

Architectures for Intelligent Robots in the Age of Exploitation

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SUMMARY

In this article, an explanation is offered for the confusion-invention-exploitation cycle and how robotics is now entering the exploitation stage of that cycle.

1. INTRODUCTION

History shows that problems that cause human confusion often lead to inventions to solve the problems, which then leads to exploitation of the invention, creating a confusion-invention-exploitation cycle. Robotics, which started as a new type of universal machine implemented with a computer controlled mechanism in the 1960's, has progressed from an Age of Over-expectation (1960-86), a Time of Nightmare (1986-90), an Age of Realism (1990-2000), and is now entering the Age of Exploitation (2000+)¹.

The purpose of this paper is to propose an architecture for the modern intelligent robot in which sensors permit adaptation to changes in the environment are combined with a "creative controller" that permits adaptive critic, neural network learning, and a dynamic database that permits task selection and criteria adjustment. This ideal model may be compared to various controllers that have been implemented using Ethernet, CAN Bus and JAUS architectures and to modern, embedded, mobile computing architectures. Several prototypes and simulations are considered in view of peta-computing. The significance of this comparison is that it provides some insights that may be useful in designing future robots for various manufacturing, medical, and defense applications.

Keywords: Intelligent robots, exploitation, eclecticism, creative control, reinforcement learning, adaptive critic

For more than 25 years, we have been exploring the concepts and applications of intelligent robots. These are often modeled by what we see when we look into a mirror. Early work was motivated by Claude Shannon's pioneering work with information theory and his examples of chess end game solutions and balancing robots. These intelligent robots are remarkable combinations of mechanisms, sensors, computer controls and power sources as shown in Figure 1. We find that each component as well as the proper interfaces among and between the components are essential to a successful intelligent robot.

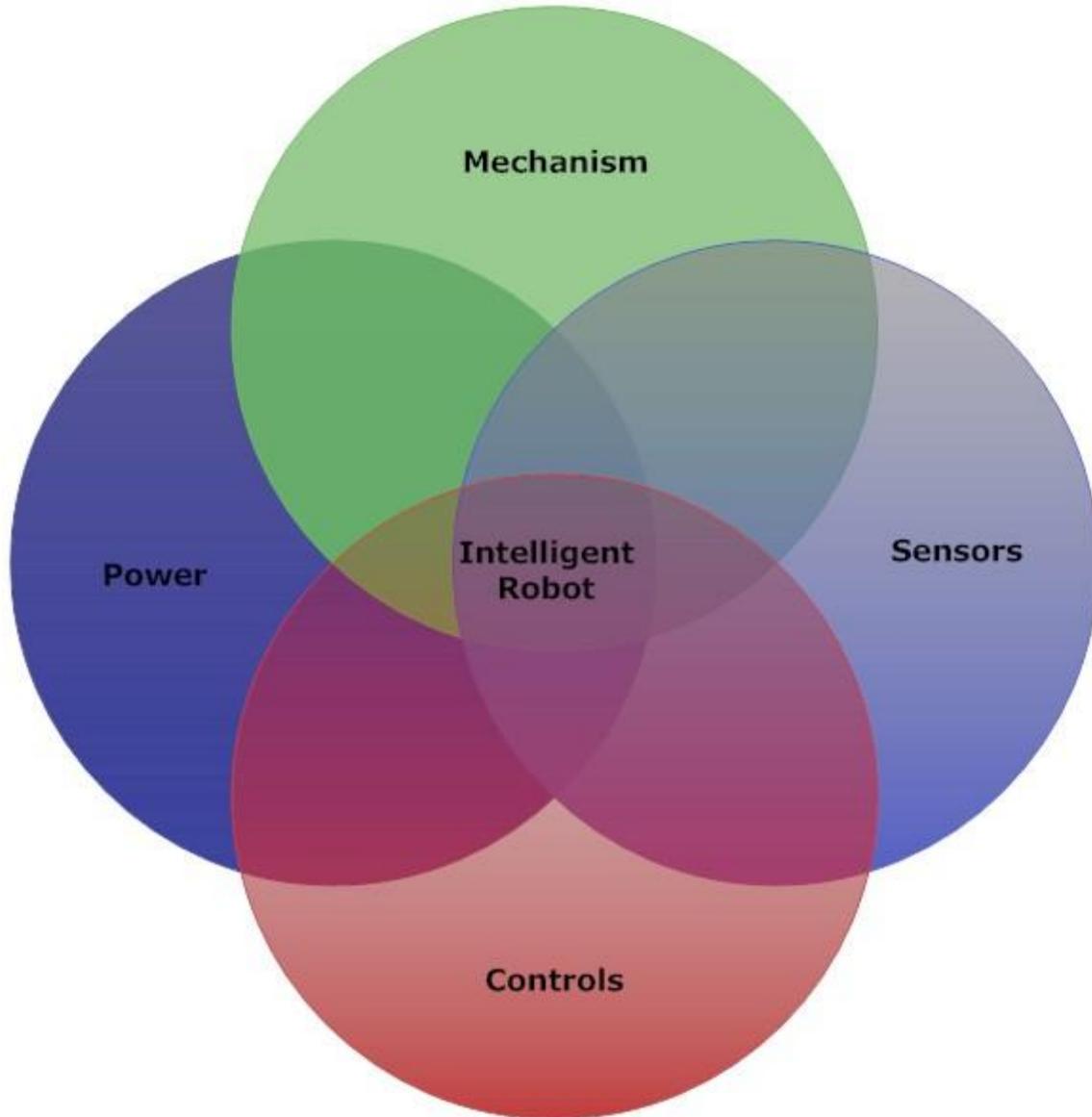


Figure 1. Intelligent robot components.

Petascale computers are machines capable of conducting 10^{15} floating-point operations per second (petaflops). These parallel machines may employ more than a million processors. With such computing power and storage comparable to the human brain, we approach the capability of controlling a robot as complicated as the human body.

In a previous paper, the concept of eclecticism for the design, development, simulation and implementation of a real time controller for an intelligent, vision guided robots was introduced.² The use of an eclectic perceptual, creative controller that can select its own tasks and perform autonomous operations was illustrated. This eclectic controller is a new paradigm for robot controllers and is an attempt to simplify the application of intelligent machines in general and robots in particular. The idea is to use a task control center and dynamic programming approach with learning and multi criteria optimization.

Dynamic Programming

The intelligent robot can be considered as a set of problems in dynamic programming and optimal control as defined by Bertsekas³.

Dynamic programming (DP) is the only approach for sequential optimization applicable to general nonlinear, stochastic environments. However, DP needs efficient approximate methods to overcome its dimensionality problems. It is only with the presence of artificial neural network (ANN) and the invention of back propagation that such a powerful and universal approximate method has become a reality.

The essence of dynamic programming is Bellman's *Principle of Optimality*:

“An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision”⁴.

The original Bellman equation of dynamic programming for an adaptive critic algorithm may be written as shown in Eq (1):

$$J(R(t)) = \max_{u(t)} (U(R(t), u(t)) + \frac{\langle J(R(t+1)) \rangle}{(1+r)} - U_0) \quad (1)$$

where $R(t)$ is the model of reality or state form, $U(R(t), u(t))$ is the utility function or local cost, $u(t)$ is the action vector, $J(R(t))$ is the criteria or cost-to-go function at time t , r and U_0 are constants that are used only in infinite-time-horizon problems and then only sometimes, and where the angle brackets refer to expected value.

We have found that in many modern problems the criteria function, J , changes during the trajectory to the goal requiring a solution of the form shown in Eq (2):

$$J(R(t)) = \sum_{i=1}^N J_i(R(t)) \quad (2)$$

Where J_i is the criteria over segment i of the trajectory for the total problem. This permits the solution of a problem that consists of both decision problems and estimation problems.

Proof by Demonstration

The UC Robot Team is attempting to exploit its many years of autonomous ground vehicle research experience to demonstrate its capabilities for designing and fabricating a variety of smart vehicles for autonomous unmanned systems operation with a variety of proofs by demonstration as shown in Figures 2, 3 and 4.



Figure 2. Bearcat Cub intelligent vehicle designed for IGVC



Figure 3. Jeep prototype at UC



Figure 4. Hybrid Vehicle

3. CONCLUSIONS AND RECOMMENDATIONS

Modern optics and computing have made enormous jumps in capabilities that permit us to redesign many current systems. The challenge is now in implementing and exploiting such concepts in practical applications. I believe that as engineers master the component technologies many more solutions to practical problems will emerge.

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