# An Introduction to Algebraic Semiotics, with Application to User Interface Design

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**Abstract:** This paper introduces a new approach to user interface design and other areas, called *algebraic semiotics*. The approach is based on a notion of *sign*, which allows complex hierarchical structure and incorporates the insight (emphasized by Saussure) that signs come in *systems*, and should be studied at that level, rather than individually. A user interface can be considered as a *representation* of the underlying functionality to which it provides access, and thus user interface design can be considered a craft of constructing such representations, where both the interface and the underlying functionality are considered as (structured) sign systems. In this setting, representations appear as mappings, or *morphisms*, between sign systems, which should preserve as much structure as possible. This motivates developing a calculus having systematic ways to combine signs, sign systems, and representations. One important mode of composition is *blending*, introduced by Fauconnier and Turner; we relate this to certain concepts from the very abstract area of mathematics called category theory. Applications for algebraic semiotics include not only user interface design, but also cognitive linguistics, especially metaphor theory and cognitive poetics. The main contribution of this paper is the precision it can bring to such areas. Building on an insight from computer science, that discrete structures can be described by algebraic theories, **sign systems** are defined to be algebraic theories with extra structure, and **semiotic morphisms** are defined to be mappings of algebraic theories that (to some extent) preserve the extra structure. As an aid for practical design, we show that the quality of representations is closely related to the preservation properties of semiotic morphisms; these measures of quality also provide the orderings needed by our category theoretic formulation of blending.

## 1 Introduction

Analogy, metaphor, representation and user interface have much in common: each involves signs, meaning, one or more people, and some context, including culture; moreover each can be looked at dually from either a design or a use perspective. Recent research in several disciplines is converging on a general area that includes the four topics in the first sentence above; these disciplines include (aspects of) sociology, cognitive linguistics, computer science, literary criticism, user interface design, psychology, semiotics, and philosophy. Of these, semiotics takes perhaps the most general view, although much of the research in this area has been rather vague. A goal of the research reported here is to develop

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a mathematically precise theory of semiotics, called **algebraic semiotics**, that avoids the error of **reification**, that is, of identifying its abstractions with real world phenomena, making only the more modest claim of developing potentially useful models. This paper focuses on applications to user interface design, but the mathematical formalism also applies to the other areas mentioned above, especially metaphor theory and cognitive poetics, within cognitive linguistics.

The job of user interface designers is to build good metaphors (representations, translations, etc.). In this area, the domains to be represented are often very clear, though prosaic, the designers are often engineers, the intended users are often mass market consumers, and quality can often be tested, e.g., by laboratory experiments and statistics. Therefore user interface design provides a good laboratory for studying the general area that we have identified. It is interesting to contrast user interface design with (say) poetry, where the objects of interest are unique brilliant creations, and analysis is difficult (but rewarding). Nevertheless, they have much in common, including the applicability of semiotic morphisms and blends.

User interface designers have long wanted the same capability as electrical and mechanical engineers to make models and reason about them, instead of having to build prototypes and test them, because proper experiments can be both time consuming and expensive. Clearly this requires an effective understanding of what user interfaces are and what makes some better than others. A major difference from the more established engineering disciplines is that social factors must be taken into account in setting up the models. Therefore purely mechanistic procedures are unlikely to be achieved in the near future. My claims are that user interfaces are representations, that their quality is determined by what they preserve, and that this can be an effective basis for design.

User interface issues are exceedingly common, despite a persistent tendency to ignore them, to downplay their importance, or to minimize their difficulty. A coffee cup is an interface between the coffee and the coffee drinker; questions like thickness, volume, and handle shape are interface design issues. A book can be considered a user interface to its content. Buildings can be seen as providing interfaces to users who want to navigate within them, e.g., a directory in the lobby, buttons outside and inside the elevators, "EXIT" signs, doorknobs, stairways, and even corridors (you make choices with your body, not your mouse). A technical research paper can be seen as a user interface, that to succeed must take account of its intended user community. Returning to the obvious, medical instruments have user interfaces (for doctors, nurses, and even patients) that can have extreme consequences if badly designed. By perhaps stretching a bit, almost anything can be seen as a user interface; doing so will highlight certain issues of design and representation that might otherwise remain obscure, though of course it will not include all possible relevant issues.

User interface issues are also important in mathematics, and have been given particular attention in relation to choice of notation and to education. As Leibniz put it,