Who is Responsible for Automatically Engineered Designs?

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Over the last twenty-five years, engineering design practices have been revolutionized, due to the widespread acceptance of Computer Aided Design (CAD). Now, another revolution has crept upon the design world. New advances in computing have given computers the capability to automatically engineer designs. "Computer Aided Design becomes Computer Design."[1] This immediately raises the key question, "who has legal liability for the design?" We must choose between the company that provides the automatic design tool, and the design engineer that uses the tool. To answer the key question, we will examine the concept of design from both engineering and computational perspectives, look at the current state of Automatically Engineered Designs (AED), restate the problem, consider the viewpoints from both sides, state our position and the main reasoning behind it, and finally conclude. Engineering design, whether manual, computer-aided, or automatic, must ultimately be the responsibility of the engineer behind that design.

The Canadian Engineering Accreditation Board's 1992 definition of Engineering design is "a creative, comprehensive, and often open-ended process … for the creation of components, systems, products and processes to satisfy specific needs and constraints. These constraints include economic, safety, health, environmental, and social factors, the requirements of standards and legislation, and other considerations such as maintainability, serviceability, and manufacturability." At the core of design is creativity. In *Applied Imagination*, Alex F. Osborn wrote, "creativity is more than mere imagination. It is imagination inseparably coupled with both intent and effort."[2]

Therefore, to carry out the design process, one needs to know the specific needs and constraints for the particular design problem, in addition to intent, effort, and imagination. Humans obviously possess the capacity to carry out each of these activities. Remarkably, computers also have the capacity for each activity over a wide range of design problems. Ignoring the subjective design constraints, it is possible to specify many

[1] Kelly, M., "Cars and Coffee Tables! Can computers be creative?", *EvoNews (The Newsletter of EvoNet – The Network of Excellence in Evolutionary Computing)*, **9**, Winter 1999, pp. 2-3.
[2] Osborn, Alex F., *Applied Imagination, 3rd Revised Edition*, New York: Charles Scribner's Sons, p. 35, 1963

design problems in ways that computers may understand. Computers automatically have design intent if their human programmer has programmed them to have design intent. Computer effort equals mindless mechanistic computation that never tires. One question remains: do computers have the imaginative capacity to carry out a design effort? The answer is a surprising "yes!" Imaginative effort in the process of design can be viewed as a search through the space of possible designs. There are now algorithms to effectively traverse this search space, to find point(s) in the space (i.e. designs) that meet the specified design constraints. Both humans *and* computers are capable of design.

Automatically Engineered Designs (AED's) have a brief but remarkable history. Peter Bentley has demonstrated the range problems in which computers may design, from aerodynamic sports car bodies, to coffee tables[3]. Computers have automatically designed satellite booms, load cells, flywheel booms, computer networks, house and hospital architectural plans, bridges, and cranes[4]. Many recent books herald this revolution in design, by demonstrating the real-world applicability (and economics) of automatic design[4,5,6]. Closer to home, a University of Saskatchewan design team recently developed an automatic analog circuit synthesis tool that is efficient enough for industry use[7]. In some cases, the AED actually outperforms human design effort[8]. Automatically Engineered Designs are here to stay, and what we have witnessed so far is only the beginning.

We have now established that both humans and computers are capable of creating designs that could be called "engineered." If a design fails, to whom should the blame be

[3] Bentley, P., "Conceptual Evolutionary Design by Genetic Algorithms," *Engineering Design and Automation Journal*, **3**, (2), John Wiley & Sons, Inc., pp. 119-131.
[4] *Evolutionary Design by Computers*, Bentley, P., Ed., Academic Press, 1999.
[5] *Adaptive Computing in Design and Manufacture : The Integration of Evolutionary and Adaptive Computing Technologies With Product/System Design*, Parmee, I.C., Springer-Verlag, 1998.
[6] *Electromagnetic System Design Using Evolutionary Optimization*, Yahya Rahmat-Samii, Y., and Michielssen , E., Eds., John Wiley & Sons, Inc., 1999.
[7] Gupta, A., Larsen, W., Hertz, G., McConaghy, T., "Analog Composer: Automatic Analog Circuit Synthesis Tool," *Innovative Design Competition and Students Papers Night*, sponsored by Saskatoon Engineering Society and College of Engineering, University of Saskatchewan, March 24, 1999.
[8] Koza, J.R., Bennett III, F.H., Andre, D., Keane, M.A., "Four problems for which a computer program evolved by genetic programming is competitive with human performance," *Proc. Of 1996 IEEE Int. Conf. On Evolutionary Computation*, IEEE Press, pp. 1-10.

placed? This was never an issue in the past, because the entity invoking the design process, and the entity creating the actual design, were one and the same: a human designer. Naturally, this person accepted the responsibility for the design. There was never a need to separate these two entities. Now, with AED, the creator of the design could quite possibly be a computer. However, computers are incapable of accepting responsibility. So, for AED, should responsibility fall on the manufacturer of the AED software, or should it fall on the design engineer who uses that software? We will now examine the arguments behind both sides.

There are a number of arguments why one may try to assign responsibility to the manufacturer of the AED software. First of all, it is the software that creates the actual design. Because it is the software manufacturer that lays the algorithmic foundation for the details of the design solution, one might argue that the manufacturer indirectly creates the design. One might also argue that the manufacturer has abstracted away the low-level implementation details too far for the human invoking the design process, such that the human has no chance of knowing if there are flaws in the computer-generated design.

How might one counter these arguments? Firstly, we must keep in mind that at least one of the two design entities in the design process is human. The other entity, the computer creating the design, can at best be represented only indirectly by the AED software manufacturer. However, the AED software would know nothing of the specific design problem that the design engineer faces. Regarding the second argument, recall that the human should know exactly what constraints to enter into the AED software. The design that the software generates is only as good as its constraints. If the human invoking the design gets lazy or sloppy in defining constraints, the computer will still generate a design. However, since the constraints are below par, the design will likely be suboptimal and possibly faulty. The AED manufacturer should not be expected to be liable for faulty designs due to lazy designers. Imagine if engineers could defer all their responsibilities to an AED manufacturer: design engineers would lose their legal incentive to be careful during the design process, and many people would get hurt from poorly designed

products. If the responsibility for designs was shifted to AED manufacturers, quality of designs would degenerate, and people would get hurt.

We may argue that all of the design responsibility lies with the human design engineer. After all, it is still the human designer that is at the top level of the design, overseeing the whole design process. It is he or she that decides to do the design, write the Statement of Work, and write the Requirements Specification. Whether or not AED is used later, these activities remain important parts of the design process. Computers cannot perform these activities. Only after these activities are completed, does the AED software get invoked. Thus, it is only the middle of the design process that has been abstracted away by a computer. At the end of the design process, the human designer must still test the design. It is the human designer that decides whether or not the final design is ready for real-world use. Therefore, even with AED, there remain many elements of the design process in which the human designer is directly involved. All these elements are the design engineer's direct responsibility, just as the Engineering Code of Ethics of pre-AED times outlines. In addition, it is the engineer, or engineer's employer, who reaps the direct financial benefits from the successful real-world application of the design. If they want to accept the positive results from their AED's, they should be prepared to accept possible negative consequences as well. Also, computers cannot take into account the subjective consequences of the design that extend beyond the scope of the AED problem as given to the computer. These consequences may include the design's impact to society and to the environment. Finally, it is the design engineer, not the AED manufacturer, who oversees the introduction of the design into the real world. In fact, for the whole design process, the AED manufacturer plays no role at all. The design engineer must accept responsibility for all consequences of the design, whether or not he or she had a computer do part of that design.

One can counter the viewpoint that the design responsibility lies with the engineer. What if the engineer did everything possible to constrain the design for the AED tool; the result seemed fine with laboratory tests and external trials; yet the design caused unforeseen problems upon adoption in the real world?

This rebuttal may be nullified by remembering what currently happens in the real world with engineering designs. Poorly engineered designs enter the real world all the time. Before their entry, the engineer may not know of any of the faults of the design. But, the engineer is willing to take responsibility for any problems that the design may cause.

In light of both perspectives considered, we must conclude that the ultimate responsibility for the engineered design must lie upon the design engineer, and not on the AED manufacturer. The AED manufacturer provides a tool for automatic design, but this tool does not automate the whole design *process*. It is the engineer who oversees the entire design process. It is the engineer who sets the design constraints, and invokes the AED tool. It is only the engineer who has the intimacy with the design to analyze the subjective impacts of the design in the real world. It is the engineer who oversees the adoption of the design into the real world. It is the engineer who must adhere to the Engineering Code of Ethics during the design process. Responsibility for the design belongs with the design engineer.

In the words of Professor John Frazer, "design by computers is the major revolution in design thinking of the 20th century"[9]. This revolution incites an ethical problem. The problem is whether the responsibility for the design should fall with the company that provides the automatic design tool, or upon the design engineer that uses the tool. To arrive at an answer, we have examined the general concept of design, looked at the current state of Automatically Engineered Designs, and considered the arguments behind each of the alternatives in this ethical problem. Upon weighing the evidence, we have realized that the design process, as a whole, is still the realm of the human design engineer. It is the design engineer who must ultimately take responsibility for the design.

- An interesting, well-presented paper
- Heading(s) might have helped guide the reader.
- An aspect you may have overlooked (or could have stated more directly) is that the client contracts with the engineer, not the computer or AED company.

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[9] Taken from P. Bentley's website at: http://www.cs.ucl.ac.uk/staff/P.Bentley/evdes.html