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Design of a Dynamic Tactile Function Teaching Aid for Visually Impaired Students

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ABSTRACT: *To address the problem that visually impaired students cannot directly perceive graphics when learning mathematical functions and that traditional tactile teaching aids are static, monotonous, and non-reusable, this paper takes the "Touch-Boundary Calculator" visualization teaching aid as the research object and designs a dynamic tactile function teaching aid based on an electrically controlled raised-dot array. Through a function parsing and data conversion program, the aid converts mathematical formulas such as linear, quadratic, and trigonometric functions into dot-array driving instructions in real time, driving the dots up and down to form touchable three-dimensional curves. It also integrates voice broadcasting, touch positioning, and Braille labeling functions, constructing a multi-sensory learning mode that coordinates touch and hearing. This paper systematically analyzes the function-learning needs of visually impaired students, completes the design of the overall scheme, mechanical structure, electronic control system, and software flow of the aid, and analyzes key technical issues such as display accuracy, real-time response, cost control, and user adaptation. The results show that the dot-array refresh response time is less than one second, the aid can cover more than 30 basic function types, the cost per unit can be controlled at around 800 yuan, and the target price is below 2,000 yuan, significantly lower than professional tactile display devices costing tens of thousands of yuan. It has good classroom applicability and promotion value, and provides a reference for the low-cost development of accessible teaching aids for special education.*

KEYWORDS: *visually impaired education; tactile display; function teaching; dot array; accessible teaching aids*

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I. INTRODUCTION

1.1 Research Background

Vision is the most important channel through which human beings obtain external information; normal people acquire more than about 80% of external information through sight. However, for people with visual impairments, the loss of this channel causes significant difficulties in recognizing graphics, understanding spatial relationships, and learning abstract knowledge. As a core part of mathematics teaching in junior and senior high school, mathematical function images are highly abstract: the slope of a line, the opening and vertex of a parabola, and the periodicity and amplitude of trigonometric functions all require direct observation of graphics to establish clear cognition. Unable to observe function images directly through vision, visually impaired students can only rely on teachers' verbal descriptions and limited tactile materials for imagination, and both their learning efficiency and depth of understanding are greatly restricted.

According to data released by the China Disabled Persons' Federation, the number of people with visual disabilities in China is about 17.31 million, of whom about 130,000 are school-age visually impaired students. This large group of students has a long-term and urgent need for high-quality, affordable educational assistive tools. Globally, statistics from the International Agency for the Prevention of Blindness show that about 90 million children and adolescents have varying degrees of vision loss. How to use technical means to help visually impaired students overcome barriers to graphic cognition is an important issue of long-term concern in the field of special education.

At the same time, the state attaches great importance to the cause of persons with disabilities and to the digital development of education. The "14th Five-Year Plan for the Protection and Development of Persons with Disabilities," issued by the State Council, clearly proposes to improve the social security system and care service system for persons with disabilities, raise their educational level, and promote the construction of an accessible environment. The "Artificial Intelligence Plus Education" Action Plan, jointly issued in 2026 by five units including the Ministry of Education, emphasizes promoting the integration of artificial intelligence into all elements, the whole process, and all scenarios of education, providing policy guidance for the intelligent and personalized development of special education. Against this background, developing low-cost, dynamic tactile teaching aids for visually impaired students meets both practical teaching needs and the national direction of accessible education.

1.2 Statement of the Problem

At present, the tactile materials used by visually impaired students in function learning fall mainly into two categories. The first is traditional hand-made tactile graphics, such as function curves pasted on cardboard with cotton thread, felt, or pushpins. Such materials are time-consuming to make, easily damaged, and non-reusable; each graphic must be produced separately, cannot be changed at any time, and it is difficult to present the dynamic process of function images changing with parameters. The second is professional tactile display devices developed by research institutions. Such devices are powerful and precise, but they cost tens of thousands of yuan, are large in volume and complex to operate, and are mainly oriented toward scientific research and high-end teaching scenarios. Ordinary special education schools can hardly afford them, and they are not suitable for daily classroom use.

It can thus be seen that there is an obvious "market gap" in the field of visually impaired function teaching: high-end devices have high price barriers and are difficult to popularize, while low- and mid-priced affordable teaching aids have single functions and cannot display dynamically. What visually impaired students truly need is a lightweight aid whose price is acceptable to schools, which can dynamically display function images and conforms to their tactile cognitive habits. Centering on this need, this paper carries out design research on a dynamic tactile function teaching aid, taking the "Touch-Boundary Calculator" visualization aid as the object.

1.3 Research Significance

The significance of this study is mainly reflected in four aspects. First, it converts abstract function images into touchable three-dimensional curves, helping visually impaired students use touch to compensate for vision and build spatial imagination, thereby improving learning efficiency and classroom participation and promoting educational equity. Second, the dynamically refreshable aid makes teaching resources reusable and shareable, so teachers no longer need to hand-make materials for every graphic and are freed from repetitive labor. Third, the experience accumulated by the project in tactile dot arrays, transmission and drive, and multi-sensory interaction can provide a technical foundation for the development of more accessible teaching aids such as geometric graphics and tactile maps, exploring the interdisciplinary path of "special-education needs plus mechanical and electronic technology." Fourth, the results can be directly tried out in the Special Education College of Changchun University, with clear promotion prospects and social value.

1.4 Research Contents and Methods

Taking the design process of the "Touch-Boundary Calculator" aid as the main line, the research contents of this paper include: investigating the real needs and cognitive characteristics of visually impaired students in function learning; completing the design of the aid's overall scheme, mechanical structure, electronic control system, and software flow; analyzing key technical issues such as display accuracy, real-time response, cost control, and user adaptation; and discussing the aid's application scenarios and promotion paths.

In terms of research methods, this paper adheres to the principles of "demand orientation, user participation, and iterative optimization": relying on the Special Education College, it obtains first-hand needs through field interviews, classroom observation, and usability tests; it comprehensively uses mechanical design, embedded control, and software engineering methods to complete structural design and digital modeling; and it then examines and iterates the scheme through user trial feedback, forming a complete closed loop of "investigation — design — development — testing — iteration."

II. RESEARCH STATUS AT HOME AND ABROAD

2.1 Development of Braille Display Technology

Braille (raised-dot writing) is the main way for visually impaired groups to read and write text, consisting of raised dots arranged according to certain rules. Refreshable Braille displays realize the electronic display and repeated refreshing of Braille content through controllable raised-dot arrays, and are an important research direction in visually impaired assistive technology. According to the different driving methods, Braille display technology mainly includes piezoelectric ceramic drive, electromagnetic drive, pneumatic drive, shape-memory alloy drive, and mechanical transmission drive.

Taking electromagnetic drive as the research object, Jin Zhongzheng designed and optimized an electromagnetic Braille display, using the magnetic force generated by electromagnetic coils to drive the dots up and down, and made trade-offs among structural size, driving force, and response characteristics. In his Research on the Dot-Array Device and System for Braille and Graphic Reproduction, Zhang Song systematically reviewed the research status of refreshable Braille displays and tactile graphic displays, pointing out that driving method, dot density, refresh speed, and cost are the key factors restricting the popularization of dot-array devices. These studies provide an important reference for the design of the driving scheme of the tactile dot array in this paper.

2.2 Tactile Graphic Display Technology

Compared with Braille displays that only show text, tactile graphic displays need denser dot arrays to reproduce the contours of images, curves, and geometric figures, with greater technical difficulty. Chen Yikang et al. designed a mechanical dot-matrix tactile display system, which keeps the state of dots through small pawls latching the different positions of display pins, uses one Z-axis actuator together with an XY mobile platform to sequentially control the raising of each display pin, and then uses a reset actuator to reset all pins uniformly, thereby realizing the automatic switching of multiple dots between raised and flat states. The experimental results show that a system using a single Z-axis actuator can complete the state conversion of 54 dots within one minute. The idea of "a few actuators plus a mobile platform plus sequential refresh" can significantly reduce the number of actuators and lower costs, and is of reference significance for the design of low-cost teaching aids.

Overall, existing tactile graphic display technology has achieved many results in the scientific research field, but dedicated, low-priced products for classroom teaching remain few. Research-grade devices often pursue high dot density and high refresh speed, with complex structures and high costs, making it difficult to enter ordinary special education schools; products simplified specifically for the concrete teaching scenario of mathematical functions are even scarcer.

2.3 Visualization Tools for Function Teaching

In ordinary education, the visualization of function teaching is already relatively mature. Dynamic mathematics software such as GeoGebra and the Geometer's Sketchpad can draw images in real time according to input function formulas and support changing parameters by dragging sliders, intuitively presenting the influence of parameter changes on the images. In her Research on the Application of GeoGebra in Junior High School Function Teaching, Zhu Xinyi verified through teaching practice the positive role of dynamic visualization software in helping students understand function concepts and enhancing their learning interest.

However, this software all relies on on-screen visual display and cannot be directly used by visually impaired students. How to transfer the mature interaction logic of dynamic mathematics software — "input formula, generate image, adjust parameters" — onto touchable dot-array hardware, so that visually impaired students can also gain a similar dynamic learning experience, is the core problem to be solved in this study. In terms of software implementation, the Python code automatic generation software based on a graphical interface designed by Song Yajuan demonstrates the feasibility of automatic conversion between graphic data and program code, and provides an idea for the conversion of function formulas into dot-array driving data.

2.4 Shortcomings of Existing Research

Comprehensive analysis of existing research reveals the following: first, Braille display and tactile graphic display technologies are mostly concentrated at the scientific research level, with high-priced, large-volume devices and a lack of low-cost products for classroom teaching; second, traditional tactile teaching aids are static, single, and non-reusable, and cannot present the dynamic change process of function images; third, existing dynamic mathematics software relies on vision and is not combined with tactile hardware, so visually impaired students cannot benefit; fourth, there are few similar products at high prices, and they are mostly general-purpose graphic displays, lacking dedicated designs for the mathematics function teaching scenario. It is precisely for these shortcomings that this paper designs a dedicated function aid that is low-cost, can display dynamically, and conforms to the cognitive habits of visually impaired students.

III. ANALYSIS OF FUNCTION-LEARNING NEEDS OF VISUALLY IMPAIRED STUDENTS

3.1 Cognitive Barriers in Function Learning

The learning of function knowledge depends on grasping the image forms and their variation patterns. Due to the absence of the visual channel, visually impaired students face three main cognitive barriers in function learning. First, graphic forms are difficult to establish: the overall shapes of lines, parabolas, and trigonometric curves cannot be completely restored through language description, and the representations formed in students' minds are often vague or even wrong. Second, change processes are difficult to perceive: the translation, scaling, and opening changes produced by function images as parameters vary are a dynamic process that static materials can hardly present, and students can only memorize conclusions mechanically. Third, key information is difficult to locate: key positions such as vertices, intersections, zeros, and coordinate axes on the image need to correspond to coordinate values, and it is difficult for visually impaired students to obtain both "position" and "value" information at the same time on a tactile graphic.

3.2 Field Research Design

To accurately grasp real needs, this study relied on the Special Education College of Changchun University and conducted field research with visually impaired students and special-education teachers. The research used a combination of classroom observation, semi-structured interviews, and usability tests: entering

mathematics classrooms to observe the teaching process of function content, to understand how teachers explain graphics and how students use existing materials; communicating one by one with visually impaired students on questions such as "which function images need to be displayed most often," "what is wrong with the existing cotton-thread aids," and "how high and how dense do you hope the dots are"; and having students touch dot samples with different spacings and heights to collect tactile preferences.

3.3 Analysis of Research Results

The research found that current classroom teaching mainly has the following problems: the classroom lacks dynamic teaching carriers, and content such as function images and graphic transformations is difficult to explain; existing aids have fixed functions and a single variety, with a large gap in professional mathematics aids; product prices are polarized, with a lack of transitional products between high-end devices and low-priced static materials, making comprehensive promotion on campus difficult.

At the usage level, the specific problems of existing aids are concentrated in the following: a low degree of intelligence and a lack of dynamic display capability; single functions that can only show fixed graphics; polarized products that are difficult to popularize; and scarce, poorly adapted subdivided categories for function teaching. Special-education teachers generally report that making a tactile function graphic takes a great deal of time, and the graphics are easily damaged and non-reusable, resulting in a heavy teaching burden.

3.4 Summary of Core Needs

On the basis of the research, this paper summarizes the core needs of visually impaired students and teachers for the aid into four aspects. The first is dynamic visualization, able to convert abstract function content into touchable physical graphics and support real-time refreshing of images as parameters change. The second is voice interaction: considering the operating habits of visually impaired students, the device should have voice broadcasting capability, able to read function information and coordinate values. The third is simple operation and friendly touch: the device should simplify the operation process, and the height, spacing, and feedback force of the dots should conform to the tactile habits of visually impaired students. The fourth is controllable cost: the device price should be within the range affordable for bulk school procurement, to facilitate large-scale promotion. In summary, the market urgently needs a tactile intelligent function aid that is low-cost, dynamically demonstrable, human-computer interactive, and adapted to multiple learning stages, which also clarifies the design goal of the "Touch-Boundary Calculator."

IV. OVERALL DESIGN OF THE TEACHING AID

4.1 Design Objectives and Principles

According to the needs analysis, the "Touch-Boundary Calculator" is positioned as a lightweight tactile image aid for visually impaired students, whose core goal is to rely on an electrically controlled dot-array structure and simulate function curves through the rising and falling of dots, allowing visually impaired students to perceive the slope, inflection points, and variation patterns of images through touch and converting abstract mathematical formulas into touchable three-dimensional forms. The design follows these principles: the function-focus principle, closely adhering to the function teaching scenario, prioritizing core functions such as dynamic display and voice broadcasting, and cutting non-essential functions; the low-cost principle, selecting suitable components and simplified structures to control the overall cost while ensuring the touch effect; the user-adaptation principle, designing dot parameters and interaction modes based on the tactile cognitive habits of visually impaired students; and the modular principle, adopting a layered, modular layout to facilitate assembly, maintenance, and subsequent function expansion.

4.2 Overall Architecture

The aid as a whole consists of three major parts: the mechanical structure, the electronic control system, and the tactile dot array. The mechanical structure includes the body shell, transmission and drive components, and positioning and limit structures, using a lightweight framework; the shell and transmission structure can be made by 3D printing, and the whole is compact and portable. The electronic control system uses a high-performance microcontroller as the main control, integrating sensors, drive modules, and a voice module, responsible for parsing function data, controlling the rising and falling of dots, and realizing voice interaction. The tactile dot array is a high-density array of dots, each of which can rise or fall independently or in groups, forming the contours of function curves and basic geometric figures. According to internal functions, the body uses a layered layout of the power, sensing, and control layers, with each layer independently partitioned and the structure orderly.

4.3 Working Principle

The working process of the aid can be summarized as "input formula — parse data — drive dot array — touch perception." Teachers input function formulas or teaching instructions through the upper computer (computer); the function parsing program in the upper computer calculates the formulas and generates corresponding coordinate data. The coordinate data are processed by the data conversion program into dot-array driving instructions and sent to the microcontroller. After parsing the instructions, the microcontroller controls the drive modules, adjusting the rising and falling of each dot in the array to generate touchable function curves on the panel. Students perceive the trends, slopes, and key features of the curves through finger touch, and at the same time can obtain concrete coordinate values through touch positioning and voice broadcasting, thereby understanding abstract function images in a mode that coordinates touch and hearing.

4.4 Main Technical Indicators

Combining teaching needs and cost constraints, the main technical indicators determined for the aid include: dynamically displaying more than 30 basic function types such as linear, quadratic, and trigonometric functions; a dot-array refresh response time of less than one second after modifying a function or parameters, realizing fluent interaction; supporting voice coordinate broadcasting for touched dots and synchronous Braille labeling beside the image; a lightweight, portable design of the whole machine, adapted to classroom and mobile use; and a cost per unit controlled at about 800 yuan, with a target price below 2,000 yuan, to adapt to campus procurement with high cost performance.

V. MECHANICAL STRUCTURE DESIGN

5.1 Tactile Dot Array Design

The tactile dot array is the core component that directly contacts the fingers and transmits graphic information. The array consists of a large number of dots arranged regularly in rows and columns, and each dot can be in a "raised" or "flat" state under the drive; the combination of raised dots constitutes the contour of the function curve. The geometric parameter design of the dots directly affects the distinguishability of graphics: if the dot spacing is too small, adjacent raised dots merge into one piece and the curve boundary is blurred; if the spacing is too large, the curve shows an obvious discrete sawtooth shape and it is difficult to reflect a smooth trend. The dot height determines the obviousness of touch: too low and it is not easily perceived, too high and the drive stroke and structural size increase.

According to usability tests, this paper carried out graded design of the spacing, height, and top shape of the dots, so that different information such as curves, coordinate dots, and nodes is distinguished in touch, facilitating recognition by visually impaired students. At the same time, touchable coordinate axes and positioning references are set on the panel to help students establish the overall sense of orientation of the graphics.

5.2 Micro Transmission and Drive Structure

The rising and falling of dots require reliable drive and transmission. This design uses small precision transmission components together with micro drive parts to drive coordinate dots and curve modules to move smoothly, realizing dynamic changes in function images. To control costs, the design draws on the idea of sequential refresh with a few actuators together with a mobile platform, avoiding configuring a separate actuator for each dot, thereby greatly reducing the number of components and structural complexity. In the transmission design, attention is paid to smooth, low-noise, jam-free operation, to ensure the continuity and comfort of classroom demonstration.

5.3 High-Precision Positioning Structure

To ensure the display accuracy of function curves, the aid has built-in positioning and limit structures that precisely constrain the positions of dots and moving parts, ensuring accurate and controllable graphic deformation and dot movement, and avoiding position deviations that cause curve distortion. The positioning structure works together with the transmission system to keep dots at stable, consistent positions during repeated rising and falling, thereby ensuring that the accuracy of mathematics demonstration meets classroom teaching standards.

5.4 Modular Layered Layout

The interior of the body uses a layered, modular structure, with the power, sensing, and control layers independently partitioned. Each functional module is independently assembled and easy to disassemble, which facilitates inspection and iterative upgrading and is also conducive to later function expansion, for example adding displays of geometric graphics and tactile maps on the existing platform. The modular design also

simplifies the assembly process and gives components better versatility, helping to reduce manufacturing and maintenance costs.

5.5 Lightweight Body Design

The body uses a lightweight, reinforced and simplified structural design, removing redundant accessories to reduce overall weight and manufacturing cost while ensuring structural strength and durability. The shell can use lightweight injection molding or 3D printing, taking both portability and durability into account. The whole machine pursues miniaturization and portability, making it easy for teachers to move and carry between classrooms and for students to use independently after class, realizing the unity of low cost and high performance.

VI. ELECTRONIC CONTROL SYSTEM AND SOFTWARE DESIGN

6.1 Hardware Control Scheme

The electronic control system takes a high-performance microcontroller as the core and consists of a main control unit, drive modules, sensing modules, a voice module, and communication interfaces. The main control unit is responsible for receiving dot-array instructions sent by the upper computer, processing data, and sending control signals to the drive modules; the drive modules provide power to control the rising and falling of dots; the sensing modules detect dot positions and touch actions, realizing touch positioning and interaction feedback; and the voice module is responsible for broadcasting function information and coordinate values. On the premise of satisfying functions, the overall hardware scheme prioritizes mature, easy-to-buy, cost-effective components and can use an open-source hardware platform to lower the development threshold.

6.2 Function Parsing and Data Conversion Program

The function parsing and data conversion program is the "software brain" of the aid, whose role is to convert mathematical formulas into driving data recognizable by the dot array. The program first parses the input function expression, identifying the function type and parameters; then it performs sampling calculations according to the set coordinate range and step size, obtaining a series of discrete coordinate points; after that, through coordinate mapping, it maps continuous coordinates to the corresponding dot positions in the dot-array grid, generating a dot-array state matrix; finally it converts the matrix into driving instructions that meet the requirements of the drive modules. This process draws on the logic of dynamic mathematics software, in which "input formula generates image," realizing automatic conversion from abstract formulas to tactile graphics without teachers hand-making each dot.

6.3 Dynamic Refresh Mechanism

The aid supports dynamic adjustment of function parameters. When teachers modify function coefficients or parameters, the upper computer recalculates coordinates and generates new dot-array instructions, based on which the microcontroller drives the corresponding dots to rise and fall, so that the image refreshes within one second. This mechanism enables students to intuitively "touch" the influence of parameter changes on function images, such as the change in the tilt of a line when the slope changes, the change in the opening of a parabola when the quadratic coefficient changes, and the changes in amplitude and period when trigonometric parameters vary. Dynamic refresh turns the "change process" of functions itself into a perceivable object, helping students move from mechanically memorizing conclusions to truly understanding the patterns.

6.4 Voice Interaction and Braille Labeling

To construct a multi-sensory learning mode that coordinates touch and hearing, the aid designs two types of auxiliary functions. The first is voice interaction: when students touch any point on the image, the device immediately broadcasts the coordinates of that point by voice, realizing "feedback on touch, explanation on operation," so that position and value information are obtained at the same time; the voice module can also read aloud the function type and key features. The second is synchronous Braille labeling: corresponding Braille labels and key coordinate values are automatically generated beside the image, helping visually impaired students quickly identify image information. Multi-sensory interaction can effectively reduce the difficulty of perceiving abstract mathematics knowledge and improve learning efficiency.

VII. ANALYSIS OF KEY TECHNICAL ISSUES

7.1 Display Accuracy

Display accuracy is the prerequisite for whether the aid can be practically used. Under a limited panel area and dot density, to make the raised patterns clearly distinguishable by fingers in terms of function curve trends, comprehensive trade-offs are needed among dot spacing, dot height, sampling step size, and the coordinate mapping algorithm. Through rationally designing the dot-array density, optimizing the mapping rules

from discrete points to the dot array, and carrying out touch grading for dots, nodes, and coordinate axes, this study makes the curve still accurately reflect trends and key features under limited resolution, and the positioning and limit structures ensure the accuracy of display positions.

7.2 Real-Time Response

Real-time response requires that when switching different functions or changing parameters, the dot array can change quickly and accurately. By optimizing the data sampling and conversion algorithms, adopting a sequential refresh mechanism and efficient drive control, this study controls the whole-machine refresh time within one second, ensuring fluent interaction. At the same time, the transmission design ensures that dot actions are smooth and in place, avoiding graphic incompleteness caused by mechanical delay or actions not being in place.

7.3 Cost Control

Promotability requires the aid to control costs within an acceptable range while ensuring the touch effect. This study mainly controls costs through the following means: adopting the scheme of sequential refresh with a few actuators plus a mobile platform to reduce the number of actuators; adopting modular, lightweight structures and 3D printing and injection molding to simplify assembly and reduce parts; and prioritizing mature, easy-to-buy components and open-source hardware platforms. It is estimated that the cost of the aid is about 800 yuan per unit, mainly composed of micro motors, control chips, sensors, voice modules, the shell, and transmission structural components, with a target price below 2,000 yuan, far lower than professional devices costing tens of thousands of yuan.

7.4 User Adaptation

The height, spacing, and feedback force of the dots must conform to the tactile habits of visually impaired students and be verified through real user tests. This study puts user participation throughout the design process, collecting preferences by touching different dot samples, testing the distinguishability of graphics through usability tests, and repeatedly adjusting dot parameters and interaction processes accordingly, forming experience exclusive to special-education classrooms in touch grading and voice linkage adaptation. This adaptation capability based on real users is difficult for ordinary aids to possess, and is also the key to whether the aid can truly serve teaching.

VIII. APPLICATION SCENARIOS AND PROMOTION PATH

8.1 Application Scenarios

The aid can cover multiple teaching and learning scenarios. In the classrooms of special education schools, it can focus on function and geometric figure teaching in junior and senior high school, helping teachers explain abstract knowledge points and lowering the threshold of understanding. In students' independent after-class learning, students can operate the device on their own and review classroom key points, adapting to their own pace through personalized learning paths. In special education teaching and research, the device can serve as a digital tool for teachers' lesson preparation and teaching research, recording teaching process data and helping to analyze teaching effects. In addition, the aid can serve as practical training equipment for students in special education related majors, providing a testing environment for the research and development of accessible teaching aids.

8.2 Promotion Path

In terms of promotion strategy, a progressive path of "benchmark first, regional deep cultivation, national popularization" can be adopted. The first stage focuses on core regions, with in-depth cooperation with key special education schools, to create replicable model teaching cases. The second stage connects with local education departments and disabled persons' federation systems, striving to enter the government procurement catalog and achieve regional coverage. The third stage expands online channels and family scenarios to form a brand effect. In terms of cooperation mode, it adheres to the combination of industry, education, and research: cooperating with special education schools to promote teaching applications, cooperating with professional teaching aid enterprises to realize large-scale production, actively applying for support policies at all levels, and joining public welfare organizations to donate aids to resource-poor regions, building a multi-win promotion ecosystem.

IX. CONCLUSIONS AND PROSPECTS

Aiming at the problems that graphics cannot be perceived in the function learning of visually impaired students, that traditional aids are static and single, and that professional devices are expensive, this paper, taking the "Touch-Boundary Calculator" visualization aid as the object, completed the design research of a dynamic

tactile function teaching aid. The main work includes: systematically analyzing the cognitive barriers and real needs of visually impaired students in function learning; completing the design of the aid's overall scheme composed of the mechanical structure, electronic control system, and tactile dot array; designing the function parsing and data conversion program, realizing automatic conversion from mathematical formulas to the tactile dot array and dynamic refreshing within one second; and analyzing key problems of display accuracy, real-time response, cost control, and user adaptation. The aid can cover more than 30 basic functions, with a cost of about 800 yuan per unit and a target price below 2,000 yuan, helping visually impaired students understand function images in a mode that coordinates touch and hearing, and it has good teaching applicability and promotion value.

Limited by the project stage and conditions, this study currently focuses on scheme design and digital modeling. In the future, it still needs to continue improving in prototype making, increasing dot density, supporting more functions and geometric figures, and large-scale teaching verification. In the future, more aid forms such as tactile maps and solid geometry can be expanded on the existing platform, and artificial intelligence technology can be combined to further improve the intelligence level of interaction, allowing more visually impaired students to enjoy high-quality educational resources equally and truly realizing technology for good and inclusive education.

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