APIs to extend its functionality, providing a dynamic and responsive interface tailored to the project's specific needs.The integration of all components—RFID, Arduino, sensors, and image processing—was meticulously tested to ensure seamless operation. Real-time feedback and data processing were key features that enhanced the project's effectiveness and user experience.

The "Smart Tool Cabinet" project represents a significant advancement in industrial tool management, integrating multiple cutting-edge technologies to create a comprehensive and efficient system. The successful implementation of this project demonstrates the transformative potential of combining RFID, Arduino, pressure sensors, and image processing within a cohesive framework.The synergy between these technologies resulted in a system that not only tracks and manages tools but also monitors their condition in real-time. The RFID technology ensured precise tool identification and usage tracking, while Arduino and sensors provided accurate data on tool status. The image processing capabilities enabled automated and reliable tool condition assessments, reducing the need for manual inspections and minimizing human error.


Figure 4: Welcome screen of interface

The project significantly improved operational efficiency by automating tool tracking and condition monitoring. The real-time feedback and intuitive user interface facilitated quick decision-making and proactive maintenance, reducing downtime and enhancing productivity. The system's ability to provide immediate alerts for discrepancies in tool inventory further streamlined operations and ensured optimal tool utilization.The C# Windows Forms application provided a user-friendly interface that was easy to navigate and interact with. This aspect was crucial in ensuring the widespread adoption and effectiveness of the system. The visual representation of tools and real-time data integration made it accessible to industrial personnel, enhancing their ability to manage and maintain tools effectively.The project's success has broader implications for various industries requiring precise tool management. Its innovative approach and technological integration can serve as a model for similar applications in sectors such as automotive, aerospace, and manufacturing. The project highlights the importance of technological integration in advancing operational practices and sets a new benchmark for tool management systems.

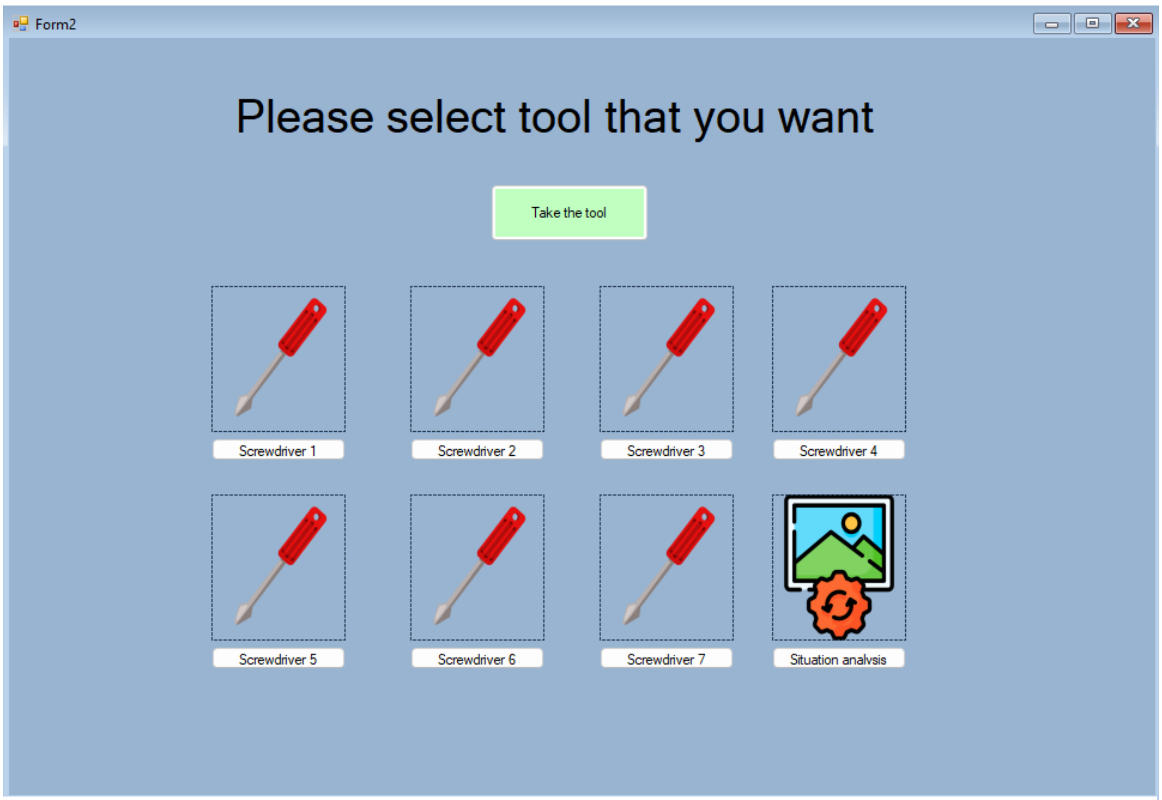


**Figure 5: Tool select screen of interface**

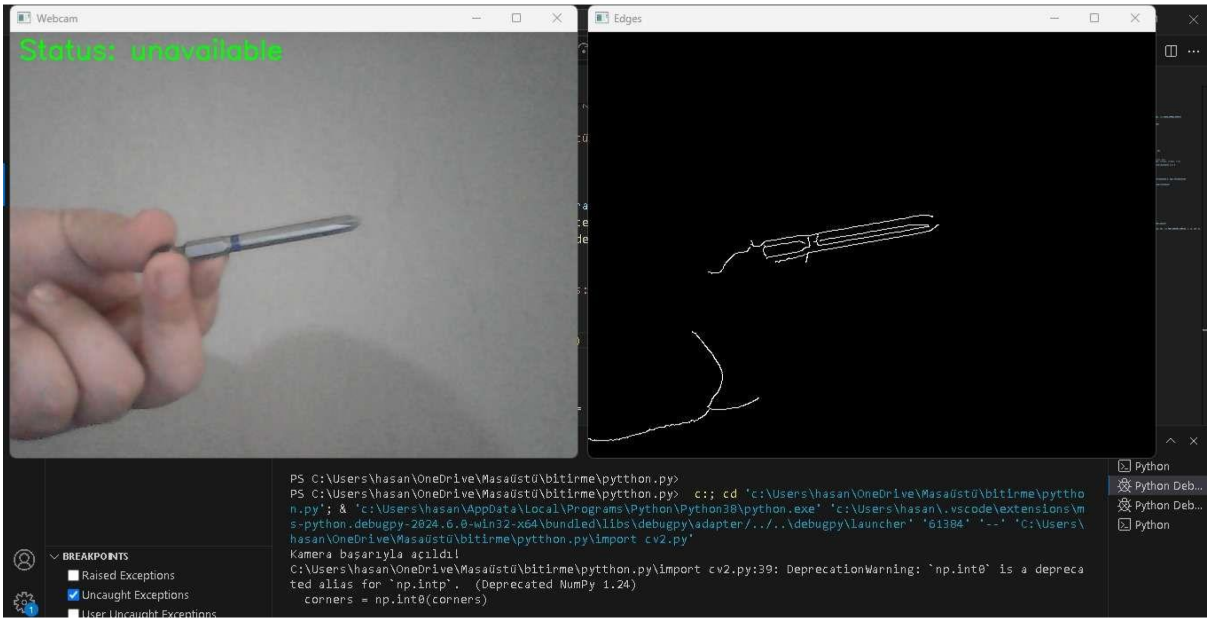


**Figure 6: Image processing screen**

The project also opens up possibilities for further advancements. Future work could include advanced user interface development, integration with IoT systems for enhanced connectivity, implementation of machine learning algorithms for predictive maintenance, and cross-platform deployment to increase accessibility. Additionally, exploring eco-friendly manufacturing options and developing comprehensive user training programs could further enhance the system's sustainability and effectiveness.

In conclusion, the "Smart Tool Cabinet" project is a testament to the transformative power of technological innovation in industrial applications. It marks a significant step forward in tool management, providing a robust, efficient, and user-friendly solution that sets the stage for future advancements in the field. This project not only addresses current challenges but also paves the way for a more technologically integrated and efficient future in industrial tool management.

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