A Model for Information Technologies that Can Be Creative

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ABSTRACT
To contribute to HCI investigation and interface design that develops interactive systems for creative solutions, I attempt to formulate a model of the human capability to combine familiar objects or concepts in an unusual way. Important components of the creative process are feature association, combination, abstraction, selection, integration, and adaptation to establish an optimal fit between two or more semantically remote entities. In the act of creating, the goal is to show (a quantity of) similarity where no one saw it before. The function is knowledge acquisition (also emotionally), to find all the available possibilities in a given situation, (showing how) to find new solutions, new ways to get what you want. The effect of a creation may be surprise as a function of the tension between similarity and dissimilarity between objects and/or concepts. Depending on individual tolerance levels, the balance between similarity and dissimilarity may be satisfying or pleasing. Consequences for representations design are discussed.

Categories & Subject Descriptors: H.1.2 [Models and Principles]: *User/Machine Systems–Human information processing*; K.6.3 [Management of Computing and Information Systems]: *Software Management–Software development*.

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INTRODUCTION
Developing relevant and consistent representations for documentation and design decisions should aim at communication both in the design team, and among the team and clients, users, and stakeholders. In order to provide a consistent integration of design views and to allow communication among relevant disciplines with adequate representations for each, at least two points are essential:

1. Representations ought to be connected to an underlying repository of design space elements

2. Representations ought to be structured according to an ontology, for example, analogous to the Groupware Task Analysis design environment [19]

However, putting these requirements into practice supposes that within the same project, clients, users, stakeholders, graphic designers, HCI researchers, and software engineers all have the same ontology in their heads. This will probably not be the case, because a design space element such as a task, role or agent may mean something completely different in another group or community. In each group, moreover, there may already exist signs, symbols, and icons for such elements, the fixed forms and meanings of which are not immediately erased by introducing new representations, irrespective of their relevance or consistency.

That is why I would like to add a third point, that is:

3. Representations ought to hook up with the familiar representations of design space elements in the ontologies already existent in participating groups and link them in a unique combination that reflects the new ontology

This way, representations become 'cross-cultural' regarding clients, users, and other groups, integrating the 'old' images into a new vision on, for instance, design decisions. In the remainder, I would like to discuss what a designer could keep in mind in creating representations that respect the familiarity of (representations of) entities, that are yet unique, and nevertheless remain meaningful. The level of treatment will be general so that insights can be applied to design environments ranging from graphics, texts, industrial design, to the arts.

Familiar but Unusual
To make something new, unique, and dissimilar from everything you have ever seen, may be desirable but is also problematical. First, people cannot make something out of nothing. Second, when something is truly only one of its kind it may entail exclusiveness and incomprehensibility, two antagonists of user-friendliness. As said, people need

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something old to understand the new [15]. Making something new, therefore, usually brings together familiar things in an unusual connection (cf. [11]). Look at the bike frame, standing on its back suspension fork (Figure 1). The features that make the bike look familiar are its cogwheel, cranks, steel tubes, and shape. Next to the bike is a picture of a horse. It has four legs, manes, hooves, and it prances. Both pictures are not unusual but put together they make a whole new picture, a prancing horse of iron (the third picture). What are the ingredients that let most people judge that the third picture is more creative than the other two?

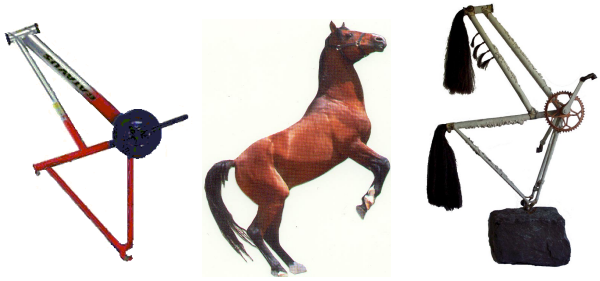

Figure 1. Bike frame, horse, and prancing horse of iron (Hoorn, 1989).

INGREDIENTS OF CREATIVITY

Why do people want to create, with that urge for the new, and why do not they always follow tradition, the fixed pattern, the safe way? Curiosity is an inborn human concern [6], a problem-solving strategy in which all possible routes are explored and evaluated on usefulness [1], [12]. In the case of a representations designer involved in a project for the British SAS, useful is what yields the optimal balance between, for example, the picture (and underlying ontology) for an 'agent' within the Intelligence Department and the picture (and ontology) of 'agent' for Systems Support:

Creativity is to put two or more familiar entities (whether objects or concepts) in an unusual combination (see [20]). Putting together means that real physical distance (δ) needs to be bridged between (features of) entities. This means that physical distance between entities before creation is larger than after: $\delta_1 > \delta_2$. As the Accessibility Options icon shows, entities can be pictures and words (a symbol for a program with a symbol for the handicapped with an icon caption) but also bikes and horses. Well, horses not really. If two concrete objects cannot be welded together in reality, at least one of them needs to be a concept or representation of that object. In the bike-horse example, the concept of a horse is combined with the physical bike but at least the concrete feature of the ponytail is stuck to the bike, decreasing physical distance. In Figure 2, plumbing materials represent the horse's hooves but before this is possible, abstraction must take place. Thus, one of the ingredients of creativity is to abstract objects to concepts to overcome physical problems.


Accessibility Options.lnk

Figure 2. Pipes represent the concept of hooves.

Although it seems counterintuitive, the entities in a creative expression should have a certain degree of familiarity. This has to do with the elicitation or association of features for those entities [3]. When humans perceive something, they activate features for that entity to compare them with features of other entities. When a feature set is empty, there is nothing to compare or connect, and thus, the creative expression remains meaningless, incomprehensible or anomalous. Familiarity is the reflection of the number of features (including relations with other features) that a person can sum up for an entity (cf. [17]). The more you know about something, the more you can tell about it. Thus, familiarity of an entity pertains to the knowledge you have about it, which is materialized in the size of the elicited feature set (for a refinement of this view, see [16]). The more features you have available, the higher the possibilities that you will find a match with features of another (distant) entity. What you know may differ from entity to entity. A creative designer, therefore, starts associating on the entities s/he has to design for to find features that can be connected to features of other (distant) entities. Association, therefore, is a way to assess familiarity and to estimate the probability of finding matches between (semantically) remote things.


Keyboard.lnk

The core of creativity is that the combination of the more-or-less familiar entities is unusual. Putting a picture of a keyboard to the icon caption Keyboard may be apt but is not creative because that word and that picture are used for keyboards all the time. Such literal uses may be quite user-friendly, very understandable, perhaps boring, but here it merely illustrates that infrequency of use plays a role in making a creative design. Given a particular community of practice,

words, images, objects and concepts have a frequency of occurrence or a frequency of use. *Maple* programmers talk about trapezoid and simpson functions more than web-designers. Horse breeders mention the word 'splint bone' more often than bike mechanics. In other words, creativity is socially dependent [2]. The trick is, then, that entities in a creative expression may be familiar and even may have a high frequency of use in the given community of practice but using them together, suggesting they belong to each other, should have a low frequency. That the entities are familiar increases the possibilities to establish meaning connections through intersecting features. That their combination is unusual makes the connections new, provides new meaning to old ideas. Metaphors are a means to do this. The metaphoric statement made by the third picture in Figure 1 is that a bike is a horse. Obviously, a bike is not a horse and a mismatch has taken place between the category of vehicles and of animals. Yet, because certain features between the categories intersect (e.g., to ride) the expression is not meaningless or nonsensical. An IT designer, therefore, should have a firm understanding of the users, stakeholders, etc., about the familiarity of entities within a group, and about the frequencies of use of combined entities to make something considered 'creative.'

Combining entities is to reduce physical distance, so I argued but there is more to it. People put things together as a kind of data-reduction. They make categories on the basis of similarity [15] and then they can talk about a few groups instead of many individuals. By putting entities together, therefore, people are forced almost to compare them (cf. [20]). In other words, there is a gliding scale of becoming similarity-focussed the closer entities get together [4]. Similarity reflects the set size of the intersecting features relative to the number of distinctive features [17]. More features are compared the closer two entities are. If there are (approximately) identical features in two sets, then, the intersection size increases the closer two entities are put together. In this way, two entities get integrated or synthesized (cf. [5], [11]). However, sometimes features originally were not in the set but are attributed, copied or borrowed from the other set, for example, when one person imitates another. In that case, the feature at first is present in the receiving set as a 'void address,' the concept of a feature, which is then filled in (copy-paste) with the feature of the providing set. Such attribution of a feature is also present in the bike-horse example. The ponytail was borrowed from a real horse and glued to the bike (cut-paste). Glue literally fills up the voids in the molecular structure of two surfaces, thus bridging physical distance. Feature attribution increases similarity and if there are 'void addresses' in a set, feature attribution increases the closer two entities are put together. Another matter is substitution.

In the Server icon, the dinner plate is replaced by a computer, so where does the feature matching come in? Would someone want to eat a computer? Substitution always is rooted in similarity. The shared feature between dinner plate and computer is that the 'menu' may be a literal feature of dinner that is served while it is a figurative feature of the computer's user interface. In all, by establishing a feature intersection, two or more entities become integrated, which is another important ingredient of the creative process.

Not every feature that is perceived or associated is used in a creative comparison. Although they are salient features of a bike, the wheels are left out and the saddle is removed in the bike-horse example. Deleting the saddle is peculiar because a saddle can be a feature bike and horse share. However, putting the bike frame upright makes the saddle occupy the 'void address' of the horsetail, and therefore, conflicts with the concept of a horse. Thus, features are selected according to their weights or importance for establishing optimal fit. What is weighted is a vexed question, however. It may be salience, prototypicality or emotional relevance [13], [9]. Yet, the important part here is that creativity involves the selection of features that are used in the comparison.

Figure 3. The bike frame is adapted by drilling a hole and adding eyes to increase similarity with a horse's head.

Features only need to be approximately identical to intersect [8]. People consider 'mouse' and 'mice' as semantically the same although formally they are not. The artist bends and bows the features to gain optimal (not necessarily maximal) similarity: The bike is standing upright, holes were drilled to add the eyes (Figure 3), the frame was painted, and a title was added. These are examples of adaptation or transformation of features to let entities fit or misfit in just the right way, that is, raising optimal similarity according to the user group (of which sometimes the artist is the only member). Thus, adaptation of features also is part of the creative process (cf. [20]).

As to the effect of the creative expression on the user, a tension may exist between similarity and dissimilarity of the entities. In the form, the shapes of the bike and the horse are roughly the same; in contents, they are both to ride on. By

contrast, the shapes are not exactly identical, horses have no wheels and bikes have no legs. Both may be to ride on, but horses can travel by themselves whereas bikes do not. It may be obvious that the individual levels of tolerating dissimilarity vary. If things brought together are perceived as too distinct, their combination may be judged as incomprehensible or anomalous (e.g., cubist portraits hardly resemble the person – 'my little girl can do that too'). If things become too similar, they may be rejected as journalism, science or 'without fantasy' (e.g., photorealistic portraits may resemble life too much – 'where is the art?'). Put differently, people build expectations upon the activated features of an entity (what they know about it, its 'familiarity'). If combined, many mismatches can occur with the features of another entity. The increase in dissimilarity violates expectations, evoking surprise, which in extreme cases can lead to rejection of the creation.

Titles can be helpful when disparate things are put on a par. They provide a concept-driven framework to interpret the unusual connection. If someone does not see a horse in the bike, the title 'prancing horse of iron' will evoke the right feature set to compare the bike-features with. The title is semantically priming the art object. Putting the horse-bike on a basalt pedestal (Figure 4) is another cue to concept-driven interpretation [14].

Figure 4. The pedestal stimulates concept-driven interpretation of the bike frame as art or fiction.

It states: 'This is art, an invitation to suppose or imagine that a bike could be a horse, not really, but in fiction' [9]. In other words, the pedestal tries to keep the statement 'a bike is a horse' away from the claim of truth [9]. Instead, the intersection of features will stimulate the similarity between the semantically distant entities and held against the distinctive sets (stimulating dissimilarity), people may judge that the image is striking or not. Thus, words help to understand the image by pre-selecting the appropriate feature sets and framing the creation as fiction avoids rejections on the truth-value.

MODEL OF CREATIVITY

Figure 5 depicts how the modules of association, combination, abstraction, selection, integration, and adaptation operate together to establish optimal similarity between entities. The process is explained for two entities but this number can easily be incremented. While perceiving an entity (whether an object or concept), features are associated and they may be attributes, literal descriptions, symbols, relations, etcetera. Thus, similarity between two entities may reflect intersecting relations, attributes, literal with figurative features, and so forth. Through the associations or simply by looking at something else, another entity comes to mind, generating a second set.

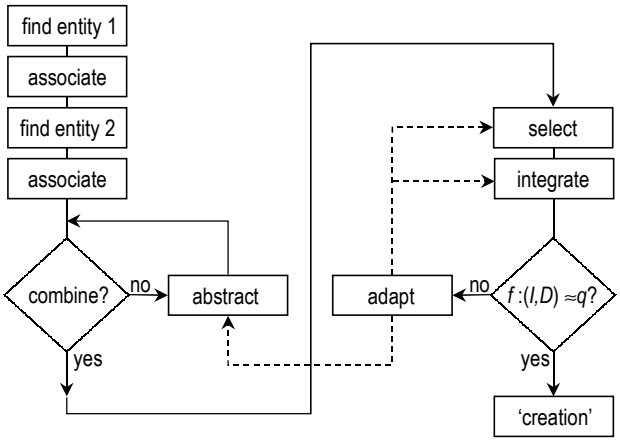

Figure 5. The creativity process. Features of entities are associated, selected, integrated, and adapted until optimal similarity (f: $(I,D) \approx q$) is reached. When entities cannot be combined physically, they are abstracted.

The first practical question is, can I physically combine the two entities? Putting a real workstation on the hand of a butler is not an easy thing to do. Thus, sometimes objects go through several cycles of abstraction before they can be combined with other entities in the form of a concept. Sometimes the concept is materialized again in the representation of that concept, a picture, symbol or other object, and then that object can be combined with another entity. Consequently, the model retains the holistic claim that as long as you make the abstraction level high enough, any two things can be combined.

After checking that two entities can be physically combined or put close together, the relevant features are selected that are needed for (semantic) integration. Feature sets are limited, then, by the importance of features. In a weighed set, features have a rank ordering of processing (cf. [10]). At least the most important features of both sets should become integrated.

Integration of two entities anchors in the intersection (I) between the respective feature sets. However, people estimate intersection size relatively proportional to the sizes of the distinctive sets (D). The value of the intersection

size, therefore, should not only be sensitive to weights but also to the weighed distinctive set sizes [17]. How intersection and distinctive sets should be related is an unsettled empirical matter [8]. The second decision diamond of Figure 5 informally refers to it as a function *f*: (*I,D*), the output of which should meet a certain criterion *q*, tolerating more or less dissimilarity in a combination.

If the balance between similarity as reflected by the intersection and dissimilarity as reflected by the distinctive sets is not optimal according to subjective criterion *q*, adaptation of features should take place. This literally may involve going back to the workshop and hammer features into a different form. Additionally, adaptation may involve going through another abstraction cycle or selecting different features (Figure 5, dashed arrows). The (now changed) feature sets are then reintegrated. The looping continues until *q* is satisfied and the creator decides to have made a 'creation.'

Whether the creation is successful or satisfactory according to the user, client, etc. is a matter of perceiving and experiencing cultural products ([7], [18]). Whether it is an artistic creation need not concern us here. The model tries to explain the creation process, not the assessment of its output. What I do hope is that when empirical values and functions are found, it helps creativity support tools to offer more ideas than clients, users, and stakeholders would generate themselves. I also hope that interactive systems become available that mine all the possible combinations in a situation, serving as the input for further problem-solving strategies. In the long run, it should help the communication among design-team members, among the team and clients, users, and stakeholders to achieve the highest satisfaction of user goals and concerns.

CONCLUSIONS

People involved in a system design project should utilize creative representations of design views. Representations of design space elements with different familiarity in different groups should be combined in a unique yet meaningful way. Choosing the most familiar representations within a group, transforming their features so that they physically fit and a firm meaning connection is established can do the job. Because entities should be used that are already known and a considerable number of features between entities should intersect, communication about the underlying ontology can take place. That the combination is unique makes the creation catchy and may help to override the imprint of the old - and supposedly undesired - image.

Yet, a framework that supports the creativity of a representations designer or the development of creative tools in advanced interactive systems should turn into testable applications. One step into that direction is to deduce which variables and functions should be on the research agenda of investigators in HCI and creativity. This section is an attempt to do so.

When two or more entities are put together, the original distance (δ) between those entities is reduced. Thus, there is a distance δ_1 and a distance δ_2, of which δ_2 is the net result of the finished creation. In between $\delta_1 > \delta_2$, then, should lie a point $\delta_\bullet$ where two entities are considered a combination or not. By making concrete objects abstract (a concept or representation), physically unbridgeable distance can be compensated.

Each entity has a value for familiarity (*F*), which is reflected by the sum of all weights *w* of all features *x* in *X*, *y* in *Y*, etcetera (see further [16]). When entities are combined the frequency of occurrence or use of that combination in a given community should be 1 to call it a creation. Thus, creativity is strongly restrained by originality. The larger the number of members in a user group, the lower the probability that a combination is creative. However, the more entities are combined, the lower the probability that the combination already exists, and accordingly, the higher the probability that the combination is creative (which is not the same as successful or beautiful). Therefore, people bias to call their work creative the smaller their community of reference is (of which the artist may be the only member).

When entities are combined, the associated features form an intersection (*I*) and distinctive sets (*D*). The more features enter the comparison, the higher the probability of finding matches. Because *F* is a reflection of feature set size and perceived similarity is a reflection of *I* as related to *D*, it follows that the higher *F* the higher the perceived similarity (*s*) and the lower perceived dissimilarity (*d*) between entities. When the distance between entities is smaller than $\delta_\bullet$ the intersection grows and similarity increases. As a result, two functions of δ on *s* and *d* may be described: Given a set with 'void addresses' or 'void features,' feature attribution (copy-paste) and thus *s* increase, whereas *d* decreases, the closer entities get. Given the existence of approximately identical features, intersection size and thus similarity increase, whereas *d* decreases, the closer entities get. If entities are completely fused, δ_2 and *d* approach zero, whereas *s* approaches 100%. However, complete similarity is not necessarily the optimum for user satisfaction: While the intersection size grows, whereas the distinctive set sizes diminish, a point *q* is reached where satisfaction with the creation reaches the top of its parabolic growth.

With this paper I wished to devise a model of the human capability to combine familiar objects or concepts in an unusual way. It articulates the relations between the process modules of feature association, combination, abstraction, selection, integration, and adaptation to establish an optimal fit between (semantically) remote entities. I also have tried to define the variables and some of the functions that I consider applicable to developing information technology for creativity. Pasting these together, however, shall take another creative endeavor.

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