Representation of Vending Device using Finite State Automata

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Abstract:- Automata theory predominates in a number of applications derived using the technique of a finite state machine . In the paper, we study the representation of a vending machine (VM) that enhances the academic institution's book delivery service using the concepts of the computation theories. The effectiveness regarding the virtual machine(VM) is viewed as a problem. Automata theory relies on the finite state machine (FSM) design to increase efficiency. The different components of a vending machine are examined at, and it is determined how they can be modelled as finite state machines. We go over the architectural considerations for vending machines, such as the selection of components, the layout of the machine, and the selection of input and output approaches. We use the theory of computation to examine the constraints and difficulties in vending machine design. The paper will design an FSM with fewer states in the end. As a result, we will learn how to increase the VM's design effectiveness and cost.

Keywords:- *Vending Machine, Finite State Machine (FSM),Virtual Machine (VM), Automata Theory.*

I. INTRODUCTION

In today's world, vending machines are pervasive and provide consumers an easy and effective option to buy a variety of products. VMs are electronic systems that are used to deliver a variety of products, including tickets, coffee, and snacks. Vending machines may appear to be simple machines, but their design is actually very complicated and takes a variety of technical, engineering, and design factors into account. [1–3] They are made to be able to receive money and dispense products in accordance with the amount inserted. The concepts of the theory of computation can be used to comprehend the design of vending machines. We can learn more about the underlying mechanisms and processes involved in vending machine operation by applying the theory of computation to the design of vending machines. The design that makes use of the automata theory affects how efficient VM is. The finite state automaton consists of every possible state and regulates changes in state with the repsponse of the input which is external. It is called as a finite state automaton, or FSM. [4] It is a method used in mathematics to explain both inputs and outputs processes.This is suitable for developing a wide range of applications, including lexical analysis systems for compilers and systems to verify the legitimacy of circuits or protocols. Among the physical systems it aids the control unit with are lifts, automated signals of traffic and vending machines. FSM is classified as mealy or moore machines. The Mealy machine, also referred to as the Synchronous FSM, is a automata machine that produces outputs based solely on input actions and inputs and current state. A state machine that only employs entry actions and depends on the current state is known as a Moore Machine which is also known as an asynchronous FSM. The regulation of VM is influenced by the no. of stages used in the design as well as the quantity of steps and tools used. The study paper's mainly focuses on the effective design of the book vending automata, which was created from the basic state diagram and is based on non deterministic finite state machine (NFSM). A model simulation can also be done with the VAS tool.

- *Components of Vending Machines*

A vending machine typically consists of several key components, including a coin or bill acceptor, a product selection mechanism, a dispensing mechanism, and a control system. Each of these elements can be rep- resented mathematically as a finite state machine, which is a model of a system that explains transitions mbetween states and has a finite number of states.By modeling these components as finite state machines, we can analyze their behavior and ensure that they operate correctly under all conditions.

- *Input and Output Mechanisms*

One of the key design considerations for a vending machine is the choice of input and output mechanisms. In most vending machines, the input mechanism is a coin or bill acceptor, which must be able to detect and validate different types of currency. The output mechanism is typically a product dispenser, which must be able to accurately dispense the correct product based on user selection. The design of these mechanisms must take into account factors such as reliability, speed, and ease of use.

- *Selection of Elements*

Another important consideration in vending machine design is the selection of components. The components must be robust, durable, and capable of operating under a wide range of environmental conditions. They must also be easy to replace or repair in case of failure. The design of the machine must take into account the weight, size, and configuration of the components, as well as the layout of the machine itself.

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➢ *Programming Languages and Simulation Tools*

Because they are needed to build the control system that regulates the operation of the machine, program- ming languages are crucial to the design of vending machines. The complexity of the machine, the required level of abstraction, and the availability of programming tools and libraries all affect the choice of program- ming language. Simulation tools can be used to test and refine the design of the machine before it is built, allowing designers to identify and correct any issues before the machine is deployed in the field.

II. RELATED WORK

In this section, we offer a comparative examination of different research papers in this domain. Table 1 below summarizes the key findings and allows us to draw meaningful insights from the data.

➢ *Definition and Elucidication of VM*

Here, VM description that takes into account problems and an intelligent approach is taken into account. Basically, VM offers a range of products when money is placed into it. In comparison to the conventional buying method, the vending machines are more user-friendly, convenient, and accessible.[7] For a variety of goods, including coffee, tickets, jewels, and platinum jewellers, they are everywhere. These machines can be created successfully in a variety of ways that is by having a microcontroller and an board of FGPA for that.In the first diagram, a condensed VM illustration is displayed.

➢ *Basic Operation of VM*

- Select your choice: The user must first choose the product they want before entering money.
- Insert money: The quantity of money that the user put into the vending machine is sent via the money counter to the control unit.
- Dispensation: The operation buttons are available for selecting the desired products. When users enter the proper amount, the products are dispensed according to the internal program of the VM.
- Change: The change will be returned by VM if the program has been designed to do so.
- Availability: If the chosen product is not available, the service will be rejected by the VM.[8]

➢ *Power of Clever VM*

The major goal of intelligent VM is the energy efficiency due to which it is used in various application. Efficient energy also shows that VM completes the basic activities expertly and with no managerial overhead. LCD, which consists of a sizable tabletop office with vending machines that might have sufficient surface area which shows LCD panels ranging in size from 6 to 14 inches.

➢ *Challenges of Intelligent VM*

Despite the many benefits of using the theory of computation in vending machine design, there are also limitations and challenges. For example, the complexity of the design may make it difficult to model certain components as finite state machines, and there may be limitations in the available programming languages and simulation tools. Additionally, vending machines may face challenges related to security, maintenance, and usability, which must be addressed through careful design and testing.

Table 1 Summary of Research on Vending Machine Designs

Year	Authors	Description
2014	Design and Implementation of Multi Select Smart Vending Machine (Varkey, M. and Sunny, J.) [5]	Researchers explain the need of multi-select VM. Using VHDL-established, optimised code that isimplemented on an FPGA board, VM efficiency can be improved. Four products are available on this VM: milk, water, fruit, and sprite. There are just two sorts of coins required: five and ten rupee coins. Both cancel and auto-billing options are available. The Xilinx ISE simulator in this case takes care of the VM simulation.
2013	Embedded System Based Automatic Ticket Vending Machine for Modern Transport System(M.Bhuvaneswari, S.Sukhumar, N.Divya, S.Kalpanadevi, N.SuthanthiraVanitha)[6]	By combining sensor, RFID, and Zigbee technology, researchers have described the concept of automatic ticket VM. The automated mechanism utilized here allows users to use smart cards, which are significantly easier to grasp during the rush hours. In addition, because every transaction is monitored and docu- mented for future identifying needs, it provides secure surroundings. One of the clever elements in the con- temporary VM is the LCD found in the specific VM utilised for ticket purchasing. The automated system allows us to decrease the wasteful use of time and resources.

2020	Design and Implementation of FPGA based Vending Machine for Integrated Circuit (Edison Kho, Manoj Kumar)	Researchers suggest a detailed account of the design and implementation of a multi-select state vending machine that uses a state machine. Users can choose a product and insert the appropriate token for each product to receive an IC, or the machine will return the inserted token if the incorrect token is inserted for each IC.
2021	The design and implementation of a vending machine based on state machine, FPGA and microcontroller (Junyi Guo, Yu Liu)	The researchers address the types, benefits, and draw-backs of state machines. State machines can also simulate a standard vending machine. This vending machine was created using the C language, an ARM microcontroller, and an FPGA development board.
2022	Depiction of FPGA Based Vending Machine UsingMealy Model (Sathiyapriya. K, Nirmala. P, Deepika. M, Revanth. J, Saravanan. M, Mohankumar. M)	Researchers suggest building a vending machine that can dispense water bottles with varying values and the potential to payback change. In this study, the finite state machine (FSM) is set aside to illustrate a vending machine in a picture. Because FPGA responds more quickly and uses less power, it is used for this vending machine.

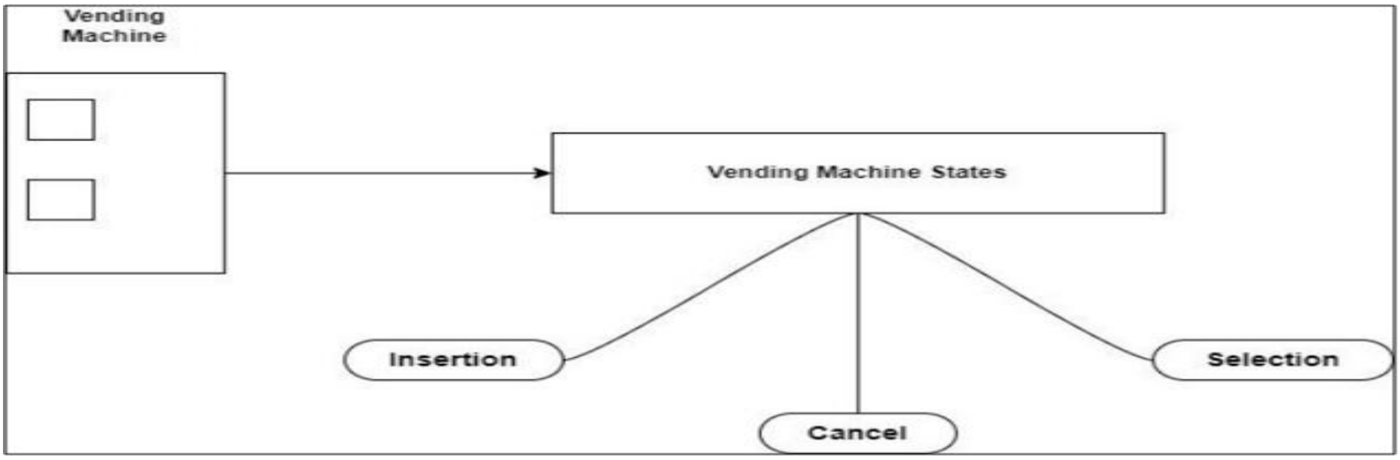

Fig 1 Basic Operations of VM

- Opportunities made possible by mobile phones: Use communication technology to accept payments and perform transfers.[9]
- Government mandates: The intelligent VM displays detailed information about medical services, weather warnings, and policies.
- User involvement has increased: Thanks to interaction via the VM activated from people's cellphones, which have the newest features and amenities.
- Remote administration: The confidential or essential information swapping that takes place when a vending machine is operating. VM operations can reduce the cost of maintenance and increase availability with the management.
- Software flexibility: The features are upgraded to be compatible with new technology.

➢ *Definition of FSA*

An abstraction of a computing system machine is called an automata theory (AT). AT is a crucial component since it regulates a fundamental concept of digital circuits and electrical machines used in software. It is also employed for the verification of all types of finite state systems. The FSA is a mathematical illustration of every computer system that has been created. FSA sends back and forth across the states with its inputs and outputs.

A Finite State Automaton (FSA) can be represented using a five-tuple (Q, Σ, δ, q0, F), where:

Q is a finite set of non-empty states.
Σ is a finite non-empty set of inputs called an input alphabet.
δ is a function that Maps $Q \times \Sigma \rightarrow Q$ is called transition function.
q_0 is the initial state.
F is the set of final states. [10]

The transition function $\delta(q, w \cdot a)$ is defined as:

$$\delta(q, w \cdot a) = \{p \in q \mid \exists r \in \delta(q, w) : p \in \delta(r, a)\}$$

III. ANALYSIS AND DESIGN

➢ *Analysis of VM*

Taking an example of the vending machine that offers four different types of books, which are English books, Arabic books, notebooks, and drafts. Each type of book has a different price, as indicated in Table 1. The vending machine accepts only 10 and 20 Saudi Riyals and will not accept any other type of currency, even if the user attempts to perform an illegal operation such as selecting an unavailable book or entering an insufficient amount. There are four selection inputs, namely SELECT1 for English books, SELECT2 for Arabic books, SELECT3 for notebooks, and SELECT4 for drafts. The user can enter the amount using two types of inputs, 1 for 10 Saudi Riyals and 2 for 20 Saudi Riyals. To cancel the request, the user can press the 'c' input. The vending machine won't give the user the book if they cancel their order or add more money than is necessary; they will get a refund or exchange in place of the book.The vending machine has been designed using Finite State Machine (FSM) modeling, where state transitions can occur without an input symbol and can transit to 0 or more states for a given starting state and input symbol. This is different from finite state machines (DFAs) where every transition is uniquely determined, and every state transition requires an input symbol. Table 2 provides the entire data for the proposed vending machine to allow users to select multiple choices easily from a single state (NFA).

➢ *Design Methodology*

The diagram representing the system includes several states, namely the initial state, user selection state, and the amount of money inserted by the user. The first state of the machine is the initial state, where users can start selecting their books. Once the user selects a book, the system transitions to one of four states (select1, select2, select3, or select4) depending on the chosen book. The system then waits for the user to enter payment, which can only be in the form of 10 or 20 Saudi Riyals. The system switches to the accepting state after the desired amount is entered. If the user chooses an English book, the system enters a state and then, based on the total amount of money deposited, travels to a particular state. For instance, the system will switch to the "10 SR" state, then the "30 SR" state, and finally the "40 SR" state if the user enters 10, 20, and 10 Saudi Riyals. The system must always decide whether or not to send the chosen book.

IV. STATE DIAGRAM

State diagrams are a graphical representation of the states, inputs, outputs, and transitions of a finite state machine. They can be used to analyze the design methodology of vending machines by providing a visual representation of the vending machine's behavior. Here are the steps to analyze the design methodology of vending machines using state diagrams:

- Identify the states: The first step is to identify the states that the vending machine can be in. For example, a vending machine could be in a state where it is waiting for the user to insert coins, a state where it is waiting for the user to select a product, or a state where it is dispensing a product.
- Define the inputs: The inputs are the events that can cause the vending machine to transition from one state to another. For example, the inputs could be coin insertion, product selection, or cancellation of the transaction.
- Define the outputs: The outputs are the actions that the vending machine performs when it transitions from one state to another. For example, the outputs could be dispensing a product or returning change.
- Create the state diagram: Using the states, inputs, and outputs identified in the previous steps, create a state diagram. The state diagram should show the states as nodes and the transitions between them as edges labeled with the input that triggers the transition and the output that is generated.
- Analyze the state diagram: Once the state diagram is created, it can be analyzed to identify potential problems or areas of improvement in the design methodology of the vending machine. For example, if there are states that are not reachable or transitions that are not defined, these could be areas for improvement in the design. [11]

V. IMPROVING EFFICIENCY

There are several ways to improve the design efficiency of vending machines using finite state machines. Here are some strategies:

- Simplify the state diagram: The state diagram should be as simple as possible, with a minimum number of states and transitions. This will make the design more efficient and easier to implement.
- Use modular design: Divide the vending machine into smaller modules, such as the payment module, selection module, and dispensing module. This will make it easier to design and test each module separately, and reduce the complexity of the overall system.
- Use software tools: Use software tools that can automatically generate state diagrams and code from high-level specifications. This can save time and reduce errors in the design process.
- Use simulation tools: Use simulation tools that can simulate the behavior of the vending machine before it is implemented. This can help identify potential issues and refine the design before it is built.
- Use standard components: Use standard components, such as sensors, motors, and actuators, that are readily available and easy to integrate into the vending machine. This can simplify the design process and reduce costs.
- Consider user experience: Consider the user experience when designing the vending machine, such as the placement of buttons, the visibility of the display, and the ease of use. A well-designed user interface can improve efficiency and reduce errors.By following these strategies, designers can improve the design efficiency of vending machines using finite state machines, resulting in more reliable and cost-effective systems. [13]

VI. APPLICATIONS

- Retail industry: Vending machines are commonly used in retail environments to sell products such as snacks, beverages, and personal care items. Using finite state machines to design vending machines ensures that the machines behave correctly and reliably, minimizing errors and reducing downtime.
- Transportation industry: Vending machines are often used in transportation hubs such as airports, train

stations, and bus terminals to sell snacks, drinks, and other products to travelers. Designing these machines using finite state machines ensures that they can handle a large number of users and operate under different conditions, such as varying levels of light and noise.

- Healthcare industry: Vending machines are increasingly being used in healthcare environments, such as hospitals and clinics, to sell medical supplies and personal care items. Designing these machines using finite state machines ensures that they meet the requirements for safety, hygiene, and accessibility.
- Educational industry: Vending machines are also used in educational institutions, such as schools and universities, to sell snacks and drinks to students. Designing these machines using finite state machines ensures that they can handle a large number of users and operate under different conditions, such as varying levels of noise and traffic. [14]

VII. FUTURE SCOPE

The future scope of designing vending machines using finite state machines is quite promising. Here are some potential areas where finite state machine design can be applied:

Fig 2 Flowchart of Proposed VM [12]

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- Smart vending machines: Future vending machines are likely to be ”smart” machines that can interact with customers using artificial intelligence (AI) and machine learning (ML) techniques. Designing such machines using finite state machines will enable efficient and reliable interaction with customers and improve their overall user experience.
- IoT-enabled vending machines: Internet of Things (IoT) is a rapidly growing field, and vending machines are likely to be a part of it. Designing IoT-enabled vending machines using finite state machines can ensure that they operate efficiently and reliably, even when communicating with a wide range of sensors and devices.

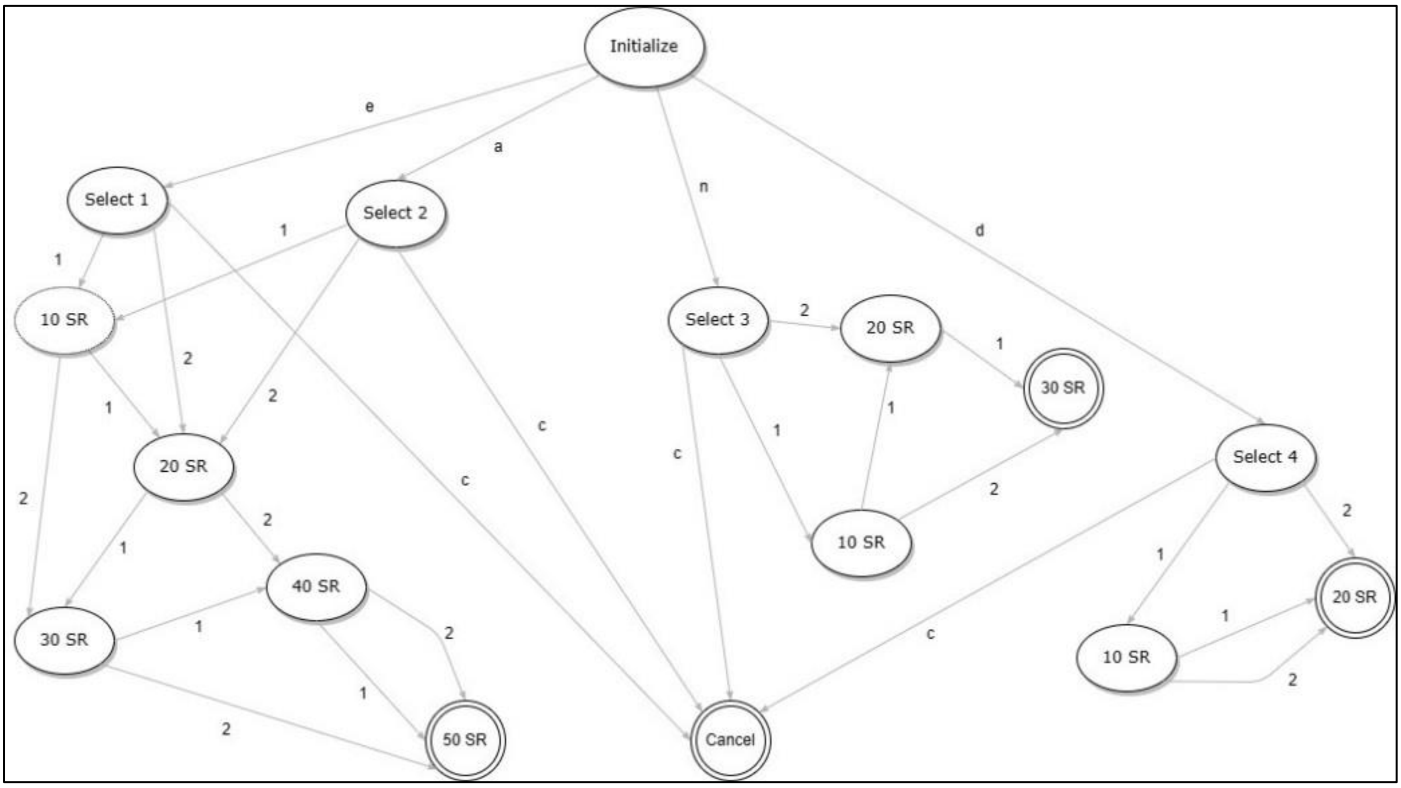

Fig 3 NFA of State Diagram of Book VM Behaviour

- Autonomous vending machines: With the development of robotics and automation, vending machines are likely to become more autonomous. Designing such machines using finite state machines can ensure that they behave safely and predictably, even in unstructured environments.
- Personalized vending machines: As customers become more demanding, vending machines are likely to become more personalized, offering customized products and services. Designing such machines using finite state machines can enable efficient and reliable interaction with customers and improve their overall satisfaction.
- Energy-efficient vending machines: Energy efficiency is a critical issue for vending machines, especially those that operate in remote areas. Designing energy-efficient machines using finite state machines can optimize the use of energy and reduce the overall environmental impact of vending machines.

Overall, the future scope of designing vending machines using finite state machines is vast and promising. As technology advances, designers can leverage finite state machine design to create more efficient, reliable, and personalized vending machines that meet the needs of customers and businesses alike.

VIII. CONCLUSION

The design process of a vending machine using FSM can begin by defining the states that the machine can be in, such as idle, selection, payment, and dispensing. Each state can be associated with a set of actions and transitions that dictate how the machine responds to input from the user. For example, the ”selection” state may be associated with actions such as displaying the available products and allowing the user to make a selection. The ”payment” state may be associated with actions such as accepting coins and bills, calculating the total cost of the selected item, and verifying the payment.

Transitions between states can occur based on the input received by the machine, such as the user selecting a product or inserting coins. These transitions can be defined using a state diagram that shows the possible transitions between states and the conditions that must be met for each transition to occur. For example, a transition from the ”selection” state to the ”payment” state may occur when the user selects a product, while a transition from the ”payment” state to the ”dispensing” state may occur when the user has paid the full amount for the selected product.

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The FSM-based design approach can also enable the vending machine to handle error conditions, such as out-of-stock items or insufficient funds. For example, if a selected item is out of stock, the machine may transition back to the ”selection” state and display a message to the user indicating that the item is unavailable. If the user inserts insufficient funds, the machine may transition back to the ”payment” state and display a message indicating that additional payment is required.

In conclusion, the design of a vending machine using a finite state machine (FSM) is an effective approach that can ensure the smooth functioning of the machine while minimizing errors and reducing complexity. Through the use of FSM, the vending machine can be programmed to respond to multiple inputs, making it more efficient and user-friendly. The implementation of FSM in the design of vending machines has also been shown to reduce the likelihood of errors and increase reliability. While there may be some challenges in the design process, such as the need for thorough testing and debugging, the benefits of using FSM in vending machine design are clear. Overall, the use of FSM in vending machine design is a promising approach that can lead to more effective and reliable vending machines.

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