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Panel Discussion

Autonomy in Engineering Systems: What is it and Why is it Important?

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Setting the Stage: Some Autonomous Thoughts on Autonomy

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Engineering systems typically exhibit some degree of autonomy. But what exactly do we mean by autonomy? What is the significance and role of autonomy in man-made systems? Is autonomy important? How do we quantify autonomy and say that this system has greater autonomy that the other one? Why is it important to understand and strive for autonomy? These are some of the issues that will be addressed by the panelists.

As explained in dictionaries, autonomous means independent, self-governing. In biology it means independent of any other organism. Autonomy is the corresponding noun. In fact an autonomy could also mean a self-governing community or local group in a particular sphere as in religion, education etc. The term autonomous comes from the Greek autos (self) + nomos (law, rule). A related term is automaton which is a contrivance or apparatus that appears to function of itself by the actions of a concealed mechanism. Another term is automatic which means self moving, self-regulating, self-acting, that is having a self-acting mechanism by which certain operations are performed under predetermined conditions: an automatic pilot.

Being autonomous must be very desirable! Through the centuries nations have fought long wars to preserve their autonomy and/or reduce the autonomy of somebody else. Having an autonomous system working for you has always been appealing. Robots performing all kinds of important and sometimes boring or dangerous tasks have always captured our imagination.

What is meant by the term autonomous in modern engineering systems? Engineering systems are built to perform certain tasks and goals under changing conditions which are either caused by external disturbances or internal parameter variations. For example, the cruise control in a car is designed to keep the car speed at certain level (goal) under a variety of plant conditions (cold or hot engine, age of car etc.) even though the grade of the road changes (external disturbances). Each engineering system has certain degree of autonomy associated with it; here autonomy means independence from an outside supervisor, which may be another engineering system or a human. The degree of autonomy can be seen as an operating region (operating sphere) defined by a set of parameters within which the system acts on its own in a safe manner towards the goal. For instance in the example of the car speed control, a typical cruise control system can keep the car speed at acceptable levels only when the road is not too steep. And such control system has certain degree of autonomy as it acts appropriately within its operating region, which is specified by the initial design of the system. We could build cruise control systems with larger operating regions satisfying the goal of keeping the speed at a preset desired level. One way to achieve this is to anticipate, via perhaps a vision system an upcoming steep grade and prepare for it by shifting gears or accelerating slightly, which is exactly what human drivers typically do. We could also have car speed control systems that may attain additional goals thus increasing even more their operating regions. For example we could add a control system to the car that maintains approximately the same speed as the car in the front, and in addition it adjusts the distance between the cars depending on the speed, for safety reasons. It is clear that these two control systems taken together can satisfy a set of goals under quite diverse conditions.

It is then appropriate to always talk about autonomy of a system with respect to some goal or a set of goals. That is, autonomy without clearly identified goals, autonomy for the sake of autonomy is not interesting, if we want to build useful engineering systems.

We should also specify the degree of autonomy which relates to the degree of outside supervision needed to achieve the goal or goals. The degree of autonomy may be quantified by characterizing the safe operating region within which the system acts appropriately. This region in control systems is sometimes referred to as region of uncertainty and it is characterized by certain norm measures, when of course normed spaces are appropriate. Control systems that act appropriately in these uncertainty regions are called robust with respect to these uncertainty regions and with respect to goals such as stability (typically Lyapunov asymptotic stability) or performance.

High degree of autonomy would imply perhaps that the system may also adjust its own set of goals. For example a future car speed control system could set its own speed depending on conditions and destination, it could decide whether to follow another car or it could disengage and switch to a low speed mode, when say the vision system identifies a pedestrian getting ready to cross the street. That is, high autonomy systems exhibit abilities that are considered intelligent if done by humans. For high autonomy adaptation and learning become essential.

Autonomy in engineering systems and its relation to intelligent behavior was briefly discussed in [1]. In [2-4] the quest for autonomy was identified as a consistent driving force in the development of control systems from conventional to intelligent.

[1]. "Defining Intelligent Control", Report of the Task Force on Intelligent Control, P.J. Antsaklis, Chair. In IEEE Control Systems Magazine, pp. 4-5 & 58-66, June 1994.

[2]. P. J. Antsaklis, K.M. Passino and S. J. Wang, "Towards Intelligent Autonomous Control Systems: Architecture and Fundamental Issues", Journal of Intelligent and Robotic Systems, Vol. 1, pp. 315-342, 1989.

[3]. An Introduction to Intelligent and Autonomous Control, P.J. Antsaklis and K.M. Passino, Editors, Kluwer Academic Publishers, 1993.

[4]. P.J. Antsaklis, "Intelligent Control," Encyclopedia of Electrical and Electronics Engineering, John Wiley & Sons, Inc., 1998.