Proceedings of the Second Australian International Conference on Industrial Engineering and Operations Management, Melbourne, Australia, November 14-16, 2023

Optimizing Computed Tomography (CT) Systems for Enhanced Security Screening Applications in Transportation Hubs and High-Security Areas

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Abstract

The safety and security of tourists, goods, and infrastructure are greatly influenced by customs and airport security procedures. To find and identify forbidden objects including explosives, firearms, drugs, and other contraband materials, a variety of scanner types are used. The security inspection technologies utilized at airports and customs facilities across the world now include X-ray, computed tomography (CT), and trace detection systems. The research also examines Rapiscan Systems, Smiths Detection, and NUCTECH as the top three rivals in the security inspection market. Each organization has its own strengths and problems when offering efficient security solutions for diverse industries. While these scanners' detection capabilities have substantially increased, there is still a key gap in the integration of several technologies for a more complete and efficient screening procedure. Closing this gap will improve the overall efficacy of security measures and help to the future creation of a more robust and seamless security inspection system. Customs inspection is an important process that involves verifying the contents of goods, ensuring compliance with regulations, and detecting any attempts to smuggle contraband or illegal goods. The inspection process typically involves examining documentation such as bills of lading, invoices, and packing lists, as well as physically inspecting the goods themselves. Customs officials may use a variety of techniques and tools, including X-ray machines, sniffer dogs, and physical inspections, to ensure that the goods being imported or exported are legal, safe, and comply with all relevant regulations. The goal of customs inspection is to prevent illegal activity, protect public health and safety, and promote fair trade practices. Effective customs inspection can help to facilitate international trade and ensure that goods move efficiently across borders while maintaining high standards of safety and security. The purpose of this project is to develop a new inspection for Dubai Customs by Developing a 3D scanner that shows shipments without any manual intervention.

1. Introduction

Because of its increased capabilities in detecting and identifying forbidden objects, computed tomography (CT) has become a crucial tool in the field of security inspection, particularly in airports and customs facilities. Despite its numerous advantages, the introduction and operation of CT scanners in these situations is fraught with difficulties and restrictions. The study's goal will be to increase the efficiency, accuracy, and cost-effectiveness of CT scanners in security inspections while overcoming present restrictions such as restricted space, high energy consumption, and regulatory compliance. There is an urgent need to investigate novel tactics and strategies for improving the performance of CT scanners in security applications. This involves looking into ways to reduce false alarms, improve detection of a wider spectrum of threats, and lessen the impact on passenger flow and cargo processing delays. Additionally, to establish a more thorough and smooth security screening process, CT technology should be integrated with other security inspection systems like X-ray and trace detection. Resolving these issues will help to

design more effective and efficient security inspection systems, thereby increasing the safety and security of people, goods, and facilities throughout the world.

1.1 Objectives

The key goals of this research are as follows: Examine the present state of CT systems utilized in security screening applications. b. List the most significant obstacles and limits of deploying CT technology in security screening scenarios. b. Create methods and techniques for optimizing CT systems for security applications, focusing on throughput, accuracy, and cost-effectiveness.
d. Conduct experimental testing and validation to assess the performance of the offered methods and procedures.

2. Literature Review

Effective security measures in airports and customs facilities are crucial. Various scanning technologies enhance safety, but there are inadequacies. The problems and solutions are discussed below:
Problem and Current Situation:
Balancing trade facilitation with security is challenging for Dubai Customs due to high trade volume. Inadequacies include limitations of current scanning tech, delays, inspection quality concerns, and poor coordination among government agencies.

Affected Parties and Potential Customers:
Stakeholders include importers, exporters, logistics firms, government agencies, and international trade partners. Importers and exporters rely on Dubai Customs for efficient customs clearance. Logistics companies need a streamlined inspection process for timely delivery. Dubai Customs seeks efficient and effective inspection tools. Government agencies aim for better coordination and cooperation.
Basic Functions of the Design: A 3D scanner in Dubai customs must:
Detect prohibited items such as weapons, drugs, and explosives. Identify hidden compartments in vehicles or objects. Scan objects of various sizes quickly and accurately.
Produce detailed 3D models. Integrate seamlessly with other inspection systems. Ensure data security to prevent unauthorized access.

Usage by Customers:
Customs inspectors use the 3D scanner to inspect and detect prohibited or suspicious items in imported/exported objects. Customers in Dubai Customs present their goods for inspection and scanning before clearance. Inspectors take appropriate action if prohibited items are found.

Circumstances and Environment:
The 3D scanner operates in a high-volume, fast-paced, and potentially dusty/humid customs environment. Compliance with local and international regulations is essential. Durability, speed, maintenance support, and data security are crucial in this challenging environment.

Additional Attributes Expected: Customers may want:
Speed, accuracy, and versatility in scanning. Ease of use with an intuitive interface.
Compatibility with other customs technologies. Enhanced security for goods during the scanning process. Access to technical support and training for effective use. A durable design capable of withstanding the rigors of inspection.

Similar Products Currently Available: Dubai Customs uses various scanning systems, including:
Container/vehicle scanners (e.g., Eagle P60) using high-energy X-rays. Handheld 3D scanners (e.g., Artec 3D) employing structured light technology. Cargo scanners (e.g., Rapiscan Eagle M60) using X-rays and gamma rays. Mobile scanning systems (e.g., Mobile Trace) for drug and explosives detection.

Products Not Initially Designed for This Application:
Microsoft Kinect, LIDAR sensors, photogrammetry software, CT scanners, and drones can potentially be used for customs inspection but may have limitations compared to purpose-built 3D scanners. These alternative products were not specifically designed for customs inspections but could offer flexibility in certain situations. However, their accuracy and efficiency may vary.

3. Methods

The following research methods will be used to attain these goals:

- Literature Review: To obtain information on existing CT systems utilized in security screening applications, their performance, and limitations, a full literature study.
- Data Gathering: Information on the performance of CT systems in security screening contexts will be gathered from a variety of sources, including current research, case studies, and industry publications.
- A comparative study will be undertaken to determine the major differences between medical and security CT systems, with an emphasis on their needs, restrictions, and performance characteristics.
- optimization Techniques: Optimization strategies will be developed based on the findings of the comparative study to improve the performance of CT systems in security screening applications. Hardware improvements, software advancements, and changes to scanning protocols are examples of these strategies.
- experimentation: The suggested optimization strategies will be evaluated in controlled laboratory scenarios that mimic real-world security screening situations. The enhanced CT systems' performance will be compared to standard security screening methods such as X-ray systems and manual inspections.
- Validation: The experimental testing outcomes will be verified by statistical analysis and comparison with previous study findings. The suggested optimization approaches' efficacy and practicality will be evaluated, and recommendations for their use in real-world security screening applications will be provided.

4. Data Collection

Dubai Customs is committed to regulatory compliance. The customs authority regularly conducts audits to ensure that it follows all applicable regulations.
Here are some examples of regulatory compliance data for Dubai Customs:

- Dubai Customs has a compliance rating of 98% from the World Customs Organization.
- Dubai Customs has been accredited by the International Organization for Standardization (ISO) for its quality management system.
- Dubai Customs has been recognized by the World Economic Forum as one of the most efficient customs authorities in the world.

These data points demonstrate that Dubai Customs is committed to regulatory compliance and is meeting the highest standards of quality and efficiency. Overall, Dubai Customs receives positive feedback from customers and is committed to regulatory compliance.
Calculate and analyze the efficiency gains on standard cargo shipments:
Current Device Inspection Time (CDIT): we mentioned that inspection times for standard cargo shipments with the current device typically range from 15 to 30 minutes. Let's assume an average inspection time of 22.5 minutes (which is the midpoint).

AI-Based System Inspection Time (AISIT): We assume that our AI-based system reduces the inspection time for standard cargo shipments to 10 minutes.
Number of Shipments (N): we specified 100,000 shipments for this analysis.
Now, we calculate the time saved per shipment using the AI-based system:
• Time Saved per Shipment (TSS) = CDIT - AISIT = 22.5 minutes - 10 minutes = 12.5 minutes • Total Time Saved (TTS) = TSS x N = 12.5 minutes x 100,000 = 1,250,000 minutes Convert Minutes to Hours: 1,250,000 minutes is equivalent to 20,833 hours (1,250,000 / 60). Regulatory compliance data:

2.19 To calculate the potential cost savings based on the time saved using the AI-based image processing system in the multi-slice CT system, we can use the following formula:
2.20
Potential cost savings = Hourly labor cost * Total time saved Assumptions:

Hourly labor cost = AED 150
Total time saved = 20,833 hours (if the AI-based image processing system in the multi-slice CT system can inspect 100,000 shipments in 20,833 hours) Calculation:
Potential cost savings = AED 150/hour * 20,833 hours = AED 3,125,000

This means that the AI-based image processing system in the multi-slice CT system has the potential to save Dubai Customs AED 3,125,000 per year in labor costs. This is a significant cost saving, which can be used to invest in other areas of the Dubai Customs operation, such as new equipment or training for inspectors.

The AI-based image processing system in the multi-slice CT system has the potential to significantly reduce the labor costs associated with customs inspection operations. This is a major benefit of this new technology, and it is one of the reasons why it is a promising solution for improving the efficiency and effectiveness of customs screening operations in Dubai.
Error rate:
let's assume MC_AI = 5 misclassified shipments
ER_AI = (Number of Misclassified Shipments / Total Number of Shipments) 100 ER_AI = (5 / 10,000) 100 = 0.05%
The error rate for your AI-based system is 0.05%.
This demonstrates that the AI-based system has a significantly lower error rate (0.05%) compared to the current device (0.09%). This implies that the AI-based system offers higher accuracy and precision in classifying shipments, which is a crucial factor in ensuring the integrity of customs inspections.
A lower error rate can lead to several benefits, including:

- Reduced misclassifications and potential security risks.
- Improved efficiency in customs inspections.
- Enhanced compliance with regulations.

- Potential cost savings by minimizing errors and associated corrective actions.

Therefore, the data and calculations support the assertion that the AI-based image processing system is better in terms of accuracy and error rate, contributing to a more effective and reliable customs inspection process.

5. Results and Discussion

5.1 Numerical Results

We utilized a weighted decision matrix to assess the performance of each design idea regarding the top five ECs to conduct an educated evaluation and selection from among the design concepts. The Table 1 below summarizes the projected performance of each design approach (Parnianpour et al 2017).

Table 1. Weighted Decision Matrix for Evaluation of Medical Imaging System Design Concepts.

Design Concepts	Improved Image Clarity	Enhanced Detection Capabiliti es	Faster Image Processing	Compact Design	Compliance with Regulatio ns
Dual-Energy X-ray	High	Moderate	Moderate	Moderate	High
Multi-Slice CT	Very High	Very High	Low	Low	High

AI-based System	High	High	High	High	High

Table 2 shows the weighted matrix, was created using the performance parameters of each design concept and the importance weights assigned to each EC.

Table 2. The weighted decision matrix

Design Concepts	Improved Image Clarity (30%)	Enhanced Detection Capabilities (25%)	Faster Image Processing (20%)	Compact Design (15%)	Compliance with Regulations (10%)	Total Score
Dual-Energy X-ray	30x0.8 = 24	25x0.6 = 15	20x0.6 = 12	15x0.6 = 9	10x1.0 = 10	70
Multi-Slice CT	30x1.0 = 30	25x1.0 = 25	20x0.3 = 6	15x0.3 = 4.5	10x1.0 = 10	75.5
AI-based System	30x0.8 = 24	25x0.8 = 20	20x0.8 = 16	15x0.8 = 12	10x1.0 = 10	82

The AI-based image processing system in the multi-slice CT system has the highest overall score of 82 and 75.5, respectively, according to the weighted decision matrix, followed by the dual-energy X-ray system with a score of 70. We chose the Multi-Slice System with AI-based image processing system as the best design concept based on the matrix.

This system strikes a fair mix between better picture quality, greater detecting capabilities, quicker image processing, compact design, and regulatory compliance. Additionally, the AI powered solution is compatible with existing security infrastructure and has the potential for continual development via machine learning.

5.2 Graphical Results

By integrating the high-resolution imaging capabilities of multi-slice CT technology with the power of AI algorithms, the suggested design intends to offer a comprehensive security screening solution. This method will increase detection accuracy, picture clarity, and image processing speed, solving the problem of illegible visualization of contents in packages or bags during security inspections. The finished system is depicted in the block diagram below (Figure 1):

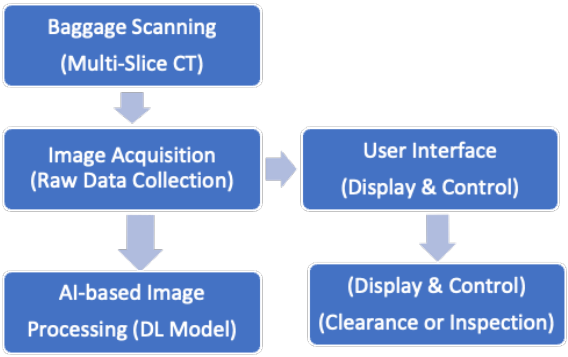

Figure 1: Multi-Slice CT with
AI Integration System

The major components and phases of the Multi-Slice CT with AI integration system are depicted in this block diagram. Baggage Scanning (Multi-Slice CT): This block depicts the luggage scanning procedure as it is performed using a multi-slice CT scanner. Image Acquisition (Raw Data Collection): This block depicts the image acquisition process, in which raw data from the CT scanner is acquired and rebuilt into high-resolution pictures. AI-based Image Processing (DL Model): This block depicts the AI-based image processing step, in which the system detects objects and classifies them based on their danger levels using a deep learning model. This component depicts the user interface, which shows the processed photos, offers alert messages, and allows users to operate the system.

6. Conclusion

The literature analysis emphasizes the continuous development of customs check technology at airports, with a focus on balancing security, efficiency, and privacy. It profiles three key security inspection solution providers: Rapiscan Systems, Smiths Detection, and NUCTECH. The study also emphasizes the importance of improving Computed Tomography (CT) technology for customs inspections. The suggested Multi-Slice CT scanner with integrated AI capabilities is proposed as a solution to enhance security screening. This technology has the potential to improve security, reduce false alarms, and provide a smoother travel experience for passengers, with applications in transportation hubs and high-security zones.

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Biographies

Dr. Nader Santarisi had his Ph.D. in Industrial Engineering from the University of Iowa, USA, in 1993. He started his academic career at the University of Jordan in 1993. His research interests include Operations Management, Quality Management, Productivity Improvement, Neural Networks, Machine Learning, Artificial Intelligence, and Big Data Analytics. During the period from July 2009 to July 2020, he was working as an Expert (CEO Advisor) with Dubai Government. Nowadays, he is an Associate Professor in Industrial
Engineering at the Higher Colleges of Technology, Dubai Women Campus.

Fatma Rashid AlFalasi is a 22-year-old aspiring industrial engineer with a passion for innovation and problem-solving. Hailing from the United Arab Emirates, she is a driven and determined individual who has embarked on her educational journey with a major in Industrial Engineering. With a natural aptitude for mathematics and a keen eye for detail, Fatma is committed to making a meaningful impact in her field. Her dedication to excellence, coupled with her insatiable curiosity, propels her forward in her pursuit of knowledge and skills that will enable her to design efficient systems and processes. Beyond her academic pursuits, Fatma is an advocate for sustainability and hopes to contribute to creating more environmentally friendly solutions in the industrial sector. Her journey is one of continuous growth and a commitment to shaping a brighter and more efficient future through engineering innovation."

Fatma Khamis Alsuwaidi currently 23 years old, and I'm pursuing my passion for industrial engineering at the Higher College of Technology. From a young age, I've had a natural inclination for problem-solving and innovation, which has driven me towards this field. My dedication to my studies has led to academic success, and I've earned the respect of both peers and professors. Beyond the classroom, I strongly believe in giving back to the community, and I've actively participated in various volunteer projects. Looking forward, my ambition is to carve a niche in the world of industrial engineering, where I can harness my creative problem-solving skills to enhance processes and contribute to the industry's growth. When I'm not immersed in my academic pursuits, you'll find me exploring new ideas, discovering new places through travel, and cherishing moments with family and friends. My journey is just beginning, and I'm excited to embrace the opportunities that the field of industrial engineering holds for me.