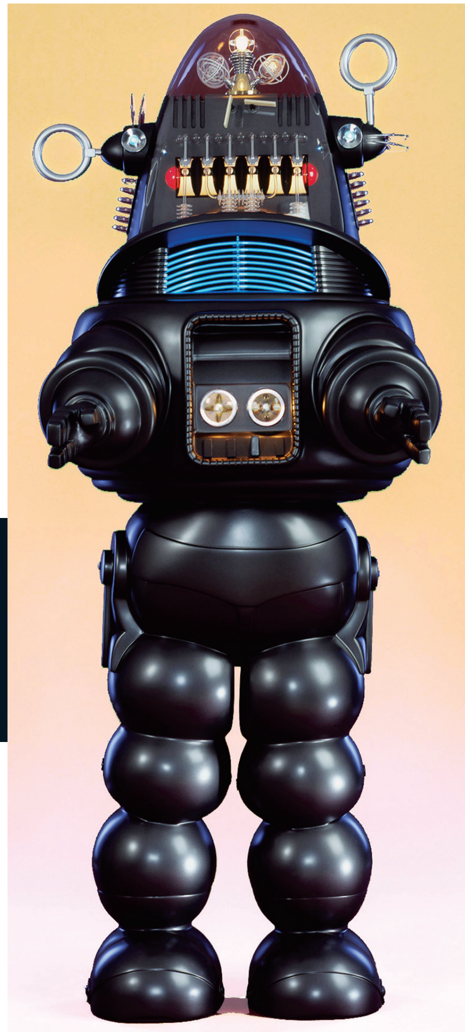
In the neuro-biological model, we cannot predict the connections of neurons as a brain learns. We don't have the mathematics or understanding to do that. When we went to subatomic physics, we changed our mathematical models, and quantum mechanics was born. In the same way, our current mathematics does not lend itself to the neuro-biological model; perhaps we will need to come up with another math model to explain how the brain works.

One thing we cannot determine is where the "logic" part of the human brain ends and memory begins or vice versa. It is my belief that this is because there is no such separation. We can't find specific neuronal circuitry for performing math in the brain, yet we are able to do things using our brains that are far beyond the fastest and most powerful computers built to date. We are in a quandary.



Robby the Robot first appeared in the 1956 MGM movie "Forbidden Planet." It exemplifies machine intelligence. Created by Fred Barton Productions from the original molds, this replica was photographed by Cynthia Ehlinger of the Bruce Museum.

MAKING THE CONNECTION

I followed along with neural nets, fuzzy logic and variations on those paradigms. Neural nets are nothing but statistical models whereby you already know all the possible connections, and all you do is give a weight to a connection and make it stronger by increasing that weighting. After two decades of researching this and doing everything I could to learn more—going to conferences, discussing this with my peers, etc.—it became obvious that we needed to stop, back up and take another look at the basic principles of the operation of the brain. For example, you don't have to be able to predict the interconnections in a child's brain for the child to do simple mathematics; all that is necessary is for the child to arrive at the correct result, regardless of how the result is determined. Even *identical* twins will not have the same wiring, and yet they can both come up with 2+2 = 4.

What is important is that we understand the principles that allow these connections to form on their own based on the learning process. We do not have to be able to predict which interconnections will take place. That's what happens with an infant. An infant's brain in a low-stimulus environment will not develop as quickly as one in a highly stimulating environment. Even though I don't propose to know how this works, I have designed, in software, a mechanism that allows these interconnections to take place in a synthetic digital brain—a brain that can, indeed, come up with the right answer and successfully solve problems, even though I cannot predict which synaptic interconnections will be made during the learning process.

All we want is the net result, and I have achieved that working with visual systems that identify objects, separate needed information from electrical noise and discriminate friend from foe in highly sophisticated robotics applications. My goal now is to apply these principles to the design of an affordable robot platform that will serve hobbyists and researchers so that this new synthetic brain technology can be further developed.

ROBOT: You have described a digital brain that solves problems through the unpredictable but systematic forming of neuronal connections. What is the nature of machine intelligence that this brain will display?

DR. JIM: Researchers at Stanford have created robot helicopters that can fly 3D aerobatic maneuvers as well as or better than human RC pilots. That is not machine intelligence as I define it; rather, that is response to external stimuli embedded in "apprentice learning" algorithms.

We cannot call a machine "intelligent" until it is able to learn on its own from its own mistakes. If we cannot separate it from its programming—what we have told it to do—it is not intelligent. From an empirical standpoint, intelligence would be seen in a machine that, rather than having programmed responses, would generate its own synaptic interconnections in the neuronal functional units of its brain (a digitally simulated mass of neurons). Until we get away from this business of predetermining how they are connected and instead come up with learning algorithms that allow making mistakes and then correcting them, we have not done it. There is no learning without being able to make mistakes.

If an intelligent machine cannot create new "thought patterns" or problem-solving behaviors on its own from the mistakes that it makes and then correct these mistakes with new interconnections and thought patterns, it is not intelligent.

ROBOT: Have you built machines that *are* intelligent?