A Transformation Model from Static Visuals to Dynamic Representation Based on Interaction Design

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Abstract. With the growing demand for interactive and dynamic user experiences, transforming static visuals into dynamic representations has become an important challenge in interaction design. However, existing practices largely rely on designer intuition and lack systematic and formalized methods.This paper proposes a transformation model that maps static visual elements to dynamic motion parameters based on interaction design principles. The framework integrates visual feature extraction, rule-based mapping, and motion parameter generation, establishing explicit relationships between visual attributes (e.g., layout, hierarchy, and color) and motion properties (e.g., duration, velocity, delay, and easing). This enables a consistent and reproducible process for generating dynamic visual effects.Experimental results based on the Rico Dataset and controlled user studies show that the proposed model improves task efficiency, accuracy, and usability compared with static and baseline animation conditions. The results suggest that the model provides an effective and extensible framework for dynamic visual design.

Keywords: Static-to-dynamic transformation; Interaction design; Dynamic visualization; Rule-based model; Motion design; User experience.

1 Introduction

With the rapid development of digital media and interactive systems, dynamic visual representation has become increasingly important for enhancing user experience and information communication [1]. Compared with static visuals, dynamic representations can better convey temporal changes, guide user attention, and improve interaction efficiency [2].

However, in current design practice, the transformation from static to dynamic visuals largely relies on designers' intuition, lacking systematic methods and formalized models [3]. This results in inconsistent outcomes and limits scalability and reproducibility.

To address this issue, this paper proposes a transformation model that maps static visual elements to dynamic motion parameters based on interaction design principles. The model establishes a structured and generalizable framework for dynamic visual design [4].

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2 Literature Review

2.1 Dynamic Visual Design in Interaction Contexts

Dynamic visual design has been widely studied in human-computer interaction and user interface design [5]. Prior research shows that motion and animation can guide user attention, reinforce visual hierarchy, and improve usability. For example, transition animations and micro-interactions provide feedback, indicate causality, and support users' mental models in interactive systems [6].

In information visualization, dynamic representations are used to convey temporal data, processes, and relationships. Animated transitions have been shown to reduce cognitive load and facilitate users' understanding of changes between visual states [7]. These findings highlight the role of motion as both a communicative and cognitive aid.

However, most existing studies focus on the effects and applications of dynamic visuals rather than their generation process. Motion design is often treated as a supplementary layer added after static layouts, lacking systematic methods to derive dynamic behavior directly from static visual structures.

2.2 Transformation Methods from Static to Dynamic Visuals

Previous work has explored generating dynamic visuals from static content, particularly in animation design and data-driven visualization. Rule-based and parameterized approaches map visual attributes (e.g., position, size, and color) to temporal variables such as duration, speed, and sequencing, enabling partial automation of motion generation.

In addition, computational models such as keyframe-based systems and algorithmic animation frameworks provide formalized and reproducible solutions for motion design. These approaches support consistency across different contexts but often focus on implementation or isolated mapping strategies.

Despite these advances, there is still a lack of a unified transformation model that explicitly links static visual semantics with dynamic motion parameters within an interaction design framework. Existing methods rarely integrate perceptual, structural, and interaction-related factors into a coherent process.

To address this gap, this study proposes a structured transformation model that connects static visual elements with dynamic representations through a systematic mapping mechanism, providing a more generalizable and method-oriented approach to dynamic visual design.

3 Methodology

3.1 System Overview

As illustrated in Fig. 1, this study proposes a structured pipeline for transforming static visuals into dynamic visual representations. The framework consists of five main stages: static visual input, feature extraction, rule-based transformation, motion parameter generation, and dynamic visual generation, followed by evaluation and feedback.

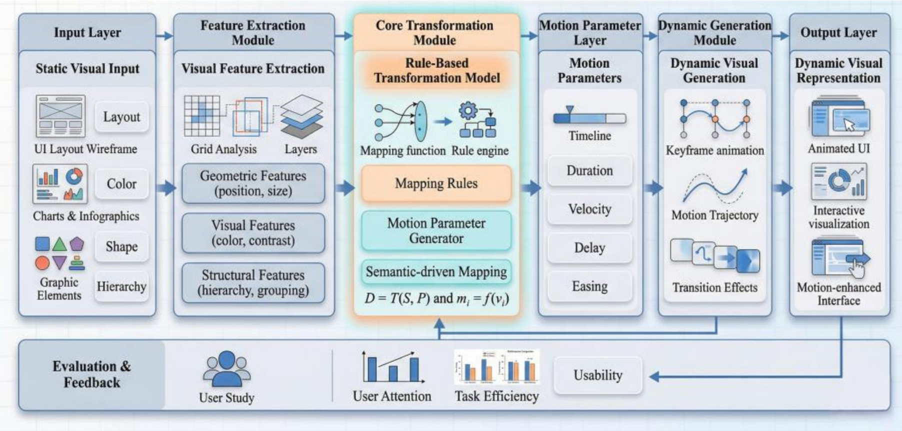

Fig. 1. Static-to-Dynamic Visual Transformation Model in Interaction Design.

3.2 Visual Feature Extraction

The first stage focuses on decomposing static visuals into structured features. Given an input layout , a grid-based analysis is applied to segment visual elements and identify their spatial distribution.

Each visual element v_i is encoded as a feature vector:

$$v_i = (p_i, s_i, c_i, h_i) \tag{1}$$

where p_i represents position, s_i denotes size, c_i refers to color and contrast attributes, and h_i indicates hierarchy level. Hierarchy is derived based on layout structure, visual prominence, and grouping relationships.

This step transforms raw visual input into machine-processable data, enabling subsequent rule-based mapping.

3.3 Rule-Based Transformation Model

The core of the proposed method is a rule-based transformation model that maps static visual features to motion parameters. A mapping function is defined as:

$$m_i = f(v_i) \tag{2}$$

where m_i represents the motion parameters assigned to element v_i. The mapping rules are derived from a combination of interaction design principles, prior studies in human-computer interaction, and analysis of established design systems. Previous research has shown that motion can effectively guide user attention, reinforce visual hierarchy, and reduce cognitive load. In addition, widely adopted design systems such as Material Design and Fluent Design provide practical guidelines for using duration, delay, and easing to convey importance and causality. Based on these theoretical and practical foundations, the rules are further refined through empirical observation of common user interface animation patterns, resulting in a set of interpretable and consistent mappings.

- **Hierarchy-driven mapping**: Elements with higher importance are assigned longer duration and smoother easing to emphasize saliency.
- **Size-based mapping**: Larger elements are associated with slower motion to maintain visual stability.
- **Color/contrast mapping**: High-contrast elements are assigned shorter delay to attract early attention.

The rule engine is implemented as a set of conditional mappings, ensuring consistency and interpretability. Additionally, a semantic-driven mapping layer is introduced to incorporate contextual meaning into motion generation.

3.4 Motion Parameterization and Dynamic Generation

Based on the mapped parameters, dynamic visual representations are generated using standard animation techniques. The motion parameter set includes duration, velocity, delay, and easing, which are organized along a timeline.

The temporal evolution of each element is defined as:

$$x_i(t) = x_i^0 + \Delta x_i \cdot g(t; m_i) \tag{3}$$

where $\mathrm{x_i(t)}$ denotes the state of element iii at time t, and $\mathrm{g(t; m_i)}$ is an easing function controlled by motion parameters.

In implementation, keyframe animation and transition effects are applied to generate motion trajectories. The system can be realized using front-end technologies or visualization frameworks, enabling practical deployment.

Finally, an evaluation module is incorporated to assess user attention, task efficiency, and usability, and the results are fed back to refine the transformation rules. This ensures that the proposed method is both effective and adaptable.

4 Experiments and Comparative Analysis

4.1 Experimental Setup

To evaluate the effectiveness of the proposed transformation model, a controlled user study was conducted using visual tasks derived from the Rico Dataset, a large-scale mobile UI dataset widely used in human-computer interaction research, along with standard information visualization scenarios.

A total of 30 participants (aged approximately 20–35) with prior experience in digital interfaces were recruited. The participant group included both users with design-related backgrounds and general users, ensuring a reasonable diversity of familiarity with interface interactions.

Three experimental conditions were designed: (1) static visual presentations, (2) simple animation without rule-based mapping, and (3) dynamic visual representations generated by the proposed model. A within-subject design was adopted, and the order of conditions was counterbalanced to reduce learning effects.

The experimental tasks were designed to reflect common interaction scenarios with varying levels of complexity, including element search (locating specific UI components), structure comprehension (understanding layout hierarchy), and comparison tasks (identifying differences between interface states). These tasks represent typical user activities in interface interaction and visual interpretation.

The evaluation metrics included task completion time, accuracy rate, and subjective usability measured by the System Usability Scale (SUS). The experimental procedure followed standard HCI evaluation protocols to ensure the reliability and consistency of the results.

4.2 Main Experimental Results

The experimental results show that the proposed transformation model significantly improves user performance compared to both static visuals and simple animation methods, as summarized in Table 1.

Table 1. Comparison of Different Conditions.

Method	Task Completion Time (s) ↓	Accuracy (%) ↑	SUS Score ↑
Static Baseline	12.6 ± 2.3	84.2	71.5
Simple Animation	11.2 ± 2.1	87.5	75.8
Proposed Method	**9.8 ± 1.9**	**91.6**	**82.7**

As shown, task completion time is reduced by approximately 22% (from 12.6 s to 9.8 s), while accuracy increases from 84.2% to 91.6%. Compared with the simple animation condition, the proposed method still achieves consistent improvements, indicating that structured rule-based mapping is more effective than basic animation.

In addition, the System Usability Scale (SUS) score reaches 82.7, indicating good usability and suggesting that users perceive the dynamically generated interfaces as more intuitive and easier to use.

Overall, the results demonstrate that the proposed model enhances both objective performance and subjective user experience, and that the improvement is primarily due to the mapping mechanism rather than the presence of animation alone.

4.3 Discussion

The experimental results demonstrate that the proposed transformation model effectively improves both user performance and perceived usability. The reduction in task completion time indicates that dynamic visual cues facilitate more efficient information processing by guiding attention and reducing visual search effort. The increase in accuracy further suggests that motion-based representations enhance clarity and support more reliable interpretation of visual structures. Moreover, the comparison with simple animation confirms that these improvements stem from the structured rule-based mapping rather than the mere presence of motion.

From a design perspective, the rule-based mapping mechanism ensures consistency and predictability in dynamic behavior. By explicitly linking static visual features with motion parameters, the model reduces arbitrariness in animation design and provides a structured and reusable approach.

However, several limitations should be noted. The current study focuses on controlled tasks and mobile user interfaces from the Rico Dataset. Although the model is grounded in general interaction design principles, its application to other domains may require adaptation. For example, data dashboards involve data semantics, while AR/VR interfaces introduce spatial depth and three-dimensional motion, necessitating extended feature representations and motion parameters.

In addition, the predefined rule set may not fully capture diverse user needs or contextual variations. Future work will explore adaptive and data-driven approaches, incorporating user feedback and contextual factors to enhance flexibility and scalability.

5 Conclusion

This paper proposes a transformation model that converts static visuals into dynamic representations based on interaction design principles. The framework integrates visual feature extraction, rule-based mapping, and motion parameterization, establishing explicit relationships between visual attributes and motion parameters for consistent and reproducible dynamic generation.

Experimental results on the Rico Dataset and controlled user studies show that the proposed method improves task efficiency, accuracy, and usability compared to static and baseline animation conditions.

However, the current approach is limited by predefined rules and constrained experimental scenarios. Future work will explore adaptive and data-driven methods to enhance flexibility and generalization. Overall, this study provides a systematic and extensible approach to dynamic visual design.

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