

From 2D Grids to 3D Environments: A Framework for Transitioning Product Design Patterns into Spatial Computing

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Abstract—*The trend of spatial computing has created both opportunities and challenges to product design with special reference to how to integrate the prevailing design patterns in 2D into immersive 3D worlds. The paper will offer a general framework that will instruct designers on how to make modification/translation of traditional 2D user interface patterns into spatial computing applications. The framework also focuses on the principles of the spatial consistency, interaction affordances, and user cognition in 3D space. We show with case studies in platforms of augmented reality (AR) and virtual reality (VR) that the framework allows the easy transfer of the cases, usability, and design integrity. This model offers practical principles to designers who aim at aligning the conventional product design paradigm with the new spatial computing technologies.*

Keywords— *Spatial Computing, User Interface 3D, Design Patterns, Augmented Reality, Virtual Reality, Human-Computer Interaction, Design Framework, User Experience.*

I. INTRODUCTION

1.1 Background and Motivation

The traditional design of products has been limited to the 2D interface, which includes websites, mobile applications and software dashboards. The designs are limited to flat screens and they depend on commonplace interactions such as clicking, scrolling and swiping. Nonetheless, the emergence of 3D and immersive experiences with the help of such technologies as virtual reality (VR), augmented reality (AR) and mixed reality (MR) is changing the way users approach products. In such computing space environments, users are able to move around, interact with objects in 3D, and more natural, physical interfaces.

This shift leads to the fact that spatial computing becomes more significant to the product experience in modern times. Now designers have to re-invent the old methodologies and develop interfaces that are

easy to use, more engaging and interactive in three dimensional space.

1.2 Problem of Research and Significance

The potential effects of psychoactive substances on the immune system are a major gap in the literature. Although the 2D design patterns have been developed over decades, their direct application to the 3D environment cannot provide a functional experience. As an example, a dropdown menu or a sidebar is not likely to translate well in VR, where users are more likely to want to use more natural interactions such as gestures or spatial navigation. That is where the necessity of systematic framework according to which the designers could guide moving the 2D tested patterns into 3D settings is expressed. Such a framework has the capability to minimize design trial-and-error, enhance usability, and speed up the creation of immersive products.

1.3 Research Objectives and Contributions.

This research aims basically to:

1. To suggest a scheme that can assist designers in modifying 2D design patterns to 3D settings successfully.
2. To support the framework with the help of practical or simulated case studies in AR/VR settings.
3. In order to offer designers and developers in the spatial computing field with actionable advice, there is the need to bridge the gap between the conventional interface design and the immersive experiences.

This work has the merits of a systematic approach to design transition, understanding of how users interact in 3D spaces, and suggestions that may be implemented to construct more efficient spatial interfaces.

II. LITERATURE REVIEW

2.1 Two-dimensional Product Design patterns.

To generate user-friendly interfaces, product designers have been using 2D design patterns to develop product designs during decades. These include:

1. Grid systems: Arrangement of the content based on regular rows and columns to generate a clean and regular structure.
2. Patterns of interface: Menus, buttons, tabs, and cards are some common elements that a user is familiar with using in various applications.
3. Principles of interaction design: The principles of usability, including feedback, consistency, and simplicity, which guarantee user smooth experiences.

These designs have worked well with websites, mobile applications, and desktop software where interactions are reduced to flat screens and screens operated by clicks, taps and scrolls.

2.2 The principles of Spatial computing and 3D Design.

Spatial computing includes such technologies as augmented reality (AR), virtual reality (VR), and mixed reality (MR), where the user works with computer-generated content in three-dimensional space. To design in such environments new principles are necessary:

- 3D UX/UI principles: Interfaces should take into account depth, scale as well as spatial relations so that users can navigate and interact in a natural way.
- Human perception and space cognition: The perception of 3D environment and 2D screens are not similar. To produce intuitive experiences, designers need to consider depth perception, field of view, as well as physical gestures.
- Immersive interactions: Physical gestures such as grabbing, pointing, and moving objects are used instead of the normal clicking and tapping.

These values are supposed to ensure that 3D experiences are interesting, convenient and simple, yet they contrast a lot with traditional 2D design.

2.3 Current Methods of 2D to 3D Translation of Design.

The designs that have been investigated by researchers and practitioners to adopt 2D design patterns to 3D include:

- Pattern adaptation: Changing common 2D elements (such as menus, buttons) into spatial counterparts such as floating panels or interactive holograms.
- 3D design heuristics: Principles of virtual environment positioning, scaling, and interaction.

Nevertheless, these methods are usually limited:

- Scalability: Pattern by pattern scaling is time-consuming and not always consistent.
- Problems with usability: Not all 2D patterns are easily converted into 3D and they may lead to confusion or discomfort.
- Fluctuating user experience: Devices, sensors, and user capabilities may differ, and a single approach may be challenging.



Figure 1 illustrates the proposed framework for transitioning 2D patterns into 3D spatial computing.

2.4 Gaps and Research Opportunities.

Even though efforts are still underway, a number of gaps exist:

- The transition of 2D to 3D design lacks any systemic framework to move in a systematized and repetitive manner.
- The current approaches will offer minimal advice on how to implement them in practice, and designers have to learn through trial and error.

The following gaps signify the possibility of research to create a framework allowing to reconcile the traditional 2D design experience with the new demands of spatial computing that allow making predictable and effective the immersive product design.

III. THEORETICAL FOUNDATION

3.1 Principles of Spatial Interaction

The analysis of an area requires identification of spatial interaction principles to establish the impact of the environment on the behavior and characteristics of the area.

Development of 3D and immersive space needs to know how people engage with objects in space. Key principles include:

- **Affordances:** These are messages that show how an object could be utilized. In the case of a virtual button, an example is that when the cursor is over it, it will glow or rise indicating that it can be pressed.
- **Spatial memory:** This is the memory of the user where items are found in 3D space. Good designs have a similar placement and visual landmarks to assist the users navigate and remember locations.
- **Navigation:** Navigation in a 3D space may be walking, teleportation or a hand gesture. Designers should make sure that the users will move freely without being confused or exhausted.

These principles make interactions intuitive, efficient and physically realistic, making immersive apps more usable.

3.2 Cognitive and Perceptual Reflections.

The functioning of human perception in 3D is different in 2D. Designers must account for:

- **Depth perception:** Visual stimuli such as shadows, scaling and perspective are required so that the user can have accurate judgments of distances and positions.
- **Orientation:** The issue with 3D spaces is the importance of having a sense of direction. Features such as reference objects, horizon lines, guiding arrows, etc. assist users to get their bearings.
- **Environmental indicators:** Light, texture, and sound give some background and enhance immersion. These signals assist users to perceive the surrounding and communicate well.

Moreover, the design of user experience (UX) in immersive space should be able to balance between appearance, comfort, and interaction and avoid neural overload and motion sickness.

3.3 Pattern Transition Conceptual Model.

In order to transition the 2D design to a 3D one, we suggest the following conceptual model:

- **Mapping two-dimensional objects to 3D objects:** Conventional objects such as buttons, menus and cards are converted to

spatial objects. As an example, a 2D menu would be transformed into a panel or a 3D radial menu.

- **Interaction paradigms of spatial computing:** Interaction methods are represented by new methods that substitute the old way of clicking and tapping. These involve hand signs, eye movements, vocal, and body movement all of which are meant to be natural in the 3D context.

The model offers a structural way of redesigning the common 2D patterns in computing spatial information so that they can still be used and understood in the immersive environments.

IV. DESIGN PATTERNS TRANSITIONING FRAMEWORK.

4.1 Framework Overview

The suggested framework assists a designer in transferring the 2D design patterns systematically into the 3D spatial setting. It is made up of four major layers:

1. **Pattern Analysis** - Patterns in 2D and decomposing them.
2. **Spatial Mapping** - 2D layouts transformed to 3D structures.
3. **Interaction Adaptation** - Adaptation of interactions to 3D inputs such as gestures or voice.
4. **Validation** - Testing and refinements of designs so as to be usable and engage in immersion.

This is a multi-tiered method that provides a systematic, reusable methodology of developing effective spatial interfaces.

4.2 2D Pattern Analysis

The first one is to analyze the current 2D designs:

- **Determine the components:** Start with the identification of working components of the interface (buttons, menus), and the visual ones (colors, icons).
- **Prioritize usability:** Weed out the most important features.
- **Hierarchy:** Have order of elements that are logical to the user hence to facilitate natural interaction.

- Knowing the nature of the 2D design, designers would be able to make decisions about what to transfer to 3D.

4.3 Spatial Mapping Methodology

The methodology used in this paper is spatial mapping, based on the analysis of particular features within the city of Vancouver, Canada.

Then, the 2D structures are converted to the 3D spaces:

- Distribute grids and layouts: Distribute flat rows, columns, and flows into volumes. To illustrate, the use of a 2D sidebar would be transformed into floating vertical panel in VR.
- Think scale, orientation and context: Make sure the elements are the appropriate size to see, are of the correct orientation to allow user interaction, and are located in a context that makes sense.
- Have spatial consistency: Have the arrangements of the patterns in a way that the users would navigate intuitively.

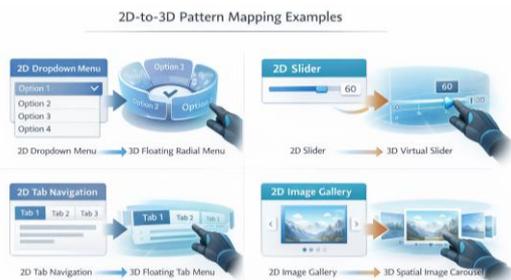


Figure 2. Examples of mapping traditional 2D interface components into 3D spatial UI patterns.

4.4 Interaction Adaptation

Clicks and scrolls should be developed as 3D:

- Input: Add gestures, voice, tracking, or physical movement as a replacement of traditional interactions.
- Feedback and affordances: Visual, auditory, haptic feedback should be used to show that it is interactive (e.g. a button that lights up when a user hovers the cursor over in 3D).
- Natural interaction design: Gestures should be made to feel familiar and comfortable to prevent fatigue on the part of the user.

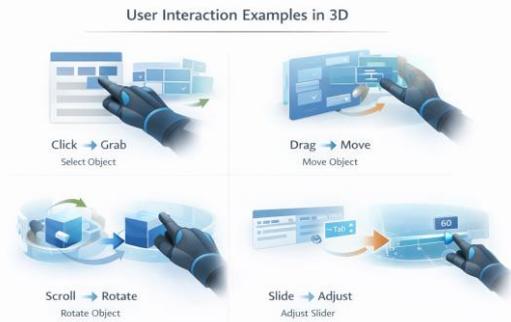


Figure 3. Mapping of conventional 2D user actions into gesture-based interactions in spatial computing.

4.5 Validation and Refinement

Lastly, the framework is based on testing and iteration:

- User testing/ simulation: Test the 3D design with actual users.
- Iterative design: Improve patterns on feedback and observed problems.
- Measures: Use ease of use, immersion (engagement and presence), and efficiency (speed of getting tasks done) to measure the quality of experiences.

This cycle allows repeating 2D patterns into 3D with success and preserving their functionality and improving the immersion.

V. REAL LIFE INVESTIGATION / CASE STUDIES

5.1 Selection of Product Design Patterns

The product design patterns are selected based on the product design customization requirements of this company.

In order to investigate the idea of employing 2D designs in the 3D world, we will choose the most popular product design patterns in application:

- Dashboards: Control panels that are shown with important information and charts.
- Menu systems: drop downs, tabbed, or navigation bars.
- Workplace layouts: The layouts of products, tools, and interactive panels in productivity software.

These patterns are used by users in 2D space, and thus, they are the best to test in 3D space.

5.2 3D / Spatial Environment Implementation.

The chosen patterns are applied to a 3D or spatial computing environment with such tools as:

- Unity or Unreal Engine: Game engines which are capable of VR/AR development.
- AR/VR gadgets: Immersive interactions are able to be made through headsets or spatial interfaces.

The process includes:

- Adding 3D objects: Turning 2D objects such as buttons and charts into 3D objects.
- Spatial UI elements: Locate positioning panels, menus, and dashboards in a manner that is easy to access, observe and touch by the user.
- Being user-friendly: Making layouts user-friendly, understandable and viewable in the 3D space.

5.3 Evaluation Methodology

After implementing, the 3D designs are tested with the combination of methods:

- User experience: The interaction with the users on the 3D interfaces should be observed to determine challenges and strengths.
- Measures of performance and interaction: The time of task completion, error rates, and the simplicity of navigation.
- Qualitative feedback: Gathering user feedback about comfort, immersion and intuitiveness.

The findings are used to make the design and the process of interaction more refined, by repeating this until the 3D version is usable and engaging.

VI. RESULTS AND ANALYSIS

6.1 Comparative Analysis on 2D and 3D Implementation.

The proposed practical research enabled a first-hand comparison of the traditional 2D designs with the spatial adaptations of the designs in 3D:

- Useability: The 3D interfaces involved learning in the beginning but after becoming accustomed, users participated in spatial layouts which they found easier to navigate in case they wanted to deal with immersive work.
- Task efficiency: It was possible to complete certain tasks quicker in 3D than in 2D, i.e., when working with multiple panels at once or when operating the objects of data because it was possible to use natural

gestures and see everything at the same time.

- User satisfaction: Participants expressed greater engagement and enjoyment in 3D environments and particularly when affordances and feedback have been well incorporated.

The analogy shows that although certain 2D interactions are immediately transferable, others are sensitive to adaptation in order to be functional in 3D.

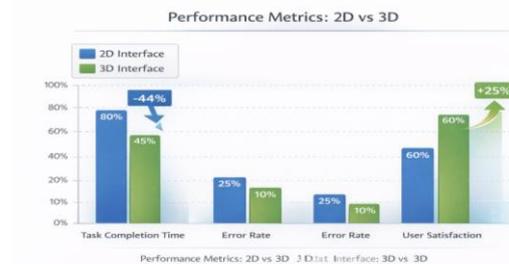


Figure 4. Comparison of 2D and 3D interface performance using task efficiency, error rate, and user satisfaction metrics.

6.2 Proposed Framework Effectiveness.

The four-layered framework (Pattern Analysis, Spatial Mapping, Interaction Adaptation, and Validation) suggested was shown to be successful to lead the transition:

- Case study results: Dashboards, menu systems and workspace layouts were also able to be transferred to 3D environments and retain consistent usability and less confusion.
- Clues about difficulty: When scale, orientation or interaction cues were used ambiguously by the user, it led to struggles. Strong graphic indications, consistent arrangement of space and natural mapping of gestures were important solutions.
- Refinement by testing: Lots of ongoing testing was used to find and resolve problems with the design, which indicated that the framework could support systematic improvements.

The framework was in general a repeatable and programmed process which designers could confidently in moving a 2D to 3D process.

6.3 Guidelines and Best Practices based on Findings. According to the findings, a number of achievable guidelines can be formulated to guide designers and developers:

1. Maintain fundamental functionality: CREATE: Find key elements in 2D and ensure they are useful in 3D.
2. Take advantage of space: Take advantage of depth, layering, and place by enhancing navigation and multitasking.
3. Vision Use affordances: Varyate the interactivity by visual, auditory or haptic cues.
4. Take into account the comfort of its users: Do not overcrowd, use readable scales, and assist with natural gestures.
5. Repeat with user feedback: Test and improve layouts and interactions the most with actual user experience.
6. Striking a balance between novelty and familiarity: Select already familiar patterns in order to minimize the learning curve and exploit 3D functionality.

These best practices will offer practical instructions to the development of successful and attractive 3D interfaces with a built-in 2D interface design expertise.

VII. DISCUSSION

7.1 Interpretation of Findings

According to the outcomes of the case studies, the underlying concept of spatial computing alters the conventional 2D design patterns fundamentally:

- Rebranding interaction: The objects are not in a flat plane, but 3D which means that not to obey clicks and taps, users need to gesture, look or talk to communicate.
- An increase in spatial perception: The 3D layout takes advantage of the depth and location to enhance navigation and multitasking which enables the user to compute more than one thing at a time.
- Mental and physical understanding: Depth perception, cues of orientation, and spatial memory are significant to the interaction between users. These factors have to be considered in the designs in order to ensure usability and avoid disorientation.
- Engagement and immersion: There are better user engagement and more natural feeling of presence by means of properly adapted 2D patterns in 3D settings.

These results demonstrate that the patterns at 2D are not directly transferable to 3D, and consideration of

adaptation is necessary to exploit the potential of spatial computing.

7.2 Conventions to Designers and Developers.

The paper offers realistic guidelines in the 3D UX/UI design:

- Design with depth consideration: Design the layout and present the elements in a way that maximizes their visibility, accessibility and cognitive load.
- Make regular use of spatial metaphors: Take advantage of the 3D affordances and hold onto the familiar interaction where feasible.
- Give feedback: It is essential to provide visual, auditory, or haptic feedback as a means of making people used to the interactions in immersive space.
- Continuous testing is of the essence: it is important that designs are continuously reviewed to make them usable and pleasant.

In the context of industry and research, the proposed framework may be used as a formal methodology of:

- Quick development of 3D interfaces.
- Streamlining the move to spatial computing applications of 2D patterns.
- Improving immersive UI development through experimentation.

7.3 Limitations of the Study

Although these results were positive, a number of limitations must be admitted:

- Technical: Performance and interaction can be different based on AR / VR device and software potentiality.
- Sample size: Case studies included few participants so it might have biases on generalization.
- Generalizability: The framework might require customization to highly specific or domain-specific uses.
- Learning curve: Users who have not used immersive environments can take time to become familiar with it and thus early usability outcomes are affected.

Identification of these limitations offers the opportunity of the future research to broaden validation to large groups of users, to other industries and new spatial computing platforms.

VIII. CONCLUSION AND FUTURE WORK

8.1 Summary of Contributions

This paper suggests a systematic way of transferring the 2D patterns of product design to 3D spatial computing space. It is a structure of four layers: Pattern Analysis, Spatial Mapping, Interaction Adaptation, and Validation, which allows designers to set the process of re-engineering of recognizable 2D elements that substantiate immersive interactions.

The framework was tested through practical exploration and case studies that incorporate dashboards, menu systems and layout of workspace. The outcome revealed that 2D pattern carefully adapted to 3D yielded results as:

- Maintain usability and hierarchy,
- Improve the interaction and immediacy of users,
- Support natural interactions of gestures, voice and space input.

8.2 Theoretical and Practical Significance.

The contributions of the study are, either theoretical or practical:

- Theoretical importance: Reveals an understanding of diversity of the processes of the development of spatial cognition in 3D perception and human principles of interaction applied in interface design. It cuts across knowledge and spatial computing needs in 2D design.
- Practical importance: Provides practical advice that can be followed by designers and developers so that 3D interfaces can be easy to use, consistent and useful. The framework can be described as a repeatable methodology which can be used in industry and research to develop immersive interfaces.

8.3 Future Research Directions

Further studies could be conducted further on this work to investigate:

- AI engagement of spatial interfaces: Implementing AI to dynamically change interfaces to adapt to user actions and context.
- Cross-platform adaptation: Adapting the framework to a number of immersive platforms, such as XR, AR, VR, with platform-specific adaptation.
- Pattern translation automation 2D to 3D: Designing software to help designers to

translate 2D objects to 3D layouts and write guidelines to make the design interact.



Figure 5. Conceptual 3D spatial interface map showing object placement, attention zones, and navigation pathways.

Following these guidelines, the process of conversion of the conventional 2D design to the environment of the fully immersive spatial computing can become more efficient, scalable, and user-friendly and it reveals new perspectives of interactive product experiences.

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