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A Systematic Visualization and Evolution of Software Architectures

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Abstract

The Matrix Visualizer is a 2D plane matrix comprising of many small square boxes of equal size. When a designer/architect gives the input of design/sketch then as per the blueprint, the matrix starts taking shape accordingly. Here the square boxes of the matrix rise to a certain height as per the sketch. This gives a practical demonstration of the sketch that rises to give the 3D and appropriate physical representation, for instance, architecture gives their sketch as input, and then the Matrix Visualizer starts processing the sketch and raises the square boxes of the matrices accordingly up to the certain height. Using the emergence of square matrix boxes, we can depict different elements of the design such as walls, chairs, beds, sofas, and other items. This allows users to experience a realistic simulation where they can physically interact with the objects and navigate through the space to accurately perceive the gaps between two objects. As soon as the user provides an input to the Matrix Visualizer, the intelligence would work on to calculate the coordinates that has to be instructed to the linear actuators. As the processing is done by the central processing unit, the signals will be transmitted to the linear actuators which then push the boxes. Hence the boxes will rise up to certain height to represent some entities. As soon as the actuators are done with their job the actual and precise visualization of the sketch is available for user. Herein the user can roam around, can touch and feel entities and can also physically visualize the dimensions of their design and can re-evaluate anytime if required to make any changes.

Keywords: Simulation, actuators, Matrix Visualizer, augmented reality (AR), virtual reality (VR), mixed reality (MR)

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INTRODUCTION

As the name suggests, Matrix Visualizer is a representation of a simulator for visualization which enables the user [1] to physically visualize a blueprint/sketch made by the designer/architect. Matrix Visualizer does not just stay in a 2D plane matrix [2], but the matrix boxes [3] rise to a certain height accordingly as per the designer's sketch.

This enables the user to visualize in 3D and to physically touch all the entities of the simulation. Firstly, we give the input through various input devices (like mobile phones, detailed blueprint, computer, provided camera). After the input is given, the intelligence [4, 5] starts calculating by various algorithms and logics. As soon as the calculation part is done and the whole sketch is processed, it then follows up to the next command.

A signal is sent to the linear actuators [6] that are magnetically encoded, which precisely sends the actual position of the actuators. If the actuators are not at the initial position, then a signal is sent to bring them to the initial position. If they are already at the initial position, then the next process begins wherein the signal to specified coordinates are sent accordingly as per the sketch.

As the signals are received by the linear actuators [7], they start moving up and down to push and pull the boxes to specified coordinates as per the desired coordinates. Once the boxes are in desired coordinates, the simulation stops, and we get our desired shape as per the sketch.

Matrix Visualizer Solves Following Problems

Designers who use 3D modeling [8, 9] to design their ideas nowadays use 3D printer to print their design. Here the design goes through various alterations which produces plastic filament wastes and is very time consuming to print even a very basic design.

For architects, it becomes quite inconvenient for them to make their customer understand the technical aspects of the architectural design, which has many different lines and different measurement scales. Even after the latest technologies of software 3D simulators and various virtual reality [10] technologies, there lies a gap of real-world feel and touch for a lay user.

Some of the best ways to use this visualizing method are mentioned below.

For a designer, this gives the freedom to make alterations in their designs. Here, the designer is not bound to a cycle of 3D printing [11] like first creating the model in the software and then printing to see the model in real world, after that performing alteration in software again. Instead, we can reshape it in real time for perfection to the design that the designer wants.

For an architect, there lies a world of real entities that are required to be illustrated to the user for a better understanding. This simulation allows the user to experience a 3D environment of the sketch that architect has designed which represents the model with five sides (all walls and floor, i.e. excluding roof). This is a dynamic representation that is very suitable to make one understand the architectural design in a simple manner, or say making it come real into life.

For other purposes, as it is not limited to some designer, it can also be used for domestic purposes where

- First the stairs on floor comes which can rise and sit back to save the space as well as it is very convenient.
- One can shape a table/chair to their own convenience where the user can make the finest and comfortable object [12] as per requirement.

COLLECTED DATA

According to our literature survey, we surfed through the internet to know about various alternatives for visualizations where we have listed some of the already existing visualizing techniques along with the problems/issues. These techniques are as follows.

Handmade Replica

The most basic and oldest form of visualization is by making handmade replicas of the design or sketch. It involves sculpting and various other craftsman skills which are implemented to get a desired output.

As the designer creates a design on either plain paper or in software, the design is then given to the craftsman who may use different kinds of materials like- wood, straw, mud, clay, etc. They carve these materials through various tools and by using force to give it a unified and desired structure as per the design.

This method comes from ancient times where the nomadic people used their craft skills to make/illustrate various designs. Nowadays various big car manufacturing companies like Rolls-Royce, Mercedes, etc. still spend thousands of dollars on clay models [13] in the design process. Even Tesla Motors [14], known for highlighting any perceived outdated practices in the industry, employs clay models during the design process.

It not only makes the visualization shape into real world but also makes re-evaluation possible to the things easily and can be corrected easily.

Problem

The problem that arises with this visualization is that it takes lot of skills and perfection to get the desired output, which is nowadays not easy to find and it is also a very time-consuming process. Even after that we cannot say for sure whether the replica would possess that much precision in its characteristics like its dimension.

3D Visualizing Software

In designer's field, many 3D modeling and visualizing software have prevailed which have the capability to make the user visualize.

This software is one of the most impactful and most widely used visualization tools that has created a buzz in the markets for the designer's community. These software, not just the specified and highly reputed CAD (computer-aided design) tool, but also other software that have grown with updated versions are found to be that much useful as any other software.

These software are remarkably equipped with features that have the tendency to take our imaginations and make it possible to convey it efficiently in a virtual environment using the software which can be done with desired shapes and sizes similar to that of real world [15].

They are used in almost every product-based company where the designing part is the top most and initial step to start an execution of a product. These software, now with updated versions, come with some extraordinary visualization, which includes the shadowing and different material visualizations such as metals, wooden, plastic, and carbon fiber, etc.

Problems

As per the records and experience of architects, most of the time they are unable to describe their complex designs to the user even after converting the 2D sketch into 3D sketch. Although it is a real-type virtual visualization that is nearly same as that of a picture clicked by a digital camera, this simulation sometimes fails to convey the real time feel as in the person cannot really touch the objects [16]. After all, it is just a 2D screen that is representing a 3D model inside which the design cannot rise, and we cannot feel it physically.

Extended Reality

Extended reality (XR) is the fusion of human-computer interaction with computer-generated graphics, manifesting both in the physical and virtual realms. In essence, XR encompasses augmented reality (AR), virtual reality (VR), and mixed reality (MR).

The emergence of XR arose as technologies like AR and VR gained widespread adoption among developers and tech companies globally. While the concept of XR has been depicted in many science-fiction films, its real-world implementation differs significantly from its portrayal in movies.

To comprehend the technical underpinnings of XR, it is essential to grasp the technologies utilized in its creation:

Augmented Reality

The concept of AR involves overlaying virtual objects and imagery onto the real world. AR does not immerse users into entirely virtual or computer-generated environments; rather, it creates the illusion within digital devices [17]. Users retain full access to the real world and can interact seamlessly in both dimensions. A prominent example is Pokémon GO, which utilized AR to allow users to interact with both the physical and virtual worlds through digital devices. Another instance of AR includes the filters found in numerous apps, which provide the illusion of presence but are not physically tangible.

AR represents an enhanced rendition of the tangible physical world, achieved through digital visual elements, sound, or other sensory inputs delivered via technology. This trend is gaining momentum among companies engaged in mobile computing and business applications in particular.

Virtual Reality

In VR, users are immersed in a completely simulated environment, where their interactions are confined to the virtual realm. Computer-generated graphics predominantly populate this environment, creating artificial objects that mimic real-world sensations. Users can fully experience and engage with the VR environment. Specialized VR devices are required to transport users into this virtual space, providing them with a 360-degree view of the simulated world. These devices are engineered to provide users with an enhanced sense of realism [18].

VR is a simulated encounter that may closely resemble or entirely differ from reality.

VR finds applications in entertainment (especially video games), education (like medical or military training), and business (such as virtual meetings).

This impression is often generated by VR headsets featuring a head-mounted display with a small screen positioned in front of the user's eyes, although it can also be achieved through purpose-built rooms equipped with multiple large screens.

Mixed Reality

Mixed reality [19] (MR) is the fusion of AR and VR, allowing users to engage with both digital and physical environments simultaneously. Users can perceive their surroundings through specialized MR devices, which are more advanced and expensive compared to VR equipment. These devices enable users to digitally interact with their surroundings; for instance, users can don an MR headset and view their surroundings digitally, where they can manipulate virtual objects, such as throwing a ball or closing windows, while the actual physical environment remains unchanged. Many companies are investing significant resources into further research in this area of reality [20].

MR refers to the integration of real-world surroundings with computer-generated environments. Both physical and virtual objects can coexist and interact in real time within MR environments [1].

In summary, XR enables individuals to virtually visit places, experience a sense of presence, and interact with others in XR. Consequently, XR represents a combination of augmented AR, VR, MR.

Problems

Three significant hurdles encountered by companies engaged in the development of XR:

1. *Cost:* The primary challenge faced by companies in XR development is cost, as XR devices are expensive. Due to the integration of multiple technologies and extensive hardware requirements, production costs are substantial. High costs may limit accessibility to the general public, resulting in decreased sales for companies and reduced investor interest in XR ventures.
2. *Hardware:* Creating the hardware for XR devices poses another obstacle for companies operating in this sector. With a myriad of software technologies and components in use, crafting hardware

becomes a challenging endeavor. The hardware must not only be durable but also compact and capable of processing vast amounts of data rapidly and efficiently, all while maintaining affordability.
3. *Privacy:* Privacy presents a challenge for both users and companies in the XR realm. As XR devices are tasked with constructing user-centric environments, a significant amount of personal information may be necessary. Storing such data can incur expenses for companies, while users may have concerns about the privacy of their information.

Even if these aspects are overcome, the user still cannot have the real-time feel or physically touch the things. This sometimes becomes quite difficult for some people to adapt in as the technology is very futuristic for some old-aged people.

3D Printing

Just like the handmade replicas, these are the replicas that are made by using 3D printers where the filament is either in the form of plastic or other materials can be used to print the design in 3D.

Though applicable across various creative sectors, architectural visualization stands out as one of the primary applications of 3D printers. While 3D modeling and rendering remain prevalent methods, 3D printing is quickly gaining ground. While digital visualization methods likeVR, AR, and MR offer hyper-realistic experiences, tangible maquettes often provide unique advantages.

Instead of investing significant time in manual maquette creation, a 3D printer can complete the task swiftly, depending on precision and model size. Initially limited to certain plastics, today's 3D printers accommodate a wide range of materials, including edible ones.

Given that 3D printing relies on pre-existing 3D models, architects must envision buildings before commencing construction, allowing clients and investors to address potential aesthetic concerns beforehand. In recent years, leading architectural firms have embraced the challenge of creating larger structures using this innovative and user-friendly technology [21, 22].

Problem

1. *Time:* This methodology is always quite difficult for someone to represent the things at a pace as the 3D printing is very time-consuming technique, where even a small model of a house can take hours to days to print a model in 3D.
2. *Wastage and Toxic Gas:* Even after it comes under some of the cheapest physical visualizations but it creates a lot of waste that are recyclable up to some extent because afterwards these wastes are also considered to be as harmful as other polyesters that are harmful to the environment. Not just that, the 3D printing produces a lot of harmful gases as the plastic inside the nozzle gets heated up and continues heating for hours and hours till the print is completed.
3. *Non-Alterable:* The 3D printing of the model may be convenient to represent the design to the user that the designer has modeled in the software but in many cases the “finalized model” needs to go through various prototypes, where the problem arises of the alteration in the design which isn’t possible in the case of 3D printed models.

STUDIES AND FINDINGS

The Matrix Visualizer is a 2D plane matrix comprising of many small square boxes of equal size. When a designer/architect gives the input of design/sketch then as per the blueprint, the matrix starts taking shape accordingly. Here the square boxes of the matrix rise to a certain height as per the sketch. This gives a practical demonstration of the sketch that rises to give the 3D structure and appropriate physical representation. For instance, architects gives their sketch as input, and then the Matrix Visualizer starts processing the sketch and raises the square boxes of the matrices accordingly up to the certain height. Through the utilization of square matrix boxes, we can depict different elements within a sketch, such as walls, chairs, beds, sofas, and other objects. This facilitates a hands-on experience for users, allowing them to physically interact with the items and navigate the space to accurately assess the gaps between two objects [23].

As soon as the user provides an input to the Matrix Visualizer, the intelligence would work on calculating the coordinates that have to be instructed to the linear actuators. As the processing is done by a central processing unit (CPU), the signals will be transmitted to the linear actuators which then push the boxes. Hence the boxes will rise up to a certain height to represent some entities. As soon as the actuators are done with their job the actual and precise visualization of the sketch is available for the user. Herein the user can roam around, can touch and feel entities and can also physically visualize the dimensions of their design and can re-evaluate anytime if required to make any changes.

Steps Involved in This Visualization

- *Step 1:* At first, the device needs an input by the user for the design or sketch that they want to visualize using the Matrix Visualizer.
- *Step 2:* Linear actuators move at initial position and a check will be imposed on them whether they are at initial point or not.
- *Step 3:* As soon as the input is given, the intelligence will calculate the dimensions precisely as per the sketch and then it would give commands to the actuators. Thereafter the designed shape would start to form.
- *Step 4:* When the actuators get their commands from the CPU, they will start to rise up and down accordingly; hence we can easily visualize the entities like walls, bed, table, chair, stairs, etc.
- *Step 5:* After all the actuators are on their particular coordinates, the fully completed 3D simulation is presented where the user can roam in and can physically touch the things for better real-world visualization.

Proposed Flowchart

Creating a flowchart for visualizing steps involves breaking down processes into clear, sequential steps. Figure 1 shows a proposed flowchart with accompanying captions.

Structural Design

The structural design of the Matrix Visualizer is based upon the fact that it would get input from the user. So as soon as the user provides an input, the intelligence would work on to calculate the coordinates that has to be instructed to the linear actuators (Figure 2).

A linear actuator can move linearly left and right when placed horizontally and up and down when placed vertically. In the Matrix Visualizer, the boxes need to be risen up and down. Our prototype has 25 boxes in a 5 × 5 matrix so there are 25 linear actuators that also require 25 servo motors for the movement.

The processing is solely done by CPU where the signals will be transmitted to the linear actuators which then push the boxes. Hence the boxes rise up to a certain height in their designated coordinates.

When the actuators are done with their job, the actual and precise visualization of the sketch is available for user. Herein the user can roam around, can touch and feel entities and can also physically visualize the dimensions of their design and can re-evaluate anytime if required to make any changes.

Performance Report

It is quite obvious from our study of existing state of art that those things may take more time and would cost more and therefore in result, they may or may not be satisfactory or up to the level of expectations that a user had (Figure 3).

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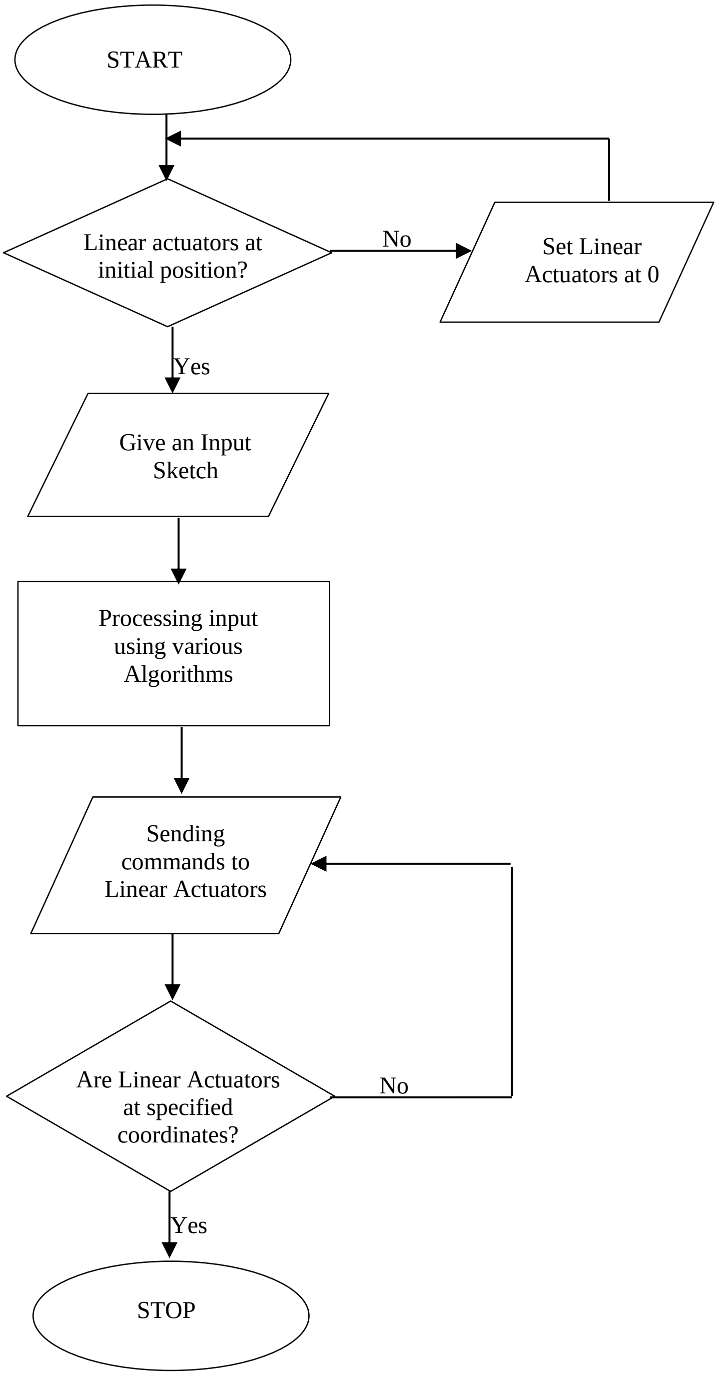

Figure 1. Flowchart depicting the structured steps involved in creating a data visualization.

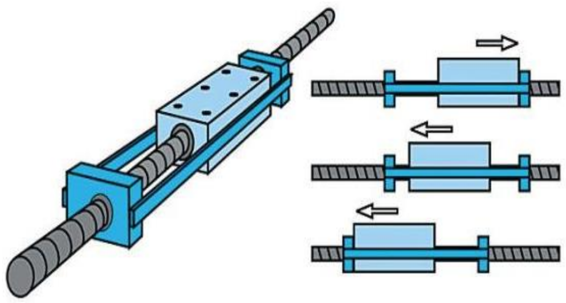

Figure 2. Motion of linear actuator.

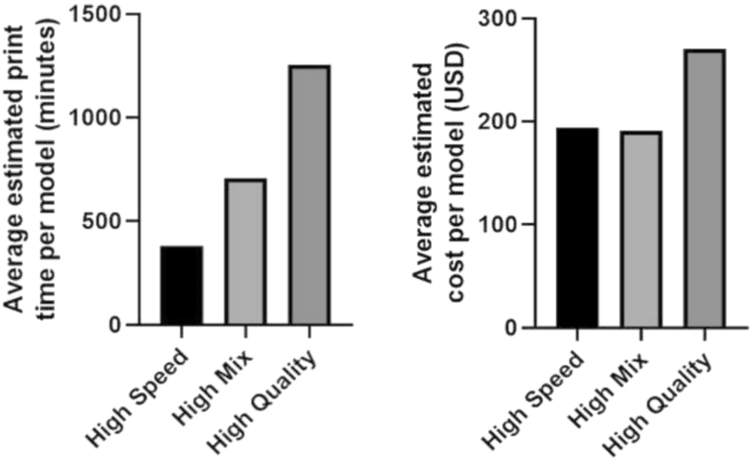

Figure 3. Performance report.

Figure 4. Structural design, 3D analysis, and actuators.

On comparison of Matrix Visualizer with the other existing state of art the performance report is ahead on satisfying a user experience with real-world entity.

This is a one-time investment which produces a fully working 3D simulation that is ahead of its competitors in time and providing a real-time feel.

The objective of this article is to provide a compact text that facilitates a global view of the Matrix Visualizer while synthesizing the given evidence. The main focus areas associated in this field are structural design, 3D analysis, and actuators. The state of the art, performances, and novel applications are disseminated through the article and the idea regarding the similar technologies are given for those readers who want to make a foray into this area (Figure 4).

CONCLUSION

One can only imagine what it would be like when possibilities of such a device increases. What would occur if the resolution of our prototype were to double or quadruple, leading to exponentially more realistic 3D content? This could open doors to a system with various interactive scenarios.

Review and Future Work

Based on the review, it is clear that the past one decade has moved the area to a new level, at the same time, has opened new research area for fundamental and topics with new opportunities.

1. A high-level task and adaption are required not only to grasp the object but also to solve constraints in the real-world environment. Users should have the ability to get experience themselves by performing tasks regularly.
2. *Affordable to user:* The future work of a Matrix Visualizer is to produce a cognitive environment which is concerned with affordability [1] to the user since the different high technologies require that much investment.
3. *Input through camera:* Presently, the inputs given by the user is through numerical values which need to be applied differently if we want the visualizer to be artificial intelligence friendly. One such advancement can be by giving input through camera.
4. *Progressive width decreasing of the actuator boxes:* If we gradually decrease the width of the boxes then that would improve the shape and sizes of the desired model. This can be interpreted similar to when the pixel size is decreased and numbers of pixels are increased in an image to improve its visibility.
5. *Advanced linear actuator that utilizes less space:* Making the base stronger is necessary so advance linear actuators that would require less space would be better and more efficient.
6. *Detailed analysis of blueprint as input:-* Scanning any blueprint or object through camera and taking that as an input can be considered as a future work towards the Matrix Visualizer.

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