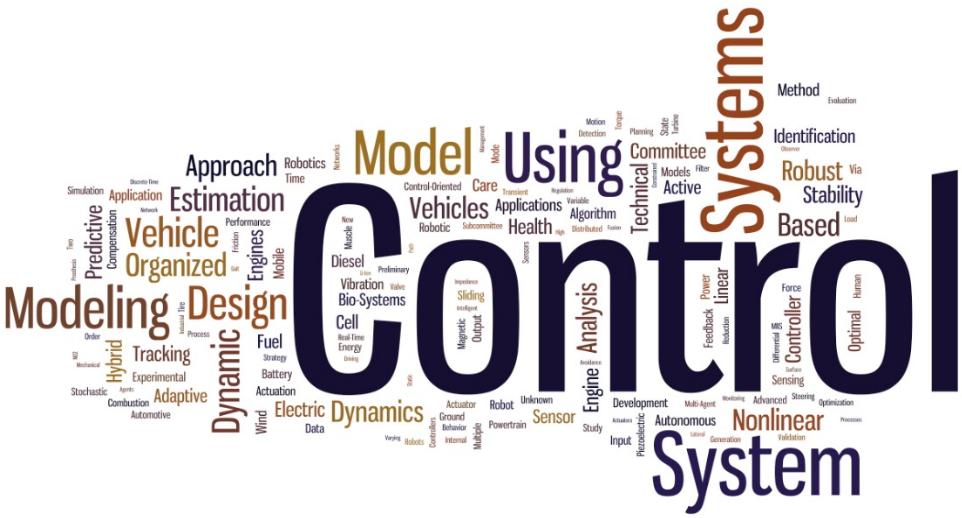
DSCD Newsletter Summer 2016

August 1, 2016



DYNAMIC SYSTEMS AND CONTROL DIVISION NEWSLETTER

IN THIS ISSUE

Editor's Note

Dear colleagues,

We are presenting the third DSCD newsletter dedicated to "special topics". As a reminder, our focus is to let members of the DSCD share their recent works which are of broad interest to the community. This allows for publication of articles which are not currently suitable for journal or conference publications.

The current issue includes a description of an outstanding informative contribution from our colleague Dr. Shaohui Foong of Singapore University of Technology & Design. The article describe a series of two undergraduate control courses with hand-on interactive laboratory sessions offered in a collaborative learning environment.

In addition, we have included the 2016 ASME Dynamic Systems Conference information, a call for paper announcement for the 107 American Control Conference and a call for paper announcement for a new journal.

We look forward to your future contributions and continued support of the newsletter.

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A Design-Centric Control Education with a Competitive Flavor

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The objective of this note is to share the pedagogical model and practice of incorporating the art and science of design and technology into a multi-disciplinary curriculum at the Singapore University of Technology and Design (SUTD). Established in close collaboration with the Massachusetts Institute of Technology (MIT), SUTD seeks to nurture technically-grounded leaders and innovators in engineering product development (EPD), engineering systems and design, information systems technology and design, and architecture and sustainable design, to serve societal needs. One of the hallmarks of the SUTD design-centric education is integration of multi-disciplinary designettes into the curriculum. *Designettes are glimpses, snapshots, small-scale, short turnaround and well-scoped design problems that provide a significant design experience* [1]. In SUTD, designettes have evolved to be invaluable pedagogical tools for teaching fundamental engineering subject matter in combination with design processes and methods to provide students with creative pedagogical experiences across courses, time and disciplines [2]. This is in-line with the global trend of engineering education towards project-based hands-on learning in teams [3]. The main difference between project-based learning and designettes is that the former usually engages in a semester-long project resulting in a single product [4] while the latter do not need to be the focus of the entire course and can be implemented with greater finesse and efficacy. Although the realm of control engineering is filled with an abundance of stimulating, engaging and practical applications, undergraduate students usually find the content challenging due to its highly abstract nature [5]. This provides an excellent opportunity for designettes which feature inherent iterative learning cycles to provide a more proactive learning environment for the students to appreciate, absorb, experiment and reflect on designing and implementing control systems. From 2014 to 2016, a total of 292 students in 3 cohorts have undergone an innovative designette infused with a competitive spirit with great success, exemplary results and encouraging feedback.

The premise and underpinnings of designed-based learning and theoretical framework of designettes is highly influenced from the learning experience progression of the Kolb Cycle [6], pedagogical models of Bloom's Revised Taxonomy [7] and active learning, interactive engagement and constructivist theories. In particular, Kolb suggests that for effective learning, students should experience the following 4 types of activities cyclically: concrete experience, reflective observation, abstract conceptualization, and active experimentation [6]. Bloom's Revised Taxonomy multi-tiered model of thinking skills echoes this notion and suggests that students do not flourish intellectually in classes that simply require them to remember and repeat information. Instead, students benefit most from a cyclic learning pattern to achieve advanced and more mature learning [8]. Designettes are engineered to benefit students by engaging them in a cycle that advances from a phase of merely acquiring information and theories to analyzing and ultimately synthesizing information for mature applications of what they have learned in a different context [2]. SUTD employs designettes at 4 levels or dimensions: the 1D focuses on activities which connect topics within a single course; the 2D integrates concepts from multiple concurrent courses; the 3D extends the integration to multi-year thematic activities; and the 4D covers independent and extracurricular activities.

In the EPD pillar of SUTD, all undergraduate junior students in their fifth semester (14-week semester) are required to take the introductory controls class **30.101** Systems & Control (5 contact hours per week). This class is a pre-requisite for the senior level advanced control class **30.114** Advanced Feedback & Control (5 contact hours per week) which is an elective and offered during the seventh semester (8 semesters in total). Both classes are conducted in a collaborative learning classroom/ laboratory where the section class size is less than 50 and, unlike many courses where control engineering is a theory only class, both classes have integrated hands-on laboratory sessions called Interactive Investigations. The course syllabus and schedule of **30.101** is shown in Table 1 and deviates slightly from most introductory control class as it incorporates elements of fundamentals of signals and Fourier Series/Transform. The class also features bi-weekly 15 min quizzes, weekly graded homework, in-class assignments and a written closed notes written mid-term and final examinations. The 4 dimensions of designettes customized for control engineering education in SUTD can be illustrated as follows:

- *1D*: A collaborative group design assignment where students play the role of a medical device control engineer to model, identify unknown parameters and use computer packages (MATLAB) to analyze the unknown high-order system and design suitable feedback controllers to satisfy a variety of clinical requirements. A technical report is the final deliverable of this assignment.
- *2D*: A competitive race where teams of students compete to design a robotic car to navigate an obstacle ridden course using nothing more than basic line detection sensors. Grading is based on the presented autonomous capability of the robot during the contest. Tied closely with **30.007** Engineering Design & Project Engineering.
- *3D*: An individual activity where students design continuous-time state-feedback controllers for an experimental inverted pendulum in **30.101** (Term 5) and then extend the controller design for LQR and discrete-time controllers in **30.114** (Term 7). These are in-class worksheets which the students submit at the end of the interactive investigation sessions.
- *4D*: Through Undergraduate Research Opportunities Program (UROP) and existing faculty research projects, students design, build and fly autonomous unmanned aerial vehicles (UAVs). A number of these systems participate in local and international UAV competitions.

Table 1. Course syllabus and schedule of SUTD EPD introductory control class 30.101 with1D, 2D and 3D designettes integration

Week	Topics	Interactive Investigation (Hands-on Activity)	Week	Topics	Interactive Investigation (Hands-on Activity)
1	Introduction, Complex Variables, ODEs, Laplace Transform	-	8	**2D COMPETITIVE DESIGNETTE**	
2	Inverse Laplace Transform, Partial Fractions, Convolution,	Convolution Visual Animation	9	Automatic Controls, Block Diagrams, PID Controllers	Computer-based controller design (MATLAB)
3	Fourier Series and Fourier Transform	Visual Representation of Fourier Series	10	Stability Analysis, System Type, Root Locus	PID Control of a DC Motor (LabVIEW)
4	Mathematical Modelling (Mechanical), Transfer Function	Electro-Mechanical Mathematical Modelling of DC Motor (MATLAB)	11	Bode Plots, Interpreting Bode Plots	Computer-based root locus analysis and bode plots (MATLAB)
5	Mathematical Modelling (Electrical), Analogous Systems, First Order Systems	Numerical Analysis of DC Motor (MATLAB)	12	State Space Representation	State-Space Modelling of Inverted Pendulum (MATLAB) **3D DESIGNETTE**
6	Second Order Systems, Thermal/Fluid Modelling, *MID-TERM EXAM*	Analyzing 2nd Order Systems (Spring-Mass System / Pendulum)	13	Full State Feedback, **1D DESIGNETTE**	State-Space Control of Inverted Pendulum (LabVIEW) **3D DESIGNETTE**
7	*RECESS*		14	Review, *FINAL EXAM*	

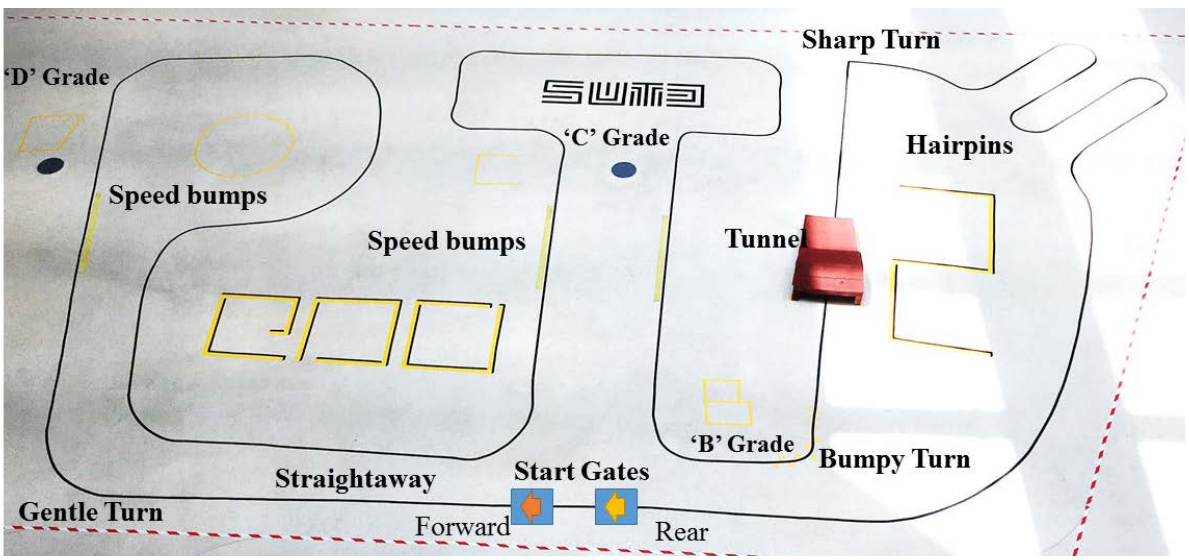


Figure 1. Layout of the line-following track with obstacles. It is designed with increasing difficulty as the track progresses clockwise.

The 2D competitive designette is perhaps one of the more prominent activities on the SUTD campus and is also revered as a renowned trademark of the course. In groups of 4-5 students, with limited supply of sensors, each team is to design, build and implement a feedback system and controller onto a differential drive wheeled robot that will allow it to *launch* and *traverse* around a line track riddled with obstacles *fully autonomously*. The designette culminates with a public, pulsating head-to-head single elimination tournament held at the main atrium of the SUTD Campus to determine the annual 2D Race Champion. As a fitting prize for the champions, each team member of the winning team receives spectator tickets to the Singapore Formula 1 Grand Prix held later in the year! To facilitate the designette, week 8, which is designated the 2D week, all **30.101** class time is dedicated for students to participate and engage in the challenge. There is no new content or assignments due during 2D week so students can fully concentrate at the task at hand.

The single lane line track is constructed using black electrical tape and covers a total length of almost 30 m (this discourages hard coding). As shown in Figure 1, the spatial layout of the circuit spells out 'PID' as a tribute and features many elements found in off-road rally racing (which is the theme of the 2016 edition) such as hairpins, gentle and sharp turns, speed bumps, obstacles and even a tunnel! Also installed at the main straightaway are two intelligent start gates where teams can place their stationary robot inside. These start gates (shown in

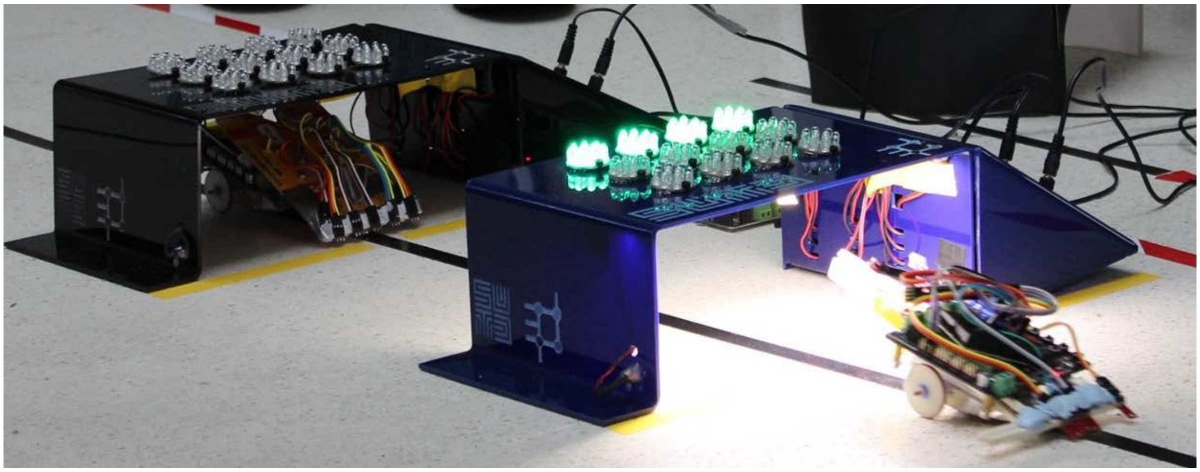
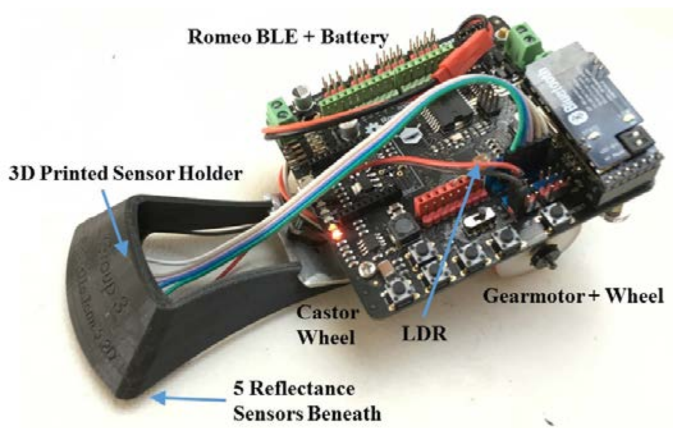
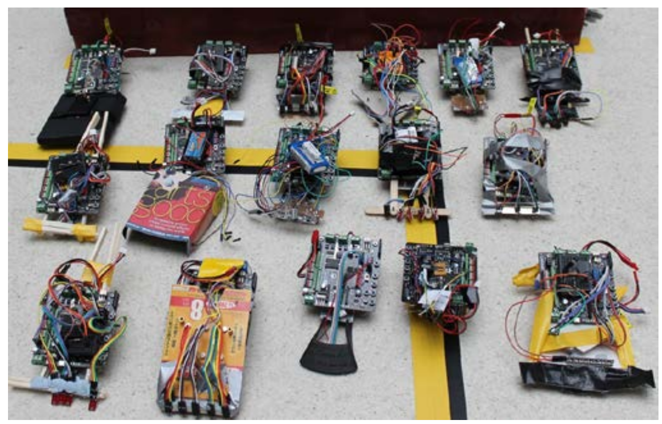


Figure 2. The intelligent start boxes (left: rear, right: forward) with exterior status and interior start LEDs.



(a) A modified robot with reflectance sensors mounted using a 3D printed bracket. An LDR placed at the top allows the robot to detect the start optical signal.



(b) A diverse collection of robotic designs for autonomous line following capabilities.

Figure 3. Autonomous line following robots design, built and implemented using feedback control

Figure 2) are fitted with exterior LED lights to denote countdown and ultra-bright interior LEDs that flood the inside of the gate with bright light to convey to the robot to commence its run. When the robot completes a full circuit (clockwise circuit), a laser emitter and receiver pair with a real-time clock in the start gate provides precise detection of the lap time. Seeding for the tournament is achieved through the ranking of the fastest successful 'qualifying lap' achieved by each of the robots. During each head-to-head race, the higher rank team will get to decide if it elects to be a chaser or runner. The runner will be placed in the forward start gate and given a 20 second head start before the chaser at the rear start gate is allowed to start. There are 3 possible outcomes in each head-to-head race, resulting in either the runner or chaser to win (no draws):

- Both runner and chaser complete 1 lap. Winner is determined by faster lap time.
- Chaser catches up and touches runner. Chaser wins.
- If one or both robots run off the track and not recoverable, the total distance covered on the track at the point of exit will be used to decide winner.

While the head-to-head rules are used to determine progression in the bracket, they are not used for academic grading of the 2D challenge. Teams are graded during their qualifying lap and the ability of their robot to autonomously navigate through the course. An 'A' grade is awarded for teams completing one lap and 'B', 'C' and 'D' grades assigned for corresponding partial completion of the lap. Hence results of the competition and grading are independent.

The differential drive wheeled robot, as shown in Figure 3, is a platform which all the students have developed, assembled and tested in their concurrent class **30.007**. All teams have the exact same mechanical chassis, DC motors (Polulu micro metal gearmotor), rubber-lined wheels, castor wheel, microcontroller with integrated DC motor driver and Bluetooth (Arduino powered DFRobot Romeo BLE) and battery (2 cell lipo). To allow the robot to achieve autonomy, each team is given the following:

- **Two** light dependent resistors (LDR). This will allow the robot to automatically launch from an external light signal.

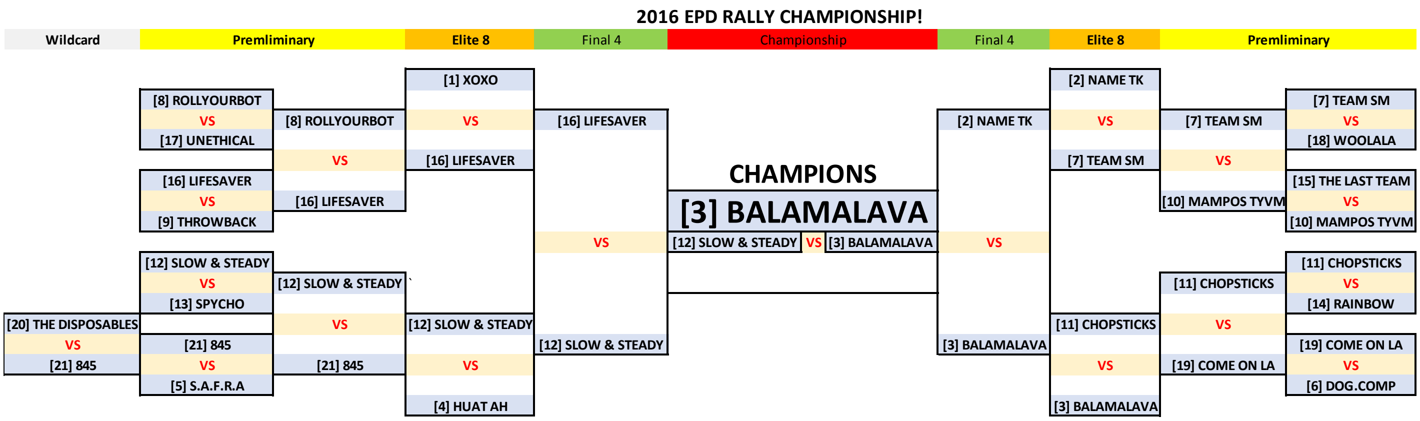


Figure 4. The final tournament bracket for the 2016 2D Championship. [#] denotes qualifying rank or seed of team. All 21 teams participated and the 3rd seed won the tournament.

- **Up to Five** reflectance sensors (Polulu QTR-1A). These non-contact sensors can distinguish between the black tape of the track and the white floor on which the track is laid.
- **One** RGB 8-pixel LED strip (Adafruit Neopixel). This is for illumination inside the tunnel or for aesthetic purposes.
- Access to rapid prototyping machines (3D printing, laser cutting, drills, bandsaws, etc.).

To achieve autonomy, students must first explore the operating principle of the reflectance sensors and how to use them to detect the track. A very obvious and simple method is to employ 2 reflectance sensors, one on each side of the black track. If either sensor can detect the black track, which means the robot is deviating and a corrective action (programmed into the microcontroller) is required to turn the robot back on track. To retrofit the sensors onto the robot, teams use a multitude of rapid prototyping approaches such as 3D printing or laser cutting. At this stage, without the student's intentional knowledge, they would have implemented a simple bang-bang feedback controller with a single Kolb learning cycle. With such a basic controller, a robot would be able to traverse the early stages of the circuit but will encounter problems as it tries to navigate through tighter turns and obstacles. The competitive element of the challenge further motivates students to improve the design through learning iterations and consider other variables such as placement of the reflectance sensors (ahead, in-line or behind the wheels), as well as separation distance between sensors (larger gives better cornering performance but poorer straight-line speed due to oscillations). As teams can use up to 5 sensors, additional sensors can be used to further enhance performance of the robots.

With regard to appreciating and understanding control systems, it is refreshing to be able to observe students be able to link material they learnt in previous weeks to direct experiential observations. One good example is the oscillatory nature of the robot as it attempts to over correct for the heading error. Most students are able to relate this to material in Second Order Systems (covered in previous weeks) and identify it as an underdamped system. As they reflect on this observation, hypothesize and experiment on avenues to reduce the unwanted oscillation (reducing the damping ratio), they would inadvertently discover that the magnitude/direction of the correcting signal is extremely important. This is the basic fundamental operating principle of a Proportional controller. Once they understood this, many teams were able to tune their Proportional controller and also implement the integral as well as the derivative portion of the PID controller. The key is being able to determine the magnitude of the instantaneous error and this can be achieved using additional reflectance sensors. This difference is quite immense. Without employing a PID feedback controller, a simple bang-bang controller configured robot can complete the entire circuit in just over 3.5 minutes. But a robot with a highly tuned PID feedback controller can traverse the entire circuit in just over 1 minute (Fastest qualifying lap was by Team XOXO - 1:07.20).

The goal of the 2D designette was to motivate students on the need for feedback control and also provide a platform for students to get a taste of autonomous technology. The 2D week is specially devised so that it occurs just before the topic of automatic control, block diagram and PID controllers are covered (see Table 1), which means the students would have no background or prior knowledge of PID controllers during the challenge week. This is done with every intention so as to invoke inductive learning rather than the norm of deductive learning. Inductive learning relies on the student's ability to notice the pattern emerging and this is accelerated by the numerous learning cycles provided by the 2D challenge. Normally conveying the principle of PID controllers to undergraduates can be difficult, as it can be a relatively abstract concept to grasp. But the students who competed in the 2D challenge were able to pick up the fundamental mathematical concepts of PID controllers with relative ease. In particular, they were able to intuitively articulate how the Proportional, Integral and Derivative terms contribute to altering the system performance.

Lastly, from the past editions of the 2D competitive designette, interestingly the fasted robot (seeded first) has never won. The fasted seeded team in 2015 and 2016 were knocked out in the semi-finals and quarter-finals respectively. In both cases, it was not because the robot was slower but because it did not launch successfully due to electrical connections. The fourth and third seed won the championship in 2015 and 2016 respectively (Full bracket results in Figure 4). However, tournament results aside, what has been most encouraging so far was that all teams, a total of 60 since 2014, have successful implemented fully autonomous qualifying laps. That is to say, all teams have so far garnered 'A's for the 2D challenge since its inception.

The author is the course lead instructor for both the introductory controls class **30.101** and advanced elective control class **30.114**. A video describing the 2D control-orientated designette can be viewed at: https://www.youtube.com/watch?v=t5qntiav1OA (Or scan accompanying QR code)

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2016 ASME Dynamic Systems and Control Conference

Minneapolis, MN, October 12-14, 2016
https://www.asme.org/events/dscc

The ninth ASME Dynamic Systems and Control Conference (DSCC) will be held in Minneapolis, Minnesota, October 12-14, 2016. The DSC Conference is the showcase technical forum of the ASME Dynamic Systems and Control Division. It provides a focused and intimate setting for dissemination and discussion of the state of the art in dynamic systems and control research, with a mechanical engineering focus. The 2016 DSC Conference Technical Program consist of sessions in all of the usual areas of interest to the Division. In addition, the conference features specific technical tracks that uniquely identify this particular DSCC. The location of the conference, in the heart of the Manufacturing and Automotive industries, makes these two areas especially appropriate for special tracks. Other special tracks include Interplay between Biology/Ecology/Life Sciences and Engineering, and Information Technology in Mechanical and Aerospace Engineering. The program includes contributed sessions, invited sessions, tutorial sessions, special sessions, workshops and exhibits.

Please register at:
https://www.asme.org/events/dscc/register
Lower early registration rates are available until September 9, 2016.

Hotel reservations can be made at:
https://www.asme.org/events/dscc/venue-travel

For more information, please visit the conference site at:
https://www.asme.org/events/dscc

2017 American Control Conference

Seattle, WA, May 24-26, 2017

The 2017 American Control Conference will be held Wednesday through Friday, May 24-26 at the Sheraton Seattle Hotel, centrally located in the heart of downtown Seattle, WA. Sheraton Seattle Hotel is near nightlife, restaurants, shopping, and entertainment, just a walk to all of Seattle's known sights such as the Seattle Waterfront, Pike Place Market, Space Needle, Seattle Aquarium, and the Washington State Ferries.

The ACC is the annual conference of the American Automatic Control Council (AACC, the U.S. national member organization of the International Federation for Automatic Control (IFAC)). National and international society co-sponsors of ACC include American Institute of Aeronautics and Astronautics (AIAA), American Institute of Chemical Engineers (AIChE), American Society of Civil Engineers (ASCE), American Society of Mechanical Engineers (ASME), IEEE Control Systems Society (IEEE-CSS), International Society of Automation (ISA), Society for Modeling & Simulation International (SCS), and Society for Industrial & Applied Mathematics (SIAM).

The 2017 ACC technical program will comprise several types of presentations in regular and invited sessions, tutorial sessions, and special sessions along with workshops and exhibits. Submissions are encouraged in all areas of the theory and practice of automatic control.

Submission deadline: Sept. 1, 2016
Submission site:
https://css.paperplaza.net/conferences/scripts/start.pl

New Journal and Call for Papers Announcements

International Journal of Intelligent Robotics and Applications (IJIRA)
http://www.springer.com/computer/ai/journal/41315

This is a new Springer journal founded by Prof. Kok-Meng Lee. The journal currently has Call for Papers for three Focused Sections (FS):
http://www.springer.com/computer/ai/journal/41315?detailsPage=press

1. FS on Intelligent Robotics for Rehabilitation and Human Assistance

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Submission deadline: August 15, 2016

Intelligent robotics plays a central role in the development of rehabilitation and human assistive robots, which is an important and increasing demand for maximizing the effectiveness/efficiency of the clinical therapy and processes, developing innovative solutions to promote independent living of senior citizens as well as persons with disability, and enhancing the power of the wearer in various environments. Recent advances in computational intelligence, and sensing and control technologies enable new applications in quantitative human motion analysis, diagnosis, monitoring and feedback allowing more autonomous personalized treatments without the need for constant therapist interaction. In an effort to disseminate current advances and identify challenges/opportunities, the focused section seeks submissions on original investigations relating to design, modeling and control of rehabilitation and human assistive robotic systems. Papers should contain both theoretical and practical/experimental results.

Potential topics include but are not limited to:
· Rehabilitation robotics
· Exoskeleton robots and power-assisting devices
· Sensors and actuators for human-assistive systems
· Prosthetic devices and assistive systems
· Modeling and control of physical human-robot interactions
· Human-centered intelligent systems
· Argumentation of motor and sensory functions

2. FS on Advances in Soft Robotics

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Submission deadline: Sept. 1, 2016

Soft robotics, inspired by biological organisms including octopuses, worms, starfish, and elephants, offers promising and innovative solutions for safe and adaptive interactions in unstructured environments and with humans. The development of soft robots presents a number of challenges in material synthesis, mathematical modeling, mechanism design, and control, and has attracted increasing attention from researchers in recent years. For instance, a soft robot comprised of sensors, actuators, and structures, all with soft, deformable, and compliant characteristics, requires advances in material development and manufacturing technology. Also, it is crucial to have distributed, effective control architecture that requires minimal computing power. Additionally, it is of great importance to develop computationally-efficient modeling tools for soft and deformable materials and structures. The goal of this focused section is to highlight some of the key advances made in the field of soft robotics.

Topics of interest for the focused section include but are not limited to:
· Electronic skin
· Soft material sensors and actuators
· Distributed sensing, actuation, and control strategies
· Mechanism design and dynamics for soft robots
· Modeling and simulation tools for soft robotics
· Enabling tools for prototyping soft robots
· Prototypes and applications

3. FS on Intelligent Robotics for Civil Infrastructure

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Submission deadline: Dec. 1, 2016

A great variety of intelligent robots are finding exciting applications in civil infrastructure. For example, in the past few years, small-size crawling and flying robots have been investigated for bridge inspection. Meanwhile, intelligent robotics and machinery of much larger size are played an important role in construction and maintenance of civil infrastructure.
Furthermore, the combination of robotics, electronics, computing and network has also thrust a significant amount of work in smart structural technologies. In an effort to disseminate current advances of various robotics technologies for large civil structures, this focused session seeks submissions in relevant areas. Papers should contain both theoretical and practical/experimental results.

Potential topics include but are not limited to:
· Robotics in construction machinery for large-scale civil infrastructure
· Mobile sensor network and robotic inspection for civil structures
· Cyber-physical civil infrastructure systems
· Prognostics, health monitoring and high-efficiency operation of large civil structures
· Robotic rehabilitation of large civil structures
· Novel actuation and control techniques for construction machinery and construction automation

These topics are of great relevance to the IEEE CSS community. Please consider submitting your work to these Focused Sections. Feel free to contact the guest editors for any questions you might have.

Manuscript Preparation
Papers must contain original contributions and be prepared in accordance with the journal standards. Instructions for authors are available online at:
http://www.springer.com/41315.
Manuscript Submission
Manuscripts should be submitted online at:
https://www.editorialmanager.com/jira. The cover letter should report and indicate the focused section names. All manuscripts will be subjected to the peer review process. If you have any questions relating to this focused section, please email one of the Guest Editors.