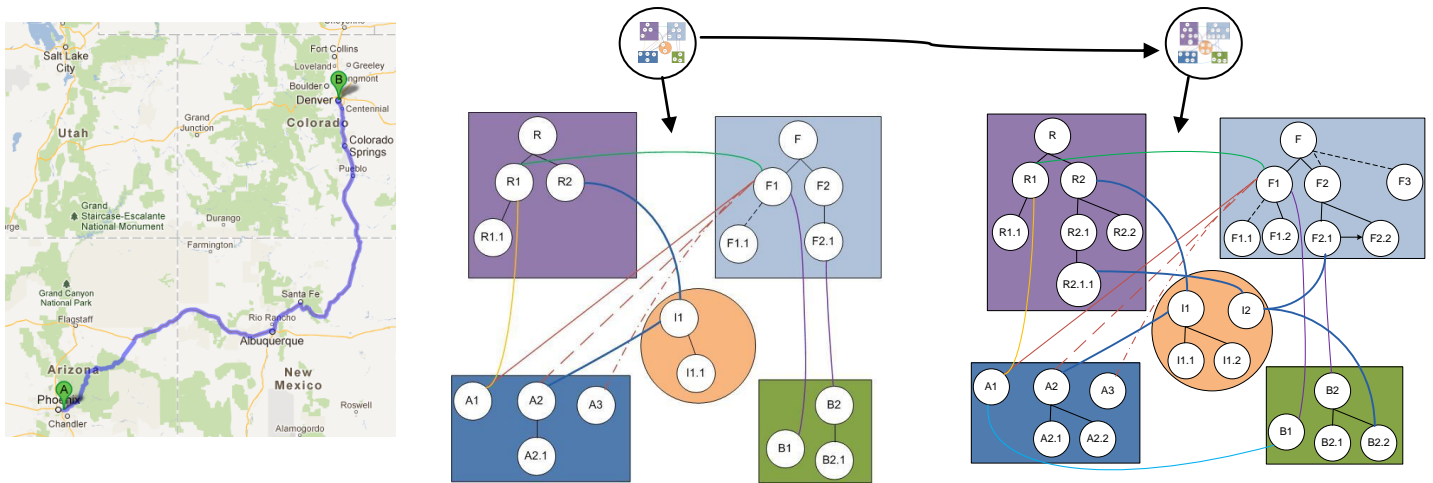


Problem Maps are intended to show paths of design thinking in the same way that geographic maps show paths of travelling. But unlike geographic maps, each location is represented with more than just a point; instead, a state model which consists of instances of five groups and their relations encompasses what a designer is thinking about at a particular moment. To be precise, it is impractical to draw a picture of one's thoughts at one moment. Rather, the changes in a state, i.e. what was added or removed since the last moment, show one's progress. A sequence of these states at the early stages of designing can reveal changes in the way designers formulate problems.

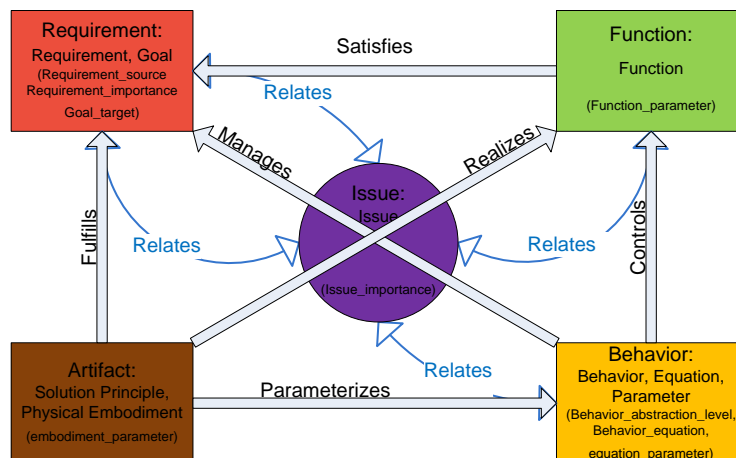


Left: a geographic map; Right: a Problem map

Entities

Considering the early stages of a typical product development process, a new design starts with explicitly specified requirements, which includes what the artifact is supposed to do (its main or highest level function); the performance levels desired (technical specifications) and overarching design goals. To that, the designer applies his domain knowledge which includes procedural knowledge (functional decomposition, search strategy, etc.) and artifact knowledge (candidate solutions, physical laws governing behavior). The designer may gain key insights, particularly in the discovery of problematic issues.

Problem Maps have five groups of entities. They are *Requirement*, *Function*, *Artifact*, *Behavior*, and *Issue*. As you saw in the right-hand side of the figure above, these groups have a hierarchical structure. In addition to the hierarchies and the directional (sequential) or non-directional relations among them, there are supporting entities such as equation under the group *Behavior*. All groups except the *Issue* group are inter-related with bidirectional relations, while the *Issue* group can have a relation to any combination of the rest of the entities.



Requirements

You usually start with a problem statement. The design problem, however, is defined with additional requirements elicited by the designer. Therefore, the problem is specified by a set of design goals and requirements. A desired design is one that realizes all the requirements and achieves better design goals.

A requirement may have a source such as “given”, “safety”, “aesthetics”, “ergonomics”, “use_environment”, etc. We assume that requirements are binary; they are either met or not met. Goals on the contrary are defined with their importance level and the targets with ranges of values that should be achieved. The improvement direction may take one of the three values: "more": the goal is desired to be more than the given target; "less": the goal is desired to be less than the given target; "about": the goal is desired to be as close to the given target as possible. Requirements and goals can be combined in the same hierarchy. The hierarchy may be thought of as an objective tree.

Functions

Functions specify the activities that the design will execute at some point and are usually defined as verb noun combinations (e.g. rupture disk, carry passenger, amplify torque). The hierarchy represents functional decompositions. Our model incorporates disjunctive composition, making it possible to have multiple functional decompositions using common sub-functions.

Artifacts

Artifacts are the physical embodiments of the design or the solution principles that the design may be using. Our model allows partial compositions of solution principles and physical embodiments, since in reality, the designer follows different parts of the sub-solutions at different times corresponding to different levels of abstraction. The hierarchy resembles a product architecture.

Behaviors

Behaviors are the physical properties and laws that govern the design. These entities include equations and physical effects, as well as the parameters that are relevant to both artifacts and functions. Physical effects may be expressed by parametric relations, which are composed of sets of parameters.

Issues

An issue is a point that the designer believes to be pivotal or problematic in achieving a design objective. An issue can arise in realizing a function with a specific artifact or behavior, in realizing conflicting design goals such as lower weight and strength of a structure or in accommodating different components in a product architecture due to incompatible interfaces to name a few. The designer gains insight in the discovery of key issues in the design and the areas of the design that should be prioritized.

Relations

You saw how different fragments can participate in a hierarchy in each of the five groups. There are other relations within and between groups. Within functions, the *before* relation shows function sequence, thus it is directional. Within artifacts, *connection* represents mating conditions among components.

Besides hierarchies and partial orderings, we have also relations between groups. This leads to a more expressive and flexible model that can show how different designers see the relations among different aspects of a problem and the alternative ways they relate.

Entity	Relation	Entity
Function	satisfies	Requirement
Artifact	fulfills	Requirement
Behavior	manages	Requirement
Artifact	realizes	Function
Artifact	parameterizes	Behavior
Behavior	controls	Function
Issue	relates	All entities and their combinations