» 25 YEARS AGO

In this issue, "25 Years Ago" revisits the article "Emerging Technologies in Control Engineering," by Marc Bodson in *IEEE Control Systems Magazine*, vol. 14, no. 6, pp. 10–12, 1994. Below is an excerpt from the article.

Despite complaints often heard from researchers that control theory is a mature field whose important problems have been solved, it seems that there are more practical control problems and more opportunities for innovation than ever before. Not only are conventional applications increasingly in need of sophisticated control methods, but exciting new problems are emerging that pose completely new challenges to control system designers.

The purpose of this special issue is to provide an overview of emerging technologies that are expected to become major areas of application for control systems technology.

The technologies that were selected were chosen due to their importance (especially in economic terms) and due to their relevance to the field of control. They are:

- intelligent vehicle highway systems
- semiconductor manufacturing
- mechatronics, and
- microelectromechanical systems.

While these subjects are all *applications* of control, rather than new *methodologies* for control, the underlying concept of this special issue is not that new theories are not emerging. As a matter of fact, one of the papers discusses nonlinear control methodologies that were developed just over the last five to ten years. Nevertheless, the emphasis on applications reflects a current situation where control researchers are increasingly required to be involved in state-of-the-art applications to demonstrate the value of their research. Further, the emerging technologies promise to bring new excitement to the engineering side of control, and to help formulate new theoretical problems.

INTELLIGENT VEHICLE HIGHWAY SYSTEMS

Concepts of intelligent vehicle highway systems (IVHS) were proposed many years ago, but suddenly received a surge of interest, due to

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congestion problems becoming critical, and due to the practical impossibility of adding new freeways in the congested areas.

Control problems in this area of technology cover a wide span, ranging from low-level numerical control (longitudinal and lateral vehicle control) to high-level, discrete-event control (scheduling).

SEMICONDUCTOR MANUFACTURING

It is no secret that manufacturing is a sector critical to the health of the overall economy, yet one in serious need of help and innovation. The need for control engineers to take a more active part in research in this area has also been recognized. Semiconductor manufacturing in itself is an important subset of manufacturing, and there have been concerns that state-of-the-art equipment was not as easily available to U.S. semiconductor manufacturing as to competitors [3]. Further, feedback control has been identified as one of the most important technologies needing to be incorporated in semiconductor manufacturing.

MECHATRONICS

Mechatronics is the combination of mechanics, electronics, and control. The emergence of this technology followed progress in power electronics (switching electronics) and computing technology. Opportunities for sophisticated control systems span from the low power range, (e.g., motion control systems used in manufacturing) to the high power range (transportation and aerospace). Overall, mechatronics covers an area of huge economic importance.

MICROELECTROMECHANICAL SYSTEMS

The field of microelectromechanical systems (MEMS) has grown tremendously over the last few years. MEMS devices have sizes ranging from a few millimeters to a few microns and are fabricated using micromachining techniques or integrated circuit fabrication methods. While preliminary concepts for the use of these devices were elaborated on as early as in the late 1950s [4], recent ideas have been very concrete, and the results have found their way even into consumer products. Applications include process instrumentation, automotive electronics, medical instrumentation, and aerospace.

Microstructures and microactuators are slower in finding their way into commercial products, yet are the real target of opportunity for control engineers. Concrete applications with potentially significant benefits are being studied, including:

- monitoring and control of airflow over aircraft wings to control turbulence
- optimization of performance of combustion and jet engines, through distributed flow control, and
- microsurgery (especially for blood vessels and nervous system repairs).

Various actuators have already been studied, including some based on electrostatic, electromagnetic, piezoelectric, magnetostrictive, and fluidic principles [5]. Of course, applications such as microsurgery would involve far more than microactuators, i.e., microrobots. In general, one problem for control theory that is expected to emerge from this area is that of distributed control with a large number of degrees of freedom (such as for flow control).

CONCLUSIONS

While space constraints limit the number of areas of technology that can be covered, and the extent of this coverage, we hope that this special issue will nevertheless provide a useful introduction to several emerging technologies where one can expect significant and exciting developments in the next decades.

REFERENCES

[3] M. Elta et al., "Applications of control to semiconductor manufacturing: Reactive ion etching," in *Proc. Automatic Control Conf.*, San Francisco, CA, June 1992, pp. 2990–2997.

[4] R. P. Feynman, "There's plenty of room at the bottom," *J. Microelectromech. Syst.*, vol. 1, no. 1, pp. 60–66, 1992 (Transcript of a talk given in December 1959 at the Annual Meeting of the American Physical Society).

[5] R. T. Howe, R. S. Muller, K. J. Gabriel, and W. S. N. Trimmer, "Silicon micromechanics: Sensors and actuators on a chip," *IEEE Spectr.*, vol. 27, no. 7, pp. 29–35, July 1990.

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