ELECTRONICS EVOLUTION: DIVERSITY REVISITED

by Lance A. Glasser

Diversity of size and function, a long accepted fact of life in the biological world, will characterize the emerging information revolution — and for the same reason: survival.

There are more small plants and animals (and more *types* of small plants and animals) than there are large plants and animals because the smaller species require fewer resources to survive in their biological niches.

In a like manner, the new generation of mobile information appliances currently entering the market will also have to compete for resources in the form of consumer dollars, and that means carving out niches of their own.

The premise that species competition is analogous to market competition can be confirmed by walking through any department store: there are more small products than large products for sale — just as there are more beetles than elephants in the biological world.

Furthermore, if electronics evolves along the lines of biology the gap between numbers of small products and large products should be substantial. Oxford University Professor Robert M. May, in an October 1992 article in *Scientific American* titled "How Many Species Inhabit the Earth?" estimates that beetles account for at least a million of the earth's six million animal species. Only four thousand species of mammals have been identified, with only two species of elephants on this side of extinction.

That means there are at least 1,500 types of beetles for every type of mammal (elephant, human, mouse, etc.), prompting the British geneticist J. B. S. Haldane to remark that the Creator has "an inordinate fondness for beetles."

Humans are likely to be fond of mobile information appliances, which will be small, light, inexpensive, numerous and connected to international-scale information services supported by satellites and global computer networks. At the forefront of this revolution will be low-cost consumer electronic distributed systems that will fill a variety of product niches over the next two decades.

The market can be subdivided into two distinct classes of products: those embedded in applications that are remote from people and those that are in intimate contact with people.

The biological analogy is particularly evident in the first class, such as devices buried deep in the machinery of a manufacturing line. In this case, miniaturization is a powerful force to create large markets and the resulting economies of scale.

Diversity is also essential. We may all buy small products in large quantities, but we will not all want to buy the same small products. This should lead to mass customization based on technologies to support design and manufacturing processes that can economically respond to consumer demands.

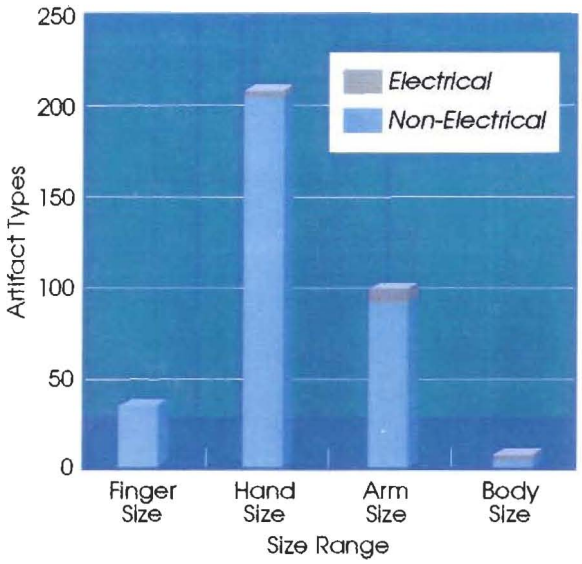
In addition to diversity of size, the new electronic products will also exhibit functional diversity. They will contain varying degrees of internal programming and external connections to the outside world via sensors, actuators and displays.

In the case of information appliances that must be touched by people, human-scale issues prevail, as I and my three children verified during an informal scientific inquiry conducted in the kitchen of our home.

Here's an experiment you can try yourself. We removed all the kitchen appliances and utensils from their usual places, and the four of us industriously measured the long axis length of each unique artifact type. We measured each different type of fork, for example, but we did not count each fork in a matched set as a separate item.

What we found was that kitchen product diversity is greatest for hand-size artifacts. I suspect the results would have been similar in any kitchen — or in most offices or workshops.

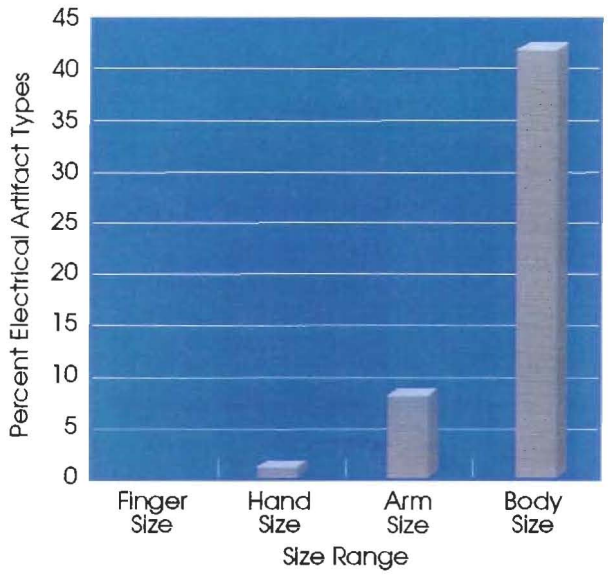
Electrical and Non-Electrical Artifacts in the Glasser Kitchen



We also assessed the share of electrical devices in the total number of types, and we found that larger devices (the size of a refrigerator, stove, table or chair) have a greater percentage of electrification than do smaller devices (spoons, corkscrews and the like).

Over time, the percentage of electrification of small devices in kitchens (and elsewhere) can be

Penetration of Electrical Artifacts



expected to increase. This process has been under way for several decades, and the results of our experiment suggest that for electronic devices that interact with people, the majority of untapped applications are in hand-size devices.

The information ***revolution*** is still in its early stages, but the pattern of electronics ***evolution*** continues to be survival of the fittest. The bulky electronic "elephants" of the past are in decline and the "beetles" that will create the large and diverse markets of the future are the hand-size devices being developed today for the new applications niches.

Dr. Lance Glasser is the Director of the Electronic Systems Technology Office at the Advanced Research Projects Agency, the principal research arm of the Department of Defense. He received his Ph.D. degree in electrical engineering from the Massachusetts Institute of Technology. He has written extensively on advanced electronic devices and computing technology, and is the coauthor of *The Design and Analysis of VLSI Circuits.*