

## Papers

- 1. Output Feedback Control for a Class of Nonlinear Systems, Keylan Alimhan<sup>†</sup>, Hiroshi Inaba**
- 2. Limiting Behaviour in Parameter Optimal Iterative Learning Control, D.H.Owens, M. Tomas-Rodriguez, J.J. Hatonen**
- 3. Frame work of combined adaptive and non..adaptive attitude control system for a helicopter experimental system, Akira Inoue and Mingcong Deng**
- 4. Modeling and Control of Hybrid Machine Systems – a five-bar mechanism case, Hongnian Yu**
- 5. Soil Parameter Identification for Wheel-Terrain Interaction Dynamics and Traversability Prediction, Suksun Hutangkabodee, Yahya H Zweiri, Lakmal D Seneviratne, Kaspar Althoefer**
- 6. Real-time Design Constraints in Implementing Active Vibration Control Algorithms, M. A. Hossain and M. O. Tokhi\***
- 7. Dynamics and Stability of Blind Grasping of a 3-Dimensional Object under Non-holonomic Constraints, Suguru Arimoto\*, Morio Yoshida, and Ji-Hun Bae**
- 8. Joint Motion Control of a Powered Lower Limb Orthosis for Rehabilitation, Nelson Costa, M. Bezdicek, M. Brown, J.O. Gray and D.G. Caldwell**
- 9. Extraction of Robot Primitive Control Rules from Natural Language Instructions, G. Wang and P. Jiang**

## **Editorial By Guest Editors**

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The research on application of control theory into robotics and intelligent machines is one of six key future application researches of control engineering identified in a report [1] by the leading control experts in control community. This special issue focuses on the research conducted in robotics and intelligent machines. The papers in this special issue are selected from the workshop on The TDU COE-UK EPSRC Workshop on Human Adaptive Mechatronics organized by Professor Hiroshi Inaba and Professor Hongnian Yu and held at Tokyo Denki University (TDU), Japan, 25 July 2005, and the invited papers from the experts in the field. The special issue including nine papers covers three themes, 1) new control methodologies, 2) automation and mechatronics, and 3) robotics.

Theme one has two papers in new control methods. The first paper, Output feedback control for a class of nonlinear systems, is contributed by Keylan Alimhan and Hiroshi Inaba. The paper investigates the global stabilization problem using an output controller for a family of uncertain nonlinear systems whose dynamic may not be exactly known but satisfies the triangular-type conditions. Using a feedback domination design method, a dynamic output compensator which globally stabilizes such an uncertain nonlinear system, is explicitly constructed. The second paper, Limiting Behaviour in Parameter Optimal Iterative Learning Control, is contributed by D.H.Owens, M. Tomas-Rodriguez, and J.J. Hatonen. The paper analyses the concept of Limit Set in Iterative Learning Control. The existence of stable and unstable parts of Limit Set is considered and is demonstrated that there will often exist in practice. This is illustrated via a 2-dimensional example where the convergence of the learning algorithm is analyzed from the errors dynamical behavior. These ideas are also extended to N-dimensional cases by analogy and example.

The second theme has four papers in automation and mechatronics. The third paper, Frame work of a combined adaptive and non-adaptive attitude control scheme for a helicopter experimental system, is contributed by Akira Inoue and Mingcong Deng. The paper presents a framework of a combined adaptive and non-adaptive attitude control scheme for a helicopter experimental system. The design method is based on a combination of adaptive nonlinear control and non-adaptive nonlinear control. Concerning with the detailed attitude control system design, two kinds of control

system frameworks are shown for the different application cases. The fourth paper, Modeling and control of hybrid machine systems – a five-bar mechanism case, is contributed by Hongnian Yu. The paper investigates the dynamic modelling of a hybrid machine with a five-bar mechanism using the Lagrangian formulation. Several important properties which are very useful in the system analysis and control system design are presented. Based on the developed dynamic model, two control approaches, computed torque and combined computed torque and slide mode control, are adopted for controlling the hybrid machine system. The simulation results demonstrate the control performance and limitation of each control approach. The fifth paper, Soil Parameter Identification for Wheel-Terrain Interaction Dynamics and Traversability Prediction, is contributed by Suksun Hutangkabodee, Yahya H Zweiri, Lakmal D Seneviratne, Kaspar Althoefer. The paper presents a novel technique for identifying soil parameters for a wheeled vehicle traversing an unknown terrain. The identified soil parameters are required for predicting vehicle drawbar pull and wheel drive torque which, in turn, can be used for traversability prediction, traction control, and performance optimization of a wheeled vehicle on unknown terrain. The proposed technique is based on the Newton Raphson method. An approximated form of the wheel-soil interaction model based on Composite Simpson's Rule is employed for this purpose. The identified soil parameters can effectively be used to predict drawbar pull and wheel drive torque with good accuracy. The use of identified soil parameters to design a traversability criterion for wheeled vehicles traversing unknown terrain is presented. The sixth paper, Real-time design constraints in implementing active vibration control algorithms, is contributed by M. A. Hossain and M. O. Tokhi. The paper presents an investigation into the analysis and design mechanisms that will lead to reduction of the execution time in implementing real-time control algorithms. The proposed mechanisms are exemplified by means of one algorithm, which demonstrates the applicability of these mechanisms to real-time applications. An active vibration control (AVC) algorithm for a flexible beam system simulated using the finite difference (FD) method is considered to demonstrate the effectiveness of the proposed methods. A comparative performance evaluation of the proposed design mechanisms is presented and discussed through a set of experiments.

Theme three has three papers in robotics. The seventh paper, Dynamics and Stability of Blind Grasping of a 3-Dimensional Object under Non-holonomic Constraints, is contributed by Suguru Arimoto, Morio Yoshida, and Ji-Hun Bae. The paper derives a mathematical model expressing motion of a pair of multi-DOF robot fingers with hemi-spherical ends grasping a 3-D rigid object with parallel flat surfaces together with non-holonomic constraints. By referring to the fact that human grasp an object in the form of precision prehension dynamically and stably by opposable forces between the thumb and another finger (index or middle finger), a simple control signal constructed from finger-thumb opposition is proposed and shown to realize stable grasping in a dynamic sense without using object information or external sensing (this is called "blind grasp" in this paper). Stability of grasping with force/torque balance under non-holonomic constraints is analyzed on the basis of a new concept named "stability on a manifold". A few of preliminary simulation results is shown to verify the validity of theoretical results. The eighth paper, Joint motion control of a powered lower limb orthosis for rehabilitation, is contributed by Nelson Costa, M. Bezdicek, M. Brown, J.O. Gray and D.G. Caldwell. The paper reports on the design and control of a new "human friendly" orthosis powered by high power pneumatic Muscle Actuators. The combination of a highly compliant actuation system with an intelligent embedded

control mechanism which senses hip, knee and ankle position, velocity, acceleration and force producing a powerful yet inherently safe operation for paraplegic patients. The paper analyzes the motion of the ankle, knee and hip joints under zero loading and loads simulating human limb mass and shows that the use of these “soft” actuators can provide a smooth, user friendly motion. The application of this technology will greatly improve the rehabilitative protocols for paraplegic patients. The ninth paper, Extraction of robot primitive control rules from natural language instructions, is contributed by G. Wang and P. Jiang. The paper investigates a support-vector rule based method for the construction of motion controllers via natural language training. It is a two-phase process including the motion control information collection from the natural language instructions and the motion information condensation with the aid of support vector machines theory. Self-organizing fuzzy neural networks are utilized for the collection of control rules, from which the support vector rules are extracted to form a final controller to achieve any given control accuracy. In this way, the number of control rules is reduced and the structure of the controller becomes tidy, which makes the controller constructed by natural language training more appropriate in practice and provides a fundamental rule base for high-level robot behavior control. Simulations and experiments on a wheeled robot are carried out to illustrate the effectiveness of the method.

#### Reference

- [1].RM Murray, KJ Astrom, SP Boyd, RW Brockett and G Stein, “Future Directions in Control in an Information-Rich World”, IEEE Control Systems Magazine, April 2003.