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Enhanced Medical Education for Physically Disabled People through Integration of IoT and Digital Twin Technologies

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Abstract: This research presents an innovative approach to revolutionize IoT service development in medical education, specifically designed to empower individuals with physical disabilities. By integrating digital twin technology, we offer dynamic virtual representations of tangible assets, facilitating real-time simulation, monitoring, and feedback. A unique visual response algorithm has been developed to enhance the processing of visual vector data, resulting in a more efficient IoT service development process. Our method demonstrates superior performance over traditional techniques, particularly in achieving higher intrinsic variable merging values, which is critical for accurate and accessible visualization. The practical applications of this technology are highlighted through case studies that demonstrate how physically disabled students can benefit from interactive and immersive educational experiences. For instance, students can engage with the digital twins of medical equipment, allowing them to practice procedures and gain hands-on experience in a virtual environment without physical barriers. This approach not only improves accessibility but also personalizes learning experiences, adapting to the unique needs of each student. The research underscores the importance of inclusive design in developing IoT services, ensuring higher inclusivity rates and addressing diverse learning patterns. The findings suggest that the integration of IoT and digital twin technologies can significantly enhance medical education, making it more accessible, effective, and inclusive for physically disabled individuals. This study lays the groundwork for future advancements in this field, highlighting the potential for ongoing technological innovations to further transform medical education.

Keywords: MedTech; inclusivity; IoT; digital twin; accessibility

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1. Introduction

The field of new service development in the Internet of Things (IoT) is evolving rapidly, propelled by the dynamic advancements in information technology. These advancements have significantly reshaped the IoT service development landscape, introducing complexities in service design, necessitating enhanced monitoring, and demanding more stringent device management. Breakthroughs in control theories, advanced communication methodologies, and the growing field of computer-related technologies drive this evolution. The incorporation of sophisticated monitoring systems, modern instruments, and intelligent sensors marks a shift towards a more digitized, intelligent, and information-rich IoT ecosystem. This transformation is critical for enriching the visualization and management of the IoT's new service development processes, leading to the creation of innovative control network architectures that are more efficient and responsive.

Digital twin technology, at the heart of this transformation, revolutionizes the monitoring and transmission of information within the IoT framework. This technology has become integral to the development and production layers of IoT services, encompassing a wide range of development aspects such as real-time process sensing, execution, and monitoring. The technology facilitates a seamless flow of critical data streams via wireless networks, which include essential parameters like development speed, progress, and other monitoring components. These data streams are vital in shaping the new IoT service development processes, providing a comprehensive and dynamic view of the entire development lifecycle.

On the other hand, difficulties arise when the data transfer that occurs inside the Internet of Things development layer is not reliable or immediate. These kinds of deficiencies can greatly limit the efficiency of development processes, have a negative influence on the quality of services provided by the Internet of Things (IoT), and, in extreme circumstances, destroy the entire Internet of Things system, which can have severe repercussions for the economy. Therefore, a robust framework for the Internet of Things (IoT) service development visualization based on digital twin functionality is urgently required [1,2]. In order to provide a more precise and effective perspective on the Internet of Things (IoT) service development landscape, this framework intends to ensure the dependability and real-time transmission of visualization processes.

As a key player in the actual development and production layer of the IoT services, it encompasses various development facets such as real-time process sensing and execution [3–5]. Crucial data streams delivered via wireless networks, encapsulating aspects like development speed, progress, and other monitoring components, play a pivotal role in the new IoT service development processes [6]. However, if data transmission within this development layer lacks reliability and immediacy, it can lead to potential pitfalls—compromising development efficiency, impacting service quality, or even grinding the entire IoT system to a halt with substantial economic repercussions [7]. Thus, the imperative need for an IoT service development visualization based on digital twin technology arises, aiming to ensure both the reliability and real-time transmission of visualization processes [8].

1.1. Research Gap

This research paper systematically explores the functionalities, challenges, and practical aspects of an advanced visualization method for the IoT service development. Through detailed analysis, the experimental platform reveals significant improvements in the visualization process, providing nuanced insights into complex datasets. The study highlights the increased amalgamation value of intrinsic variables, resulting in greater clarity and precision. As technology continues to evolve, incorporating more advanced wireless equipment, actuators, and similar field devices into the visualization framework becomes feasible. The paper concludes by emphasizing future prospects and the pivotal role of visualization in the ever-evolving landscape of IoT technology.

1.2. Paper Organization

The paper is organized into five main sections. First, Section 2 examines existing research on IoT services, digital twin technology, and their applications in medical education. Section 3 provides a detailed description of the experimental setup, the developed visualization method, and the integration of digital twin technology. Section 4 presents and analyzes the experimental findings, highlighting improvements in intrinsic variable merging values and overall performance. Section 4.3 delves into the implications of these findings, particularly for the medical education of physically disabled individuals, supported by case studies and practical examples. Finally, Section 5 summarizes the research contributions, significance of the findings, and suggests future research directions.

2. Literature Review

This research provides an in-depth examination of the role of visual monitoring in the context of Industry 4.0, a term that signifies the fourth industrial revolution, characterized by the integration of digital technologies into manufacturing. The study emphasizes the profound impact of emergent technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI) on enhancing digitization and intelligence within the industrial sector. This study addresses the methodical use of visual aids, including advanced instruments like microscopes and binoculars, to rigorously evaluate systems and uncover any anomalies. This method is applicable in a variety of settings, including control rooms, machine rooms, and platforms such as programmable logic controllers, human–machine interfaces, supervisory control, and data acquisition [9].

This investigation implies that visual monitoring is a viable method for the prognosis analysis of a system's health and the pre-emptive mitigation of possibilities to ensure better efficiency and reliability in industrial procedures all over the world. This report summarizes new research findings [10]. Among other things, the report presents potential examples of how digital twins can enhance the development of industrial products. The practice of digital twins, or digital copies of real-world objects [11], is growing more popular in the realm of product development. This discussion delves into how the combination of the Internet of Things, big data analytics, and cloud computing can enhance the capabilities of distributed technologies, thereby bridging the gap between the real and virtual worlds. The proposed arrangement model by DTs offers a more experience-based approach to technology research and integrates better ontology and tracking technologies [12]. An example from the industry proves that this model works.

This project undertakes research in several technologies that can address privacy and protection in the Industrial Internet of Things [13]. The author offers a new theoretical perspective in this paper on the integration of blockchain and digital twins with existing technologies. The DPRG serves as a solution to the fundamental mechanism of the blockchain technology, which is the Proof of Authority link.

We demonstrate the performance level of the available technology stack using a simulated blockchain ledger, aiming to assess how blockchain, digital twins, and the IoT sensor network combine to enhance security and conserve energy. The outcomes show a major breakthrough in energy conservation [14]. This work sheds light on the potential of digital twins to transform the state of the human health industry. This involves investigating how disruptive technologies like artificial intelligence (AI), digital twins (DTs), and the Internet of Things (IoT) can effectively disrupt the health sector [15]. This involves investigating how disruptive technologies like artIoTs and blockchain technologies are powering a brand new electronic health landscape, aided by strong artificial intelligence methods for making health easier and more neutral. This study confirms that current organizations will need to allocate significant resources to the future electronic health landscape aided by strong artificial intelligence methods for making health easier and more neutral. Through this study, it is confirmed that the future will involve a major turn of resources from the current organizations.

This study uses digital twin technology to graphically represent the development of new services in the Internet of Things (IoT) arena [16]. Its main goal is to improve both the effectiveness and clarity of the development process. In this research, the development of a unique visual response algorithm specifically for the digital twin development process is a key innovation. This algorithm processes visual vector data, aiming to vividly capture and convey the essence of the new service development process within the IoT context. Our experiments showed that the digital twin technology-based approach is the best at visualizing how the IoT's new services are made, mostly because it has a higher maximum intrinsic variable merging value [17,18]. This study's Table 1 highlights this. What sets this study apart from others in the field is its concentrated emphasis on applying digital twin technology to the visualization of the IoT's new service development process. In contrast, other studies frequently focus on the chaotic iterative positioning within a two-dimensional subspace in development process visualization and its impact on low intrinsic variable merging values.

Table 1. Results for the comparisons between the previous studies of digital twins.

Paper	Purpose	Features	Results
[19]	Improve product design for smart industrial products	-Digital twin-driven approach for product design -Focus on smart industrial products	-Improved design processes -Enhanced product performance
[20]	Enhance security and trust for digital twin technology in Industrial Internet of Things	-Blockchain-based trust mechanism -Digital twin for Industrial Internet of Things	-Improved security and trust in digital twin technology -Enhanced performance of Industrial Internet of Things
[21]	Improve monitoring and management of computer rooms	-Digital twin for monitoring computer room -Visual monitoring method	-Improved monitoring and management of computer room -Enhanced performance of computer room
[22]	Improve healthcare management and performance with digital twin, DLT, and IoT technology	-Digital twin integrated with DLT and IoT -Automated healthcare ecosystem	-Improved healthcare management and performance -Enhanced security and trust in healthcare systems

In this research paper, we have presented a comprehensive overview of the application of advanced technologies in various sectors, highlighting the transformative impact of visual monitoring, digital twins, blockchain, and IoT. These technologies not only improve operational efficiencies, but they also pave the way for innovative solutions in product design, industrial security, and healthcare, thereby shaping the future landscape of these industries in the context of Industry 4.0 and beyond (Table 1).

3. IoT Service Development Using Digital Twin Technology

This research underscores the importance of a comprehensive visual dimension reduction space for illustrating the IoT service development process. Traditional computer graphics, limited to two or three dimensions, often require subspace dimension reduction, visualizing only a fraction of the high-dimensional data space. The proposed multi-dimensional architecture aims to overcome this limitation, providing a more sophisticated visualization of the IoT development process. This enhanced visualization framework incorporates advanced wireless equipment, actuators, and field devices, optimizing model behavior for user-specific needs [23].

The research integrates digital twin technology, offering a real-time simulation and analysis platform for IoT services. This approach enables the dynamic and accurate visual representation of the service development lifecycle, from conceptualization to deployment. Digital twins enhance real-time monitoring and modeling, providing valuable insights into performance, potential issues, and improvement opportunities. The interactive environment allows stakeholders to engage with and modify the virtual representation of IoT services, leading to more advanced and effective design solutions.

Additionally, the study explores the use of visual aids like microscopes and binoculars to evaluate systems in various environments, including control rooms and SCADA systems, enhancing system health analysis and pre-emptive issue resolution. The potential of digital twins in industrial product design, combined with IoT, big data analytics, and cloud computing, is also examined. A case study on miniature manifolds validates the model's effectiveness in real-world scenarios.

In addressing privacy and security in IoT, the research advocates a combination of blockchain and digital twin systems, utilizing the Proof of Authority mechanism and a deterministic pseudo-random generation method. This approach enhances data security and energy efficiency, aligning with the sustainable and human-centeredd technologies of Industry 5.0.

The study also highlights the transformative potential of digital twin modeling in healthcare. By integrating machine intelligence, distributed ledger technology, and IoT, the research proposes a new electronic healthcare delivery system focusing on resource efficiency, cost-saving, and a holistic approach, benefiting patients, healthcare providers, and researchers.

3.1. Methodology

The Internet of Things (IoT) service development process provides an explanation of the process of visualizing large, multi-dimensional data sets.

(a) The first iterative step in the point visualization is arranging the 'n' parallel coordinate axes in which each of these axes represents a coordinate point to be made. This step is required to form the basis in a visual representation of an n-dimensional point, where its central purpose is to 'see' one single point from numerous other respective points of view. We 'orient' 'n' on its coordinate points; this will help us align our point in n-space. The importance of these n conditions is to overview the significance of 'seeing' a single point made within numerous perspective dimensions. This will extensively provide the knowledge of the point's features and its attributes within a developing context of an analytical process as an Internet of Things service.

(b) The arrangement above is made possible by 'combining' the 'n' coordinate points. In other words, we are able to orient our point in an n-dimensional space. The importance of this step is to show the significance of viewing a point from numerous perspectives, and each of them provide an understanding of points and density in the state of development within the IoTS. It is noted as possibly impossible, however, it is significant since its relationship dimensions may vary.

(c) At each instance of each iterative step, we 'choose' two variables to have a conditional dimension with a nonlinear constraint. The variables' condition is expressed in Equation (1) where α and β are low-dimensional coordinate points. We select these variables to make a pair based on the condition of nonlinear constraint on two committed variables; the rest are constants.

(d) We select two variables from the three coordinate point variables, keeping the third constant at the initial point. This selection allows users to observe the optimization model's inherent characteristics through iterative progress on the subspace. For instance, keeping the chosen variables constant leads to the convergence point coordinate after six iterations. This results in a significant reduction in the objective function value from 7.29 to 0.27.

(e) Afterwards, we identify the optimal point coordinate value by maintaining variables and setting a constant. As the optimization process progresses, it becomes evident that the iteration point converges towards the boundary, culminating in an ultimate outcome where the values and function values are 0.111. We obtain this result under a defined constraint condition. Table 2 and Figure 1 clearly illustrate the subspace iterative procedure for the variables.

Table 2. Subspace iteration process of variables x_1, x_2, and x_3.

Number	Variable Name		Constant Name	x_1	x_2	x_3	$f(x)$
1	x_1	x_2	x_3: 0.100	1.600	0.700	0.1	0.27
2	x_2	x_3	x_1: 0.100	1.600	0.688	0.355	0.182
3	x_1	x_3	x_2: 0.100	1.386	0.688	0.462	0.125
4	x_1	x_2	x_3: 0.100	1.306	0.768	0.462	0.112
5	x_2	x_3	x_1: 0.100	1.306	0.786	0.453	0.111
6	x_1	x_3	x_2: 0.100	0.786	0.786	0.422	0.111

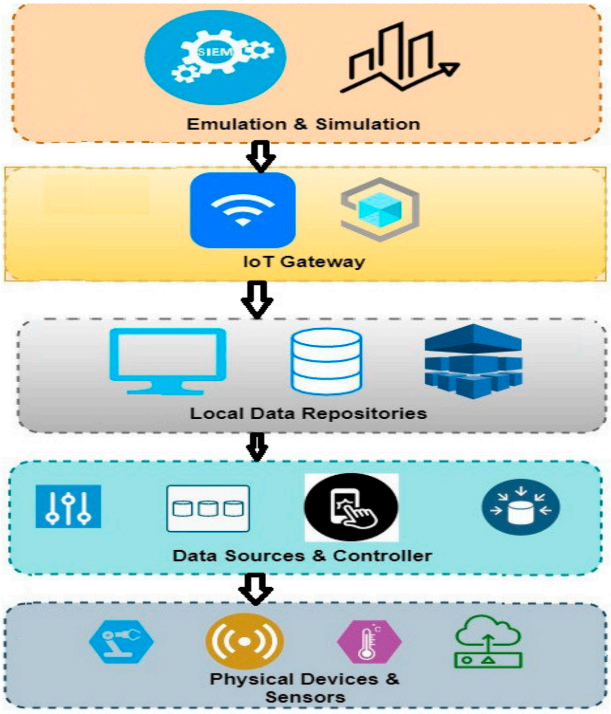

Figure 1. Flow chart of proposed work.

This expanded approach effectively illustrates the multi-dimensional visualization process in IoT service development, utilizing digital twin technology. By adopting this method, the paper underscores the ability to handle complex data sets and derive meaningful insights through iterative visualization, enabling a deeper understanding and more effective development of IoT services.

According to the design variables of the iteration process of table neutron space, the stress value is obtained by finite element analysis, and then the constraint function value is obtained as shown in Figure 2.

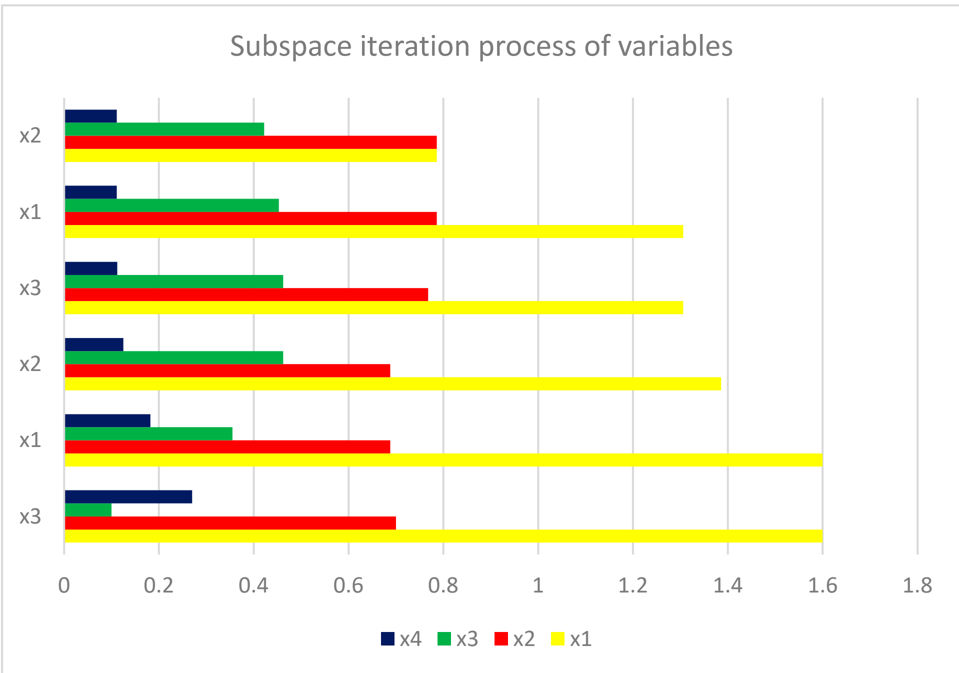

Figure 2. Visualization of the iteration process of variables x_1, x_2, and x_3.

The formula is as follows:

$$K(x_1, x_2, x_3)\delta = P$$

In the formula, K is the structural stiffness matrix, and when the functional relationship between the corresponding parameter variables and the known parameters is implicit, the relationship between the test results and the parameter variables can be designed through the response surface method, and the coefficients of the parameter variables can be obtained. Finally, the functional relationship between the response and the parameter variables can be established, that is, when the relationship between $g(x)$ and x cannot be expressed explicitly, $\widetilde{g}(x)$ can be used to express $g(x)$ approximately. That is to say, two parameter variables are used to construct the space with the lowest dimension reduction. Therefore, it is necessary to clarify the exact relationship between parameter variables and spatial dimension in the in-depth exploration of reduction outcomes and visual response algorithms in digital twin development.

The structural node displacement vector is influenced by the external load vector P. Based on this, the known constraint variables of the visual dimension reduction space in the service development process can be obtained. Based on this, the visual dimensionality reduction of service development process is solved. Since dimensionality reduction is an inverse problem, it involves a large number of objective functions and constraint functions [22,23]. To directly solve the ratio of constraint value to the design variable, the complicated nonlinear implicit function is simplified, and the input value of the dimensionality reduction response is visible in the development process [24]. The ratio is included into the function of multiple variables, and the implicit expression of the variable function's content results in the appropriate parameter variables [25].

The functional relationship between the corresponding parameter variables and the known parameters is implicit; the relationship between the test results and the parameter variables can be designed through the response surface method, and the coefficients of the parameter variables can be obtained.

3.2. Detailing the Dimension Reduction Outcomes

According to the reduction findings [26], various combinations of two-parameter variables are investigated, and the spatial dimension reduction outcomes of each unique combination are meticulously documented [27]. Following the collection of data from a multitude of experiments, a detailed analytical relationship between the duo of variables and the spatial dimension reduction results emerges [28]. This relationship can be leveraged to generate a response surface for the yield model [29]. Let us denote the parameter variable by α and the result of spatial dimension reduction by β. The proximate expression is represented as follows:

$$y = K(x_1, x_2, x_3) + \varepsilon \tag{1}$$

In this equation, ϵ denotes a stochastic error. When θ represents the anticipated response magnitude, the surface delineated by θ is identified as the response surface. Assuming our constraint function is represented by g, and our current point of consideration is x_0, the subspace corresponding to x_0 can be derived. To initiate, the design variables x_1 and x_2 are interactively chosen, while other variables are affixed. Specifically, this is given by x_0. A comprehensive sampling ensues for the chosen domains of x_1 and x_2, culminating in N distinct sampling outcomes:

$$N = (x_{11}, x_{21}, x_{30}), (x_{12}, x_{22}, x_{30})(x_{13}, x_{23}, x_{30}), \cdots, (x_{1n}, x_{2n}, x_{3n}) \tag{2}$$

These sampling outcomes undergo an analysis leveraging the finite element methodology, culminating in the construction of the visual dimension reduction space tailored to the service development process.

3.3. Crafting the Visual Response Algorithm for Digital Twin Development

In consonance with the previously discussed visual dimension reduction space for the service development process, we chart out the visual response algorithm specific to the digital twin development paradigm. Our goal is to ascertain an apt approximation for the ff function. Within a stipulated range of independent variables, the authentic function is emulated using a polynomial of a relatively lower degree. The computation for this is given as follows:

$$y = \beta_0 + \beta_1 x_3 + \beta_2 x_2 + \beta_3 x_1 + \varepsilon \quad (3)$$

Herein, aa, bb, cc, and dd are coefficients awaiting determination, and ηη signifies the fitting deviation. To ensure the polynomial model's function mirrors a logical approximation across the entire independent variable space, we employ RSM analysis in a fitting surface guise. If this fitting surface resonates closely with the function ff, it can be deemed nearly identical to the genuine function. The computational formula for this actual function is as follows:

$$f(x) = \beta_0 x_1 + \beta_1 x_2 + \beta_2 x_3 + \beta_3 + \varepsilon \quad (4)$$

For dilemmas of a higher order, the quadratic model offers a precision considerably surpassing that of the first-order model. Hence, for the purposes of our approximation, we opt for the quadratic model. A visual representation of this can be glimpsed in Figure 3.

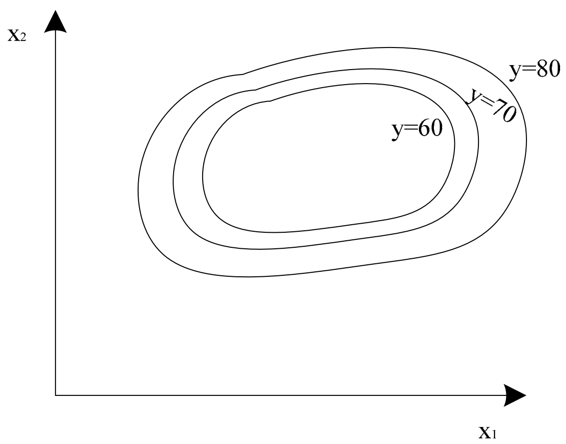

Figure 3. Visual response contour of digital twin development process.

3.4. Importance of Testing for Accurate Data Collection

We cannot overstate the critical nature of testing, especially when delving into the complexities of the issues under consideration. Such testing becomes paramount in gathering a substantial number of observed values relating to the response volume. This data accumulation facilitates the calculation of coefficients for the second-order response surface model, a process that can be visually depicted through isolines on the graph [30].

3.5. Determining Data Points and Assessing Location Impact

The first essential step is to determine the number of data points needed to create an accurate response surface, as this forms the foundation for subsequent visualization stages. Identifying the necessary factors and selecting appropriate data points or patterns is crucial for ensuring the model's precision and relevance. Further research is needed to explore how the locations of these data points affect the accuracy and efficiency of the response surface strategy.

In IoT service development where systems are complex and multi-faceted, the design of the experiments that capture these complexities is vital. For example, in second-order response surface designs involving linear connections, the size and selection of data points are critical for model fitting. The data must be relevant and informative about system behavior under varying conditions. This involves using data patterns suitable for different operational conditions, environmental stability, and service settings within the IoT context.

The accuracy of the response surface model significantly impacts the development of IoT services, allowing developers to predict outcomes based on various service settings and operational behaviors. Visualizing the optimal service behaviors and algorithms enhances the development process, making the model highly relevant to the current IoT services.

The research aims to develop a robust model for visualization and validation using digital twin software in an IoT environment. Achieving this requires the careful selection of data points within the IoT model, ensuring the model's strength and applicability.

3.6. The Interplay of Design Variables and Sample Points

The number of design variables is crucial to the granulation of the approximation model. More design variables require the approximation model to be generated with more sample points to secure the model's accuracy [31]. Thus, adopting an experimental screening model is critical as it filters the redundant certainty with the solely necessary entities that impact the researcher's response substantially [32].

3.7. Striking a Balance between Test Points and Coefficients

When creating a scheme with minimal test points, it is essential to ensure that the count of these points at least equals to the coefficients present in the fitting model. Nonetheless, one should not misconstrue this to mean that the number of tests conducted will always align with the coefficient count. Particularly in the context of the second-order response surface design, it is possible to repeat specific tests at specific test points. We often prefer a testing plan that incorporates the residual degrees of freedom [33]. This implies that the test count might exceed the number of coefficients needed for computation.

3.8. Experimental Design Necessities for the Second-Order Model

To ensure the experimental design aligns with the requirements of the second-order model and guarantees accurate parameter estimation, it is vital that each component embodies three distinct levels. We integrate model parameters into an equal-diameter design strategy to achieve this. This process culminates in the center combination design, which combines two factor design point levels and two axis points. It also includes multiple center point groups, culminating in the combination center design of the representation, which is visualized in Figure 4.

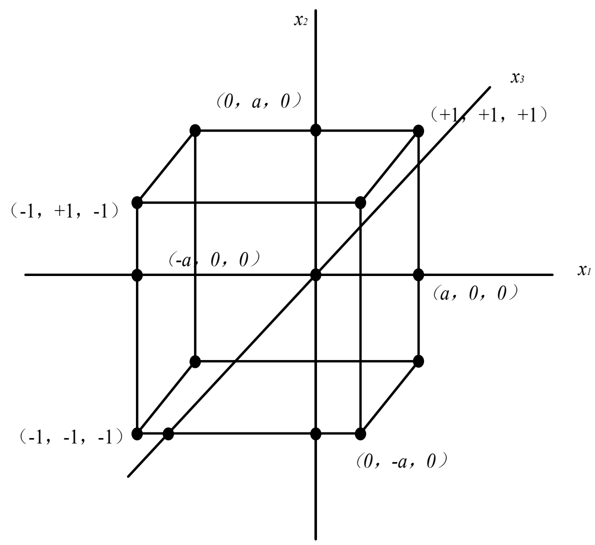

Figure 4. Combination design of the visualization center in digital twin development process.

Through the multi-dimensional variables in the two-dimensional space in Figure 4, the visual vector matrix of the digital twin development process is designed. The formula is as follows:

$$D = \begin{bmatrix} x_1 & x_2 \\ -1 & -1 \\ -1 & 1 \\ 1 & -1 \\ 0 & 0 \\ -1 & 0 \end{bmatrix} \tag{5}$$

Then, the results of the fuzzy cumulative distribution $\hat{x}(t)$ of access control are as follows:

$$F = f(t)\sum_{j=1}^{D} cr_j \tag{6}$$

where, $f(t)$ represents the uniform distribution parameter, and c represents access time cost.

According to the uniform distribution design points determined by the equal path of the visual vector matrix, the visual vector data in the development process was processed.

In the evolution of new IoT services, one can discern process objects by identifying database markers. These process objects can be compartmentalized based on their distinct roles in the visual data processing journey [34]: source object, filter, and mapping. Source objects bifurcate into two distinct kinds:

1. Those that integrate with external data, reading from data files to spawn data fields—termed reading source objects.
2. Those that instigate data fields within the program, referred to as program source objects.

While source objects exclusively generate output data, they are equipped to auto-delete this output post-processing, especially when situated mid-pipeline. Filters, on the other hand, operate as independent computation units, transfiguring the traversing data field to yield a fresh data output [35]. By astutely orchestrating multiple filters, we can distill the desired computational outcomes from the foundational data, a process visualized in Figure 5.

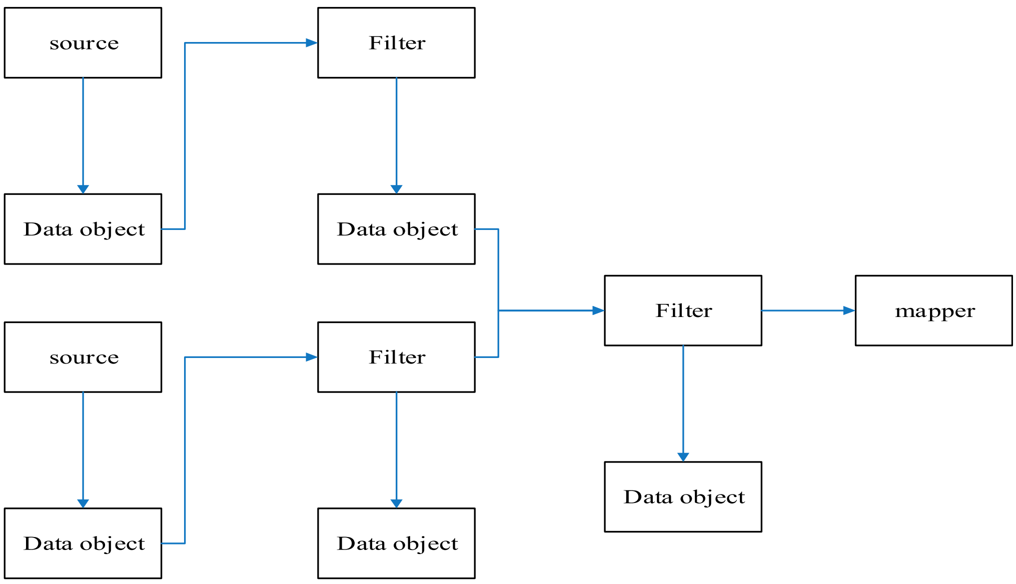

Figure 5. Vector data output mechanism in the development process of new Internet of Things services.

The "Vector data output mechanism in the development process of new Internet of Things services," illustrates the flow and processing of data through various components essential for IoT service development. It depicts a structured approach to managing and filtering data objects from their sources to their final mapping stage. Here is a detailed explanation of each component:

i. Source: This is the starting point where raw data originates. In the context of IoT services, this could be sensors or other data-generating devices.
ii. Data object: Data from the source is encapsulated into data objects. These objects represent structured data packets that are ready for further processing.
iii. Filter: Data objects pass through filters which process and refine the data. Filters can perform various tasks such as noise reduction, data normalization, or extraction of relevant features. The diagram shows multiple filters, indicating sequential or parallel data processing stages.
iv. Mapper: After filtering, the data is passed to a mapper which transforms the processed data objects into a format suitable for visualization or further analysis. This is the final stage in the depicted process.

Figure 5 highlights the importance of each step in ensuring the integrity and quality of data as it moves from raw input to a usable output. The intrinsic variable merging values, although not explicitly detailed in the figure, are implied to be a key metric that measure the effectiveness of this data processing pipeline. Higher merging values suggest a more precise and coherent representation of the development process, which is crucial for creating reliable IoT services. The significance of this metric lies in its ability to ensure that the processed data retains its relevancy and accuracy, which is vital for the subsequent stages of IoT service development and deployment.

To map the spatial dimensions of IoT services, regular grids are used to define the geometry's structure, while irregular grids illustrate finite differences and finite element meshes, offering a versatile method for depicting intricate service structures. These grids can accommodate a variety of structural types, including points, lines, triangles, polygons, and hexahedrons, enhancing the visualization process.

This research conceptualizes regular points as discrete points in space without topological connections, represented by various data types that provide a detailed view of individual components in the IoT service development process. Vector field data mapping visualizes these data points brought to life using point icons such as arrows, cones, and directed line segments, collectively referred to as spines [36].

In a two-dimensional vector field, arrows effectively illustrate the direction and magnitude of vectors, provided they do not obscure each other. This point icon method is simple and intuitive for mapping flow field data, accurately depicting the flow of information and the directionality of new IoT service creation through flow field visualization.

The initial data for vector field visualization is often derived from numerical computations or measurement results, encompassing both scalar and vector data types such as velocity, temperature, and pressure. The visualization software module must convert this data into a suitable format for subsequent processing to effectively visualize the new service development process for IoT [37]. An accurate and effective representation of the complex data inherent in IoT service development is crucial for facilitating a clearer understanding and a more efficient development process.

4. Experimental Analysis

Comparative experimentation offers insights into the effectiveness of different techniques or systems. In this context, the focus is on contrasting three visualization methods:

i. Operation and maintenance monitoring visualization.
ii. Information multi-terminal display visualization.
iii. IoT new service development visualization based on digital twin technology.

The experiment's crux lies in assessing the "inherent variable merging values" of each method, deciphering which offers the most efficient, accurate, and user friendly visualization.

4.1. Test Platform's Purpose and Goals

The experimental platform aims to amalgamate visualization with digital twins in IoT service development, ensuring efficient wireless data capture, intelligent embedded data acquisition, and fieldbus monitoring. Created in a laboratory setting, the platform uses the IoT service development process data for virtual, object-based experimental validation.

4.2. Pre-Experimental Setup

For the experiment, wireless data is earmarked as the primary object, with the development process emulated via a virtual object. Given the similarity in data production across various objects, only one variable—either decision-making, optimization, or control—is selected for validation. The wireless channels are meticulously configured to ensure uniformity and efficiency.

4.3. Experimental Outcomes

The experiment evaluates the intrinsic variables of the three aforementioned visualization methods. The results, captured in Table 3, offer comprehensive insights into each method's strengths and limitations.

Table 3. Merging values of inherent variables in development process visualization.

Group	Visualization Method of Operation and Maintenance Monitoring (10^4)	Visualization Method of Information Multi-Terminal Display ($10^{4)}$	Method of This Paper ($10^{4)}$
1	1.457	1.365	2.481
2	1.850	1.084	2.457
3	1.754	1.177	2.384
4	1.150	1.564	2.522
5	1.434	1.846	2.040
6	1.351	1.895	2.593
7	1.914	1.131	2.501

Upon analyzing the data presented in Table 3, we can observe that the intrinsic variables' merging values for the development processes of all three methods stand at 10^4. It is worth noting that visualizing the new service development process for the Internet of Things (IoT) is intricate, mainly because when the merging values of the intrinsic variables are lower, the visualization outcomes tend to be less clear and discernible. This complexity is further compounded by the multitude of classifications involved. For the operation and maintenance monitoring visualization method, the range of the intrinsic variable merging values spans from a minimum of 1.150×10^4 to a maximum of 1.914×10^4. In the case of the information multi-terminal display visualization method, the values fluctuate between a minimum of 1.084×10^4 and a maximum of 1.895×10^4. Most notably, the visualization method for the new service development process of the IoT based on digital twin technology exhibits a broader range. Its intrinsic variable merging values range from 2.040×10^4 at the lower end to 2.59×10^4 at the upper end. Consequently, from this data, we can infer that the visualization method for the new service development process of the IoT that employs digital twin technology offers superior visualization capabilities. This method not only presents a wider spectrum of merging values but also likely provides clearer and more comprehensible visualization outcomes, making it more effective for users aiming to understand and harness the IoT service development process shown in Figure 6.

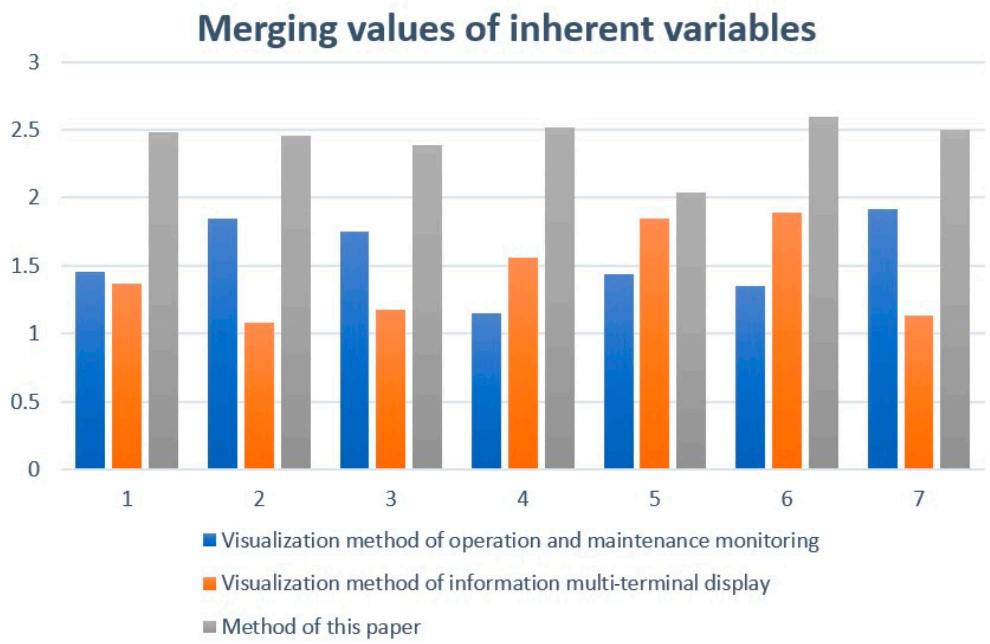

Figure 6. Chart of merging values of inherent variables in development process visualization.

Figure 6 presents the merging values of inherent variables across three different visualization methods: the visualization method of operation and maintenance monitoring, the visualization method of information multi-terminal display, and the method proposed in this paper. Each method is represented by different colors (blue, orange, and grey, respectively) and is compared across seven different scenarios or variables. While Figure 6 effectively summarizes the merging values, the discussion needs to more explicitly connect these values to practical outcomes or improvements in IoT service development, especially within the context of medical education for physically disabled individuals. The merging values indicate how well each method integrates and represents the data, which is crucial for understanding the development process.

For instance, the proposed method (grey bars) consistently shows higher merging values across most scenarios, suggesting that it provides a clearer and more integrated visualization of the data. This can lead to better decision-making and more effective development processes. However, the figure alone does not elaborate on how these improvements translate to practical benefits, such as enhanced learning experiences or increased accessibility in medical education. To address this, the discussion should highlight specific examples of how higher merging values lead to tangible improvements. For example, higher merging values could mean more accurate simulations of medical scenarios, allowing physically disabled students to engage with complex medical procedures in a virtual environment. This enhances their learning experience and better prepares them for real-world medical practices. Additionally, the improved data integration and visualization could support educators in tailoring their teaching methods to better suit the needs of all students, including those with physical disabilities.

Elevated merging values for intrinsic variables suggest that the visualization method provides a clearer representation of the development process, the digital twin technology visualization method stands out, boasting the highest minimum and maximum merging values. This indicates that this method offers a superior visualization experience, making the development of new IoT services via digital twin technology more comprehensible and accessible.

Our study showcases the effective application of digital twin technology in creating innovative and accessible IoT-based educational tools and services. These advancements offer a more rewarding learning experience for all medical students, with particularly significant benefits for physically challenged individuals. The generation of a student's physical digital twin is a breakthrough in medical education, fundamentally transforming accessibility and personalization. This development allows students with physical challenges to engage in interactive and immersive education, simulating real-life medical scenarios and operations. Consequently, this approach not only enriches the educational experience but also better prepares students for real-world healthcare environments.

The findings confirm the importance of inclusive designs in creating new IoT services. By developing services that maximize accessibility, usability, and comprehension, we ensure higher inclusivity rates, accommodating a broader range of the students' needs and learning patterns. The success of this research highlights the promising future of medical education through the IoT and digital twin advancements. As technology continues to evolve, there will be more opportunities to enhance these innovations for physically challenged individuals. This study's outcomes can be regarded as a significant milestone in the field, guiding future developments.

5. Conclusions

This research has made significant strides in improving the visualization process for IoT service development, particularly in the context of medical education for physically challenged individuals. By identifying and addressing key functionalities, challenges, and practical considerations, the study has enhanced the merging value of intrinsic variables, resulting in clearer and more accurate visualizations. This improvement facilitates more precise and insightful interpretations of complex data sets, which is crucial for developing effective IoT services. The integration of digital twin technology has proven to be a pivotal advancement, offering dynamic virtual representations and real-time simulation capabilities. These advancements not only enhance the clarity and depth of visualizations but also provide significant benefits for physically challenged students. By enabling realistic and immersive simulations, digital twins make complex medical scenarios accessible, enriching the educational experience and better preparing students for real-world medical practices. Looking ahead, the potential for further advancements in this field is vast. The ongoing evolution of sophisticated human–computer interaction (HCI) software and the integration of advanced wireless tools, actuators, and other field devices promise to further enhance visualization processes. These technological advancements will likely improve the overall efficiency and effectiveness of IoT service development. This study lays a solid foundation for future innovations, highlighting the critical role of visualization strategies in navigating the complexities of IoT service development. By emphasizing the importance of inclusive design and the practical applications of these technologies, the research serves as a catalyst for continued exploration and development. The findings underscore the transformative potential of IoT and digital twin technologies in medical education, particularly for physically challenged individuals, and point towards a future enriched with advanced, accessible, and effective educational solutions.

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