Workshop Title: Principles of Repurposing

Possible Workshop Dates: Late Spring / Early Summer 2008
14-16 July, 2008

Workshop Location: Santa Fe Institute, Santa Fe, New Mexico

Workshop Organizers:
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Introduction:

Most problems are solved not by generating a completely novel set of specialized tools, but rather by modifying and combining preexisting tools – developed perhaps for an entirely different purpose – to generate new solutions. This process, which we are calling *repurposing*, plays a critical role in innovation across a wide range of domains.

If one construes the term sufficiently broadly, any innovation can be defined as repurposing. At one extreme, there are circumstances in which a particular tool is taken unmodified and applied to a new problem. One example is tinfoil which was originally developed for thin-film applications in the space industry and is now commonly used to store food. At the other extreme, the smallest components of a tool could be reorganized to perform a new function. For example, a new structure could be constructed by "repurposing" carbon molecules from another structure. In many contexts, this would be a trivial example; however, in certain contexts, such as converting amorphous carbon to carbon nanotubes for use in nanotechnology, this type of low-level repurposing is not trivial.

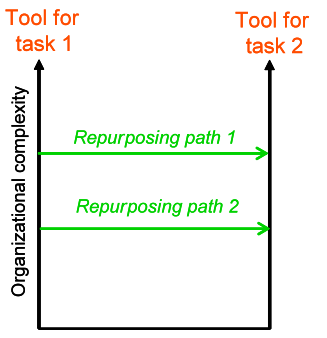

Figure 1. Schematic of two repurposing paths in which path 1 indicates greater repurposing than path 2. Factors that influence which path is selected might include: features of the tool for solving task one, such as the degree of modularity; and features of the task itself, such as the degree of precision required.

The workshop will adopt this broad definition of repurposing and will focus on developing a framework in which to characterize degrees of repurposing and its consequences. For example, one can consider two tasks – a source task that is accomplished by an existing tool, and a target task that needs to be accomplished. We are interested in cases where the target task can be accomplished by a new tool that involves some kind of reorganization or modification of the existing tool. We imagine that there are two or more different repurposing paths available that differ in the level of organizational complexity at which the transfer occurs from one context to another. One path might involve disassembling the existing tool into three component parts, and reassembling them in a different way. A second path might involve disassembling each of these three components into five sub-components. The new tool would be developed by reassembling these fifteen subcomponents. The degree of repurposing in this case, would be a function of the number of component parts from task one that are used in solving task two, and the complexity of each component part.

Discussion will center on comparing the consequences of these different paths in an evolutionary context. Intuitively, we might assume that there are multiple possible solutions to the target task,

and that the path passing through the lower level of organizational complexity would have access to a wider range of those solutions. On the other hand, the path through the higher level of organizational complexity might generate a solution to the problem more quickly.

As a concrete example, we might compare two modes of evolution in molecular biology. An evolutionary path representing a low level of organizational complexity might include the accumulation of point mutations – changes in individual nucleotides in the DNA sequence. A path at a higher level of evolutionary complexity would include concerted changes in whole stretches of DNA, as through gene conversion and/or recombination. In discussing repurposing in multiple contexts, and its potential advantages and disadvantages, we are referring to this comparison among different paths representing varying degrees of organizational complexity.

Description of Workshop:

The workshop will investigate repurposing in each of four contexts: biological, technological, and social systems, as well as human cognition. Our primary aim is to develop a conceptual framework that can be extended to quantitative analyses in diverse systems. We will bring together researchers who have studied aspects of this process in the domains listed above, as well as those who have thought more broadly about critical features of innovation. The workshop will have several goals:

1) *Identification of a common vocabulary for comparing repurposing across diverse domains*. Aspects of this process have been explored in the context of particular systems and applications. For instance, there is substantial literature on the role of learning spillover in the development of technologies. In biological evolution, phenomena referred to as "cooption" or "exaptation" have been documented in both morphological and molecular contexts. One goal of the workshop is to find useful ways of discussing both similarities and differences among these processes.
2) *Definition of archetypal repurposing structures that can be identified across multiple domains*. Even within a single domain, repurposing can take a variety of forms. In fact, we expect a particular instance of repurposing to share more structural similarity with specific cases in other domains than it shares with many examples from its own domain. For example, one such archetypal structure might be the generation of diversity within one system (e.g., the immune system/ or the semiconductor industry), followed by a second system using that diversity for an unrelated purpose (e.g., neuronal signaling and kin recognition/ or thin-film energy technologies).
3) *Identification of features of a tool or system that facilitate or inhibit repurposing.* For example, how important is the role of modularity in allowing repurposing? There are many examples in the technological domain in which modularity is deliberately designed into systems specifically for the purpose of facilitating slight modifications or improvements to a device so that it can better fulfill its original purpose. More recently researchers have begun considering how modularity can allow devices or device components to adapt to new purposes. In the case of biological evolution, which operates without foresight, are there cases in which this type of future evolvability is favored by natural selection? Are there analogous features and processes that can be identified in the cognitive and cultural domains?
4) *Identification of features of a tool or system that influence the long-term consequences of using repurposing as a primary route to innovation*. On the one hand, we expect that a system capable of innovating through repurposing will be able to arrive at solutions for particular problems more rapidly than a system that constructs an entirely new solution from the ground up. On the other hand, by using tools that have evolved or been

designed for a different purpose, the repurposed solution may be suboptimal when compared with a hypothetical special-purpose solution. Furthermore, in the context of an ongoing process of iterated innovation, repurposing can result in commitment to structures that inhibit innovation in the long run. We are interested in asking what features of a particular tool or system accentuate the benefits of accelerated innovation, and what features enhance exposure to the potential for long-term negative consequences.

We have identified three specific domains in which a process of this type occurs. Our list of invitees includes representatives from each of these domains. The three domains are:

1) *Technological innovation*. Most new technologies rely on multiple preexisting subsidiary technologies, both component technologies required for the functioning of the device as well as those required to manufacture the device. We will focus here particularly on those cases in which a technology component or set of components is playing a role different from that for which it was originally designed. Within this domain, we will consider specific examples of repurposing in a variety of industries and at several scales (aircraft, semiconductor devices, nano/biotechnology, software design), and more generally, the role repurposing plays in the dynamics of technological evolution (e.g. rate of change, longevity of an industry).
2) *Biological evolution*. In biological evolution, repurposing takes (at least) three forms. In some contexts, we will mean changes that take place as an organism adapts to a new environment, where a feature is modified to take on a new function. In other contexts, we will mean a feature (such as a gene product) that is used simultaneously for different functions, for example in different tissue types in a multicellular organism. Other biological features are produced by duplication and divergence of an existing feature (e.g., gene duplication or segmented body plans).
3) *Cognitive science*. Here we will focus particularly on the roles of metaphor and analogy as conceptual tools. In this case, we have a conceptual framework or model that has been developed (either by the culture or by the individual) in one context. These models are then applied metaphorically in a very different context to orient thinking and provide understanding of a very different system. In this domain, we can ask what types of understanding most easily lend themselves to metaphorical repurposing. Also, what patterns of similarity and difference between the original and repurposed contexts make this type of repurposing most valuable.

Anticipated outcome of the workshop:

As with any exploratory workshop at SFI, the outcomes are somewhat uncertain. However, we anticipate one or more of the following possible results.

If we are successful in identifying general principles of repurposing that transcend the details of particular systems, a working group might be assembled to write a review paper highlighting these principles.

The workshop may also help to identify one or more small trans-disciplinary groups that could meet in the future to address a more focused sub-topic. In particular, we plan to structure much of the discussion around our concept of archetypal repurposing structures. One example of such a structure is the case where the dynamics of operation of a system generates some form of diversity. Repurposing might occur when another system makes use of this diversity for an unrelated purpose. For example, in the biological domain, natural selection on the immune system generates diversity at the population level, and has generated mechanisms that create

diversity within the individual organism. Other systems, including the nervous and olfactory systems, have used this diversity in contexts that are unrelated to immune system function. There are examples of this structure in the technological innovation as well. We hope to identify examples from other domains where a similar type of transition occurs. A future working group might then focus specifically on a topic like “the generation and cooption of diversity.”