

3D Vision Accessibility: the Product Development Process

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Research indicates a significant increase in the use of prescription glasses worldwide. Along with this trend, there is an increasing interest in 3D movies (stereoscopic cinema) in the film industry. This requires an image overlay system associated with the use of specific glasses (3D glasses). However, the challenge faced by consumers who already wear prescription glasses is their use in conjunction with 3D glasses. Therefore, the purpose of this work is to describe the Product Development Process (PDP) and its application in developing a solution that enhances the immersive experience, providing greater comfort to users of prescription glasses while watching 3D movies. Keywords: Product Development Process. Accessibility. 3D Vision. 3D Movies. Prescription Glasses.

The global prevalence of eyeglass usage among adults exceeds 4 billion, with projections indicating that by 2050, half of the world's population will rely on prescription eyewear, as reported by the American Academy of Ophthalmology (n.d.) [1]. Concurrently, in 2023, over 113 million individuals frequented movie theaters in a single year. Within the cinematic landscape, the popularity of 3D films has surged over the past decade, although recent years have witnessed a decline, particularly in the wake of the COVID-19 pandemic. Despite this, significant advancements have been made in transitioning from traditional two-dimensional (2D) imagery to immersive three-dimensional (3D) experiences [2,3].

Addressing a fundamental social demand for spaces conducive to relaxation and escapism from daily routines, film viewing remains one of the foremost leisure activities worldwide. To meet evolving consumer expectations, the film industry has prioritized enhancing entertainment quality through technological innovations, notably through the production of 3D movies [3].

3D cinema, leveraging stereoscopic techniques, creates an illusion of depth perception by projecting identical images from distinct viewpoints,

necessitating the use of specialized glasses for optimal viewing. This technology relies on the human brain's ability to fuse these disparate images, facilitating the perception of three-dimensional space [4,5]. However, individuals who already wear prescription glasses encounter unique challenges when attempting to enjoy 3D films, resulting from the cumbersome overlay of two sets of eyewear.

This overlap could present discomfort, visual distortion, and impede the intended immersive experience. Although 3D glasses incorporate technologies to simulate depth, their compatibility with prescription eyewear remains limited, compromising visual acuity. Consequently, the inability to provide a seamless viewing experience for individuals with visual impairments poses a significant challenge to the 3D film market, potentially constraining its audience base and market growth. The first approach to capturing and displaying 3D images was based on the concept of stereoscopy. Stereoscopic systems are based on the imitation of the human binocular visual system (HVS). Following this idea, a pair of photos (or movies) of the same 3D scene is taken with a pair of cameras configured with some horizontal separation between them. Later, the images are shown independently to the observer's eyes so that the left eye (or right) can only see the image captured with the left (or right) camera.

This way, some binocular disparity is induced, which stimulates the convergence of visual axes.

Received on 22 July 2025; revised 21 September 2025.

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J Bioeng. Tech. Health 2025;8(5):424-430
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This process provides the brain with information that allows it to perceive and estimate the deep content of the scene [4].

Acknowledging these challenges underscores the imperative of enhancing accessibility in entertainment. Accordingly, this study aims to address the intersection of 3D glasses usage by prescription glass wearers and the associated difficulties. Through the application of Product Development Process (PDP) methodologies, this research endeavors to propose innovative solutions that optimize comfort and immersion for prescription glass wearers during 3D movie viewing.

Rozenfeld and colleagues (2006) emphasize the importance of robust product development efforts that align with international standards, underscoring the need for enhanced expertise in PDP management [6]. This study adheres to standardized procedures while adapting to the unique requirements of each project, leveraging multidisciplinary collaboration to devise conceptual solutions.

This paper presents a comprehensive approach to addressing the challenges posed by 3D movie viewing for prescription glass wearers, applying a PDP methodology, methods, and tools. Through collaborative efforts, this study aims to enhance accessibility in entertainment, providing an inclusive and immersive cinematic experience for all viewers.

Materials and Methods

The method employed in this research is based on a traditional product development approach that incorporates both quantitative and qualitative methods. The sequence presents the method applied in this research, which is organized into four phases: design specification, conceptual design, preliminary design, and detailed design.

Design Specification Phase

Identifying the clients' needs: To map potential market opportunities, potential

consumer problems were identified through joint brainstorming sessions. After identifying the problems, the process of mapping key criteria began, including the target audience, market demand, problem interfaces, the existence of applied and/or similar solutions, and the motivation for development. With the preliminary information mapped, the target problem for this study was chosen.

Study of the State-of-the-Art and Technological

Mapping: This stage involved surveying, analyzing, and synthesizing the current knowledge available on the subject. Through research in different databases and consultation with the Google Patents platform, an extensive investigation was conducted on 3D glasses technology and its limitations. To address this, the development team conducted various activities, including defining the problem system, analyzing the primary interfaces involved, examining the product life cycle, mapping competitors and similar products, surveying relevant standards and regulations, and analyzing the business model.

Market Research and Analysis: Following an understanding of the problem, the process of identifying customer needs commenced. This stage was carried out through the elaboration and application of a questionnaire aimed at the target audience of the product under development (young adult users of prescription glasses), using the MS Forms tool. The application of the survey resulted in the collection of 35 responses, which were statistically analyzed, generating a list of expressed needs.

Quality Function Deployment (QFD)

Application: The QFD application stage involved translating the needs identified in the previous stage into requirements, analyzing the relationship between these needs and the translated requirements, and conducting a marketing analysis to evaluate conflicts between the requirements.

Conceptual Design Phase

Definition of the Functional Structure: After consolidating the QFD matrix, the process of defining the functional structure began, starting from identifying the primary function of the device under development (global function). After validating the global function, the decomposition of this function into the other involved functionalities (functional synthesis) was performed.

Elaboration of the Morphological Matrix: The detailing of the functional structure of the device was preceded by elaborating the morphological matrix, a tool capable of mapping the possible solutions/variations for each function proposed in the functional synthesis, enabling the generation of different concepts through the combination of the different solution options raised.

TRIZ Method Application: The application stage of the TRIZ (Theory of Inventive Problem Solving) method involved analyzing the conflicting requirements identified by the QFD matrix. The process was carried out by identifying engineering parameters equivalent to the project requirements and applying TRIZ to identify inventive principles recommended as a solution for each conflict. Based on the identified principles, the team identified applications for each one in solving the problem.

Concept Generation and Prioritization: After completing the morphological matrix and analyzing the contributions obtained through the TRIZ method, the process of generating ideas for the product began, considering the information gathered in the previous stages and combining the different variations predicted for each function in the morphological matrix. After the ideation phase, the concepts were evaluated and prioritized through the Pugh decision matrix. This tool enables comparative analysis between the generated concepts and customer needs, based on a reference product [7].

Preliminary and Detailed Design Phase

Concept Detailing: At the end of the process and with the concepts already prioritized, the best solution was selected and refined into a more detailed concept, including product specifications, key features, and customer benefits.

Results and Discussion

Problem System

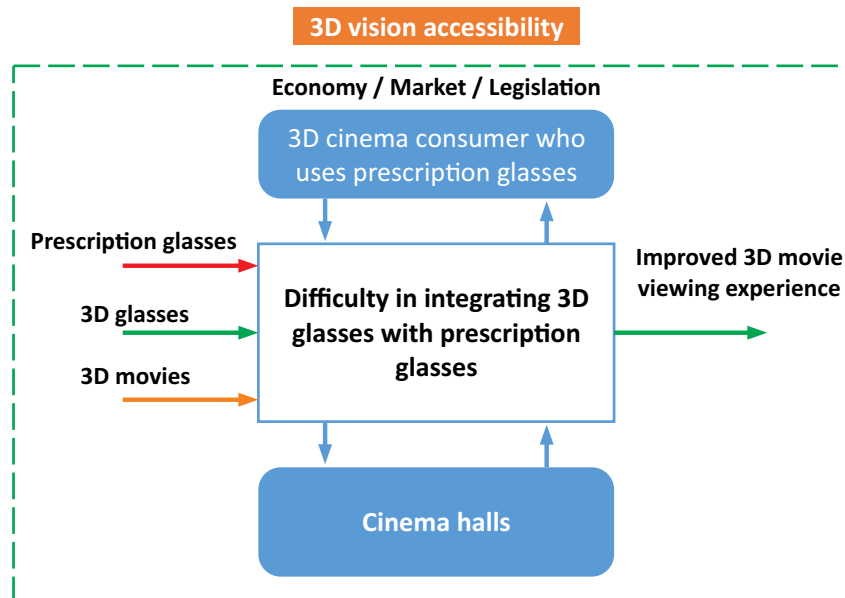
The selection of a problem for investigation resulted in the identification of three key issues. Problem A focuses on improving the separation of household waste to facilitate recycling, while Problem C aims to optimize the process of cleaning, drying, and storing clothes in domestic environments. Problem B, which was chosen for detailed development, addresses the challenges that eyeglass wearers encounter when watching 3D movies. The incompatibility of conventional 3D glasses, which cause discomfort when worn over prescription glasses, highlights the need for a more integrated and comfortable solution. The key interfaces of the problem include prescription and 3D glasses, the user, the projected film, and the cinema halls. Figure 1 illustrates the target problem system of the research.

Life Cycle

Following the team's analysis, information was gathered about the product's lifecycle and its primary customers, as presented in Table 1.

Similar Competitors and Patents

For a detailed analysis, the Google Patents platform was used to examine patent data from 1993 to March 2024, initially identifying 450 documents, which were filtered down to 358 granted patents. These patents showcase significant advancements in 3D glasses, emphasizing customization and comfort with adjustments for interpupillary distance, temple length, and visual focus. Innovations such as heating

Figure 1. Problem system interfaces.**Table 1.** Product lifecycle and identification of main customers.

Type	Phase	Customers
Manufacturer	Demand/Opportunity	Project team
	Development	Project team
	Manufacturing and assembly	Third-party product manufacturer
Intermediary	Transportation and Storage	Logistics company
	Purchase and Sale	e-commerce
External	Installation	Cinema
	Use	End user
	Maintenance	Cinema
	Reuse, Recycling, and Disp'osal	Recycling companies

pads and cold compresses enhance prolonged use by reducing fogging and visual fatigue. Additions such as augmented reality, integrated audio, modular designs, and the use of materials like silicone and fluorescent paint enhance immersion and comfort, particularly in low-light environments.

Identification of Customer Needs

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fluorescent paint enhance immersion and comfort, particularly in low-light environments.

The method used to gather customer needs was through an online survey form. Initially, the survey targeted 35 individuals who had experience with 3D movies in cinemas and used prescription glasses. Based on the survey results, customer needs were analyzed and transformed into specific requirements for product development.

Quality Function Deployment (QFD)

Utilizing the Quality Function Deployment (QFD) methodology, a prioritization ranking of the specified requirements was determined. This ranking incorporated the significance assigned to each requirement by both the client during the research phase and the development team. Additionally, the results of the requirements conflict tool were included in the ranking. The results showed that the requirements associated with comfort and practicality were more pronounced, such as the number of adaptable models, percentage of transparency, number of operations, and mass. Otherwise, the lowest was the commercialization cost, which is associated with the cinema owner's needs. The expectation was that the number of corners and edges associated with the consumer's comfort would be considered a relevant requirement; however, it was not.

The primary emphasis among the requirements lies in the adaptability of 3D glasses to accommodate prescription glasses, a pivotal aspect in fulfilling a fundamental necessity. A diverse range of adjustments enhances compatibility with various models of prescription glasses available in the market. Additionally, the transparency percentage garnered significant attention, guaranteeing the provision of sharp images. Mass emerged as another critical requirement, directly impacting user comfort. Moreover, the number of operations, quantity of parts, and manufacturing/operational expenses play vital roles in assessing the economic feasibility of the product. Decreasing these metrics is advantageous in meeting the

requirements of both cinemas and manufacturers, thereby diminishing operational and logistical expenses.

Another ranking was generated using the QFD tool through benchmarking. During this phase, the primary competing products underwent evaluation against the exact pre-established requirements. This facilitated the identification of the product that most effectively fulfilled the requirements, thereby serving as a benchmark for concept development. The outcomes of the main competitors' ranking are illustrated in Table 2.

Morphological Matrix

Based on the morphological matrix, three concepts were generated, each with possible solutions for the functions proposed in the functional synthesis. This matrix enables the generation of different concepts to fulfill the assigned functions, combining various solution options that have been identified. This systematic and organized approach facilitates the analysis and selection of the best combinations of solutions to meet the requirements of solution development. To achieve better results in concept generation, the TRIZ tool was used to identify innovative solutions based on the conflicts presented in the QFD roof. The application of TRIZ aims to identify the equivalence among the 39 technical parameters.

Table 2. Benchmarking ranking of primary competitors.

Model	Ranking
Clip on polarized 3d glasses	121
Anaglyph Hinged Glasses	111
Benq Link Active 3D Glasses	97

Concept Selection and Detailing

Proposed by Altshuller and the project requirements. For this purpose, the five priority requirements from the ranking generated by the QFD presented in Table 3 were used to analyze the conflicts between them. Based on the TRIZ matrix, inventive principles resulting from the conflicts are identified to search for analogous solutions adapted to the problem. For concept selection, the Pugh decision matrix is applied. This method is used to compare the generated concepts with customer needs. It is used in engineering and design to make informed decisions about which concept or solution is most suitable for meeting project requirements. For the application of the Pugh method, the clip-on polarized 3D glasses were defined as the reference product, corresponding to the benchmarking product that obtained the highest score in the QFD, for evaluating the performance

of each generated concept in relation to meeting the needs, as presented in Figure 2.

The first concept showed the highest potential for meeting the proposed requirements, presenting better performance possibilities than the evaluated commercial competitors. This concept is based on a solution that caters to both glasses-wearers and non-wearers, with a stronger emphasis on users of prescription glasses to provide greater comfort and convenience while maintaining style and simplicity. This concept is presented in Figure 3. The system was designed using flexible, moldable material to adapt easily to the user's face and fit various models of prescription glasses, enhancing usability, operation, and maintenance. Its central and lateral locking pins provide increased stability.

A key feature is its modularity, which allows for the simple addition of extra lenses and straps. This enables the replacement of lenses with different types as needed by the cinema and offers strap

Figure 2. Pugh matrix for concept selection.

Need	Customer grade	Customer weight	Generated Concepts				
			I	II	III	IV	
Adaptable to prescription glasses	6	0.6	✓ 1	✓ 1	✓ 1		Reference
Clear image	9	0.6	✓ 1	✗ -1	! 0		
Be comfortable	9	0.6	! 0	✓ 1	✓ 1		
Do not damage prescription glasses	1	0.6	✓ 1	✗ -1	✓ 1		
Good fixation on the face	6	0.6	✓ 1	✓ 1	! 0		
Easy to operate	3	0.6	✓ 1	✗ -1	✓ 1		
Allow a wide field of view	6	0.6	✓ 1	✓ 1	! 0		
Be light	3	0.6	✗ -1	✓ 1	! 0		
Low operation/maintenance cost	6	0.3	✓ 1	✗ -1	✓ 1		
No contamination between users	9	0.3	! 0	! 0	! 0		
Low acquisition cost	3	0.3	! 0	✓ 1	✓ 1		
Be resistant/robust	9	0.3	! 0	! 0	! 0		
Be compact	6	0.3	✓ 1	✓ 1	! 0		
Low manufacturing cost	9	0.1	! 0	! 0	! 0		
Few pieces	6	0.1	✓ 1	✓ 1	✓ 1		
Total:			21	11,7	14,7		

Figure 3. 3D glasses concept with the highest potential for meeting the proposed requirements.



options for users without prescription glasses, with a structure that is moldable to various face shapes. The project chose polarized lenses due to their popularity and cost-effectiveness in cinemas compared to active glasses, which require higher lighting performance and image quality for overlay. Although aimed at incremental improvements in commercial solutions, the development involved medium complexity in terms of 3D cinema technology and user experience. Ensuring comfort and adaptability is crucial, requiring an understanding of subjective scenarios.

Conclusion

The product development process plays a crucial role in creating innovative and competitive solutions. According to Rozenfeld¹⁰, it is fundamental for companies to succeed in developing innovative, competitive, and high-quality products, allowing them to meet market demands efficiently and effectively. Despite the research outcome presenting a simplified solution aimed at incremental improvement in commercial solutions, the development demonstrated moderate complexity in the domain of 3D cinema technology and a limited understanding of the user experience in this context. Meeting the needs for comfort and adaptability is a commitment to quality criteria, which requires perception and understanding of subjective scenarios.

Acknowledgments

The authors express their gratitude to SENAI CIMATEC and its Postgraduate Program in Industrial Management and Technology.

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