OPTIMAL CONTROL OF 3D CHANNEL FLOW

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The automatic sensing and containment of a chemical or biological cloud in a passenger terminal, transportation tunnel, tall building or a channel conveying water to a municipality is vital because of its catastrophic potential to human life. This paper describes the construction of a prototype at laboratory scale and the development and application of a novel technology for the automatic detection and real-time control of accidental or deliberate chemical releases in a conduit containing an ambient fluid. Microsensor arrays capable of detecting a broad menu of chemical and biological agents are installed at strategic locations in the prototype channel. The sensors detect the instantaneous, spatially distributed concentration of the chemical agent and transmit the associated information to a predictive control model. The model provides optimal operation scenarios for computer controlled bleed valves mounted on the channel wall and connected to a common manifold through a double wall construction around the channel. Mitigation and final elimination of the chemical cloud is achieved by optimal blowing and suction of ambient fluid or injection of counteracting chemicals. The predictive control model employs a Large Eddy Simulation model [1] for three-dimensional flow and fate and transport [2]. Gradient information is obtained by use of the Adjoint Equations [3], so optimization of the control actions is achieved with the highest possible efficiency. The control is optimized over a finite prediction horizon and instructions are sent to the valve manifold, which attempt to intercept the chemical cloud [4]. The sensor arrays detect all changes effected by the control and report them to the control model, which advances the process over the next finite horizon. Sensing, optimization and feedback is achieved in a time period shorter than the prediction horizon, so the process can proceed in real time. The sensors are tested under hostile environmental conditions, different fluid velocities and chemical concentrations. The optimal location, density and configuration of sensors and actuators is established for a variety of chemical agents.

References

[1] Bardina, J., Ferziger, J. and Reynolds, W. (1983) "Improved turbulence models based on large eddy simulation of homogeneous, incompressible turbulent flows," *Technical Report TF-19. Dept. of Mechanical Engineering*, Stanford University.

[2] Bradford, S. and Katopodes, N.D., "Monotonicity Preserving Model for Free-Surface Flow with Sharp Density Fronts," *Estuarine and Coastal Modeling*, November 1999

[2] Cacuci, D.G. (1981) "Sensitivy Theory for Nonlinear Systems. I. Nonlinear Functional Analysis Approach," *Journal of Mathematical Physics*, Vol. 22, No. 12, 2794-2802.

[4] Vandelli, N., Wroblewski, D., Velonis, M. and Bifano,T. , (1998) "Development of a MEMS Microvalve Array for Fluid Flow Control," *Journal of microelectromechanical Systems*, Vol 7, no 4, pp 395.

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