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| MIMO Control  system |
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# Multi Input Multi Output

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| Description of MIMO control system. **S**ingle variable **I**nput or **S**ingle variable **O**utput (SISO) control schemes are just one type of control scheme that engineers in industry use to control their process. They may also use MIMO, which is a **M**ulti-**I**nput-**M**ulti-**O**utput control scheme. In MIMO, one or more manipulated variables can affect the interactions of controlled variables in a specific loop or all other control loops. A MIMO control scheme is important in systems that have multiple dependencies and multiple interactions between different variables- for example, in a distillation column, where a manipulated variable such as the reflux ratio could directly or indirectly affect the feed flow rate, the product composition, and the reboiler energy. Thus, understanding the dependence of different manipulated and controlled variables in a MIMO control scheme could be extremely helpful in designing and implementing a control scheme for a process.  One method for designing and analyzing a MIMO control scheme for a process in steady state is with a **R**elative **G**ain **A**rray (RGA). RGA is useful for MIMO systems that can be decoupled (see the article about determining if a system can be decoupled). For systems that cannot be decoupled, model predictive control or neural networks are better choices of analysis tool than RGA. A good MIMO control scheme for a system that can be decoupled is one that can control a process variable without greatly affecting the other process variables. It must also be stable with respect to dynamic situations, load changes, and random disturbances. The RGA provides a quantitative approach to the analysis of the interactions between the controls and the output, and thus provides a method of pairing manipulated and controlled variables to generate a control scheme. |
| What is RGA? **R**elative **G**ain **A**rray is an analytical tool used to determine the optimal input-output variable pairings for a multi-input-multi-output (MIMO) system. In other words, the RGA is a normalized form of the gain matrix that describes the impact of each control variable on the output, relative to each control variable's impact on other variables. The process interaction of open-loop and closed-loop control systems are measured for all possible input-output variable pairings. A ratio of this open-loop 'gain' to this closed-loop 'gain' is determined and the results are displayed in a matrix. |
| Understanding the Results of the RGA  * The closer the values in the RGA are to 1 the more decoupled the system is * The maximum value in each row of the RGA determines which variables should be coupled or linked * Also each row and each column should sum to 1   **Difference between SISO & MIMO**  **MIMO:**  Multiple input, multiple output (MIMO) systems **describe processes with more than one input and more than one output which require multiple control loops**. These systems can be complicated through loop interactions that result in variables with unexpected effects.  **SISO:**  **single-input and single-output (SISO) system is a simple single variable control system with one input and one output. In radio it is the use of only one antenna both in the transmitter and receiver**  **to clarify this abstraction suppose taking communication system as example :**   * In SISO system only one antenna is used at transmitter and one antenna is used at Receiver while in MIMO case multiple antennas are used. Figure depicts 2x2 MIMO case. * MIMO system achieves better Bit Error rate compare to SISO counterpart at the same SNR. This is achieved using technique called STBC (Space Time Block Coding). With STBC coverage can be enhanced. * MIMO system delivers higher data rate due to transmission of multiple data symbols simultaneously using multiple antennas, this technique is called as Spatial Multiplexing (SM). With SM data rate can be enhanced. * MIMO with SM and beamforming can be employed to obtain enhancement to both the coverage and data rate requirement in a wireless system      Where is MIMO used?  * MIMO technology is used for Wi-Fi networks and cellular fourth-generation (4G) Long-Term Evolution (LTE) and fifth-generation (5G) technology in a wide range of markets, including law enforcement, broadcast TV production and government. * Examples of MIMO systems include heat exchangers, chemical reactors, and distillation columns. These systems can be complicated through loop interactions that result in variables with unexpected effects. Decoupling the variables of that system will improve the control of that process.  MIMO Controller:A MIMO Control and Signal Processing Example An extraordinary problem of great current interest is that of canceling noise in the passenger compartment of commercial aircraft. A new generation of airplanes is being developed using a combination of turbojet engines and propellers that promises to be 30 to 40 percent more fuel efficient than the best turbojet airplanes flying in the mid 1990s. The engines and pusher propellers will most likely be mounted at the tail. A serious drawback is the increase in cabin noise resulting from the use of propellers. We propose to utilize adaptive inverse control systems of the MIMO type to control and cancel noise due to the turbojet engines and the propellers.  Referring to Fig. 10.22(a), we see the aircraft with a turbine-driven propeller at the rear. We assume that there will be two engines and two propellers, and that they will be synchronized. Thus, obtaining a single reference signal from a sensor on the shaft of one of the engines should be sufficient. We will need to obtain signals corresponding to the fundamental and harmonics of the turbine blades, and the fundamental and harmonics of the propeller blades. A single reference signal containing a sum of all those components would be satisfactory. The shaft sensor signal might need to undergo nonlinear processing to generate all the important harmonics.  The proposed approach to the problem of canceling the noise is presented in Fig. 10.22(b). Each passenger seat has an internal microphone located approximately at the passenger's head level. Loudspeakers are placed inside the aircraft cabin at some distance away from each other and from the microphones. The engine reference signal is fed to an adaptive noise canceler. The microphone signals are also fed to the adaptive canceler. The output of the canceler is a set of loudspeaker signals, obtained by optimally filtering the engine reference signal and intended to drive the loudspeakers so that their acoustic outputs will cancel the ambient engine and propeller noise in the vicinity of the microphones, near the heads of the passengers. The system illustrated uses two microphones and two loudspeakers. The number of microphones and loudspeakers could be increased as required.  The objective for the adaptive system is to generate the loudspeaker signals in order to minimize the sum of the powers of the microphone outputs. The microphone outputs are the error signals of the system. Figure 10.23 is a schematic diagram showing the origin and the propagation paths of the engine and propeller noise and the loudspeaker sound output. Each microphone senses the sound, a sum of these components, and outputs an electrical signal in accord with its acoustic to electrical transfer function. Adaptive filters drive the loudspeakers. Their inputs come from the common engine reference signal. The question is: How should one adapt the adaptive filters?  An answer to this question comes from the block diagram of Fig. 10.24. The microphone signals, the error vector of the system, are minimized in the mean square sense (minimize the mean of the sum of the squares of its components) by using the filtered-є algorithm of the MIMO type to adapt the controller [Ĉ]. To filter the error, we need a delayed *plant inverse.*The way to get this inverse is shown in Fig. 10.25  **Figure 10.22**Aircraft noise problem and adaptive system for its mitigation.    **Figure 10.23**Schematic of noise propagation paths and noise canceling system.    **Figure 10.24**Vector block diagram of adaptive aircraft noise-canceling system. |

**Figure 10.25**Plant modeling and inverse modeling for the aircraft noise-canceling system.

The noise canceling system diagrammed in Figs. 10.22–10.25 uses adaptive inverse control techniques to control noise for the passengers in an aircraft. Once again, one can see the close relationship that exists between control problems and signal processing problems. In many cases, they are really quite the same.

The noise canceling system described above can be used to simultaneously cancel noise at more than two microphones. The number of canceling loudspeakers should be equal to the number of microphones. Other ways using adaptive MIMO techniques could be employed to solve this problem. For example, without using an engine reference signal, the microphone signals alone could be adaptively filtered making a MIMO version of the earphone noise canceling system illustrated in Figs. 8.13–8.14. The noise coming from the microphones would be treated like plant noise, and the loudspeaker outputs would be used to cancel this noise. Many other ways can be thought of to approach and solve this important noise canceling problem.

The First International Conference on Active Control of Sound and Vibration was held at Virginia Polytechnic Institute, April 15-17,1991. The meeting was sponsored by NASA Langley Research Center, Office of Naval Research, and the U.S. Army Aerostructures Directorate. The *Conference Proceedings*were published by Technomic Publishing Co., Inc. (851 New Holland Ave., Box 3535, Lancaster, PA, 17604, USA, Fax: (717)295-4538). The *Proceedings*were edited by Professors C.A. Rogers and C.R. Fuller of Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Papers were presented describing work on the above problem by British Aerospace and others. Many papers reported on canceling fan noise in air conditioning ducts, canceling auto exhaust noise, and canceling road noise in cars. Most of these projects make use of the filtered-X LMS algorithm. Adaptive noise and vibration canceling has become a major new field.