



KNOWLEDGE INCUBATION FOR TEQIP, IIT KANPUR

TEQIP Workshop on Control Techniques and Applications September 19 - 23, 2016



Various control techniques find applications in numerous systems ranging from aerospace systems, to robotics, and process automation. With the recent focus being on developing autonomous vehicles for carrying out sophisticated tasks, understanding system identification, state estimation and control techniques has gained importance. A group of IITK faculty who specialize in the field of control/autonomous systems with association of Knowledge Incubation for TEQIP organized a 5 day Workshop on “Control Techniques and Applications” at IIT Kanpur from September 19 to September 23, 2016. The primary objective of this workshop was to introduce the participants to advance control techniques, system identification methods, and their applications to aerospace systems like quadrotors, fixed-wing vehicles, and helicopters. Students and teachers from various academic and scientific institutions, primarily from electrical, mechanical, and aerospace engineering academic background with strong interest in control theoretic applications, enthusiastically participated in this workshop.

TOPICS DISCUSSED

- Challenge in Flight Control Systems
- Linear Control
- Dynamic Inversion
- Feedback Linearization
- Lyapunov Theory and Design
- Adaptive Control
- Optimal Control
- Design, Dynamics, and Control of Variable-pitch quadrator
- Dynamic Stability of Artillery Rockets
- Backstepping Design
- Intelligent Control
- Fuzzy Logic Control
- State Estimation
- Introduction to Model Predictive Control
- A gentle introduction to model predictive control (MPC) formulations based on discrete state space models
- Control of 4WS4WD Electric Vehicle
- Closed Rotation Sequences
- Rolling Cones and Attitude Trajectories
- Flight Control with Backstepping
- Demonstration of Autonomous Flight at IITK Flight Laboratory

LIST OF SPEAKERS

- Dr. Mangal Kothari, Department of Aerospace Engineering, IIT Kanpur
- Dr. Soumya Ranjan Sahoo, Department of Electrical Engineering, IIT Kanpur
- Dr. Laxmidhar Behera, Department of Electrical Engineering, IIT Kanpur
- Dr. Ramprasad Potluri, Department of Electrical Engineering, IIT Kanpur
- Dr. Nishchal K. Verma, Department of Electrical Engineering, IIT Kanpur
- Dr. Abhishek, Department of Aerospace Engineering, IIT Kanpur
- Prof. A K Ghosh, Department of Aerospace Engineering, IIT Kanpur
- Dr. Gaurav Pandey, Department of Electrical Engineering, IIT Kanpur
- Prof. Sachin C Patwardhan, Department of Chemical Engineering, IIT Bombay
- Prof. Ravi. N Banavar, Department of System and Control Engineering, IIT Bombay
- Prof. Radhakant Padhi, Department of Aerospace Engineering IISc Bangalore
- Dr. Sanjay Bhat, TCS Hyderabad
- Dr. Abhay Pasilkar, NAL Bangalore
- Dr. Vijay V Patel, ADA Bangalore
- Dr. Shubhendu Bhasin, Department of Electrical Engineering, IIT Delhi

Workshop Organizers:

- **Dr. Mangal Kothari**
Department of Aerospace Engineering,
IIT Kanpur
- **Dr. Soumya Ranjan Sahoo**
Department of Electrical Engineering, IIT Kanpur



PARTICIPATING INSTITUTES

Institute	Number of Participants
BIET Jhansi	2
NIT Raipur	1
NIT Kurukshetra	3
VNIT Nagpur	3
College of Engineering Kidandoor Kerala	1
GBPUAT PANTNAGAR	2
PSG College of Technology	1
AMU	2
MCKV Institute of Engineering	1
Jadavpur University	2
NIT Jalandhar	2
KNIT Sultanpur	1
Government Engineering College, Ajmer	4
IIT Guwahati	4
VNR Vignana Jyothi Institute of Engg. &Technology, Hyderabad	1
RCC Institute Of Information Technology	2
Total	32

WORKSHOP SCHEDULE

September 19, 2016

Time	Event
8: 00 – 8:30	Registrations
8:30 – 8:50	Inauguration Ceremony <i>Prof S. Mittal, Prof. S. P. Das, Dr. Sahoo, Dr. Kothari</i>
8:50 – 9:10	Tea break
9:10 – 10:30	Challenge in Flight Control Systems <i>Dr. V. Patel</i>
10:30 – 10:45	Break
10:45 – 12:15	Linear Control <i>Dr. S R. Sahoo</i>
12:15 PM – 13:15	Lunch Break
13:15 PM – 14:45	Dynamic Inversion <i>Dr. M Kothari</i>
14:45 – 16:15	Feedback Linearization <i>Prof. R Banavar</i>
16:15 PM – 16:30	Tea Break
16:30 PM – 18:00	Feedback Linearization <i>Prof. R Banavar</i>

September 20, 2016

Time	Event
9:00 – 10:30	Lyapunov Theory and Design <i>Dr. S. Bhasin</i>
10:30 – 10:45	Tea Break
10:45 – 12:15	Adaptive Control <i>Dr. S. Bhasin</i>

12:15 PM – 13:15	Lunch Break
13:15 PM – 14:45	Optimal Control <i>Prof. R Padhi</i>
14:45 – 16:15	Optimal Control <i>Prof. R Padhi</i>
16:15 PM – 16:30	Tea Break
16:30 PM – 18:00	Optimal Control <i>Prof. R Padhi</i>

September 21, 2016

Time	Event
9:00 – 10:30	Design, Dynamics, and Control of Variable-pitch quadrator <i>Dr. Abhishek</i>
10:30 – 10:45	Tea Break
10:45 – 12:15	Dynamic Stability of Artillery Rockets <i>Prof. A K Ghosh</i>
12:15 PM – 13:15	Lunch Break
13:15 PM – 14:45	Backstepping Design <i>Prof. L Behera</i>
14:45 – 16:15	Intelligent Control <i>Prof. L Behera</i>
16:15 PM – 16:30	Tea Break
16:30 PM – 18:00	Fuzzy Logic Control <i>Dr. N Verma</i>

September 22, 2016

Time	Event
9:00 – 10:30	State Estimation <i>Dr. G Pandey</i>
10:30 – 10:45	Tea Break

10:45 – 12:15	State Estimation <i>Dr. G Pandey</i>
12:15 PM – 13:15	Lunch Break
13:15 PM – 14:45	Introduction to Model Predictive Control <i>Prof. S Patwardhan</i>
14:45 – 16:15	A gentle introduction to model predictive control (MPC) formulations based on discrete state space models <i>Prof. S Patwardhan</i>
16:15 PM – 16:30	Tea Break
16:30 PM – 18:00	Control of 4WS4WD Electric Vehicle <i>Dr. R Potluri</i>

September 23, 2016

Time	Event
9:00 – 10:30	Closed Rotation Sequences <i>Dr. S Bhat</i>
10:30 – 10:45	Tea Break
10:45 – 12:15	Rolling Cones and Attitude Trajectories <i>Dr. S Bhat</i>
12:15 PM – 13:15	Lunch Break
13:15 PM – 14:45	Flight Control with Backstepping <i>Dr. A Pashilkar</i>
14:45 – 16:15	Flight Control with Backstepping <i>Dr. A Pashilkar</i>
16:15 PM – 16:30	Tea Break
16:30 PM – 18:00	Demonstration of Autonomous Flight Flight Lab

SUMMARY of FACULTY FEEDBACK

Workshop

<i>Questions</i>	<i>Excellent</i>	<i>Good</i>	<i>Ordinary</i>
Clarity of communication about workshop	05	02	00
Organization of the sessions	05	02	00
Quality of lectures	06	01	00
Effectiveness of discussions	04	03	00
Effectiveness of learning experience	05	02	00
	<i>Appropriate</i>	<i>Short</i>	<i>long</i>
Duration of workshop	03	04	00
	<i>Definitely</i>	<i>Maybe</i>	<i>No</i>
Would you like to have more such	05	01	01
Would you like e-lectures by experts on special topics?	04	02	01
Suggest specific topic that you would like additional expert lectures on	<ul style="list-style-type: none"> • Optimal control, intelligent control, model predictive control, optimization techniques. • Fuzzy control, automatic automobile control. • MARC, MPC 		
Additional Suggestions	<ul style="list-style-type: none"> • Totally theoretical based course, so requires some hands on experience. • Hands on sessions could have improved the quality of the workshop. All the lecture sessions were mostly theoretical except some demo videos. • Food variations were desirable. • Some hands on session should introduce (at least 1-2 hrs/day) helpful to me to learn how advance control system do work. • Variations of food. • Sliding mode controller, Flat Output, Neural Controllers. • Some hands on are required to go into insight of the topic. 		

Teaching

Which subjects do you teach?	<ul style="list-style-type: none"> • Process instrumentation and control • Microprocessor & microcontroller, Digital Electronics, Elementary & Remote Control, Soft Computing. • Microprocessors, Control Theory, Circuit Communication Theory. • Control System • Robotics, Machine Vision, Automation, Artificial Intelligence. • Process Control & Instrumentation. 		
What is average student to teacher ratio in your institute?	<ul style="list-style-type: none"> • 10:01 • 20:01 • 17:01 • 15:01 		
Questions	YES	NO	
Do you have additional support for teaching (tutors, graders, teaching Assistants, etc)?	06	01	
Do you give class projects for UG classes?	07	00	
Do you give class projects for PG classes?	05	01	
Do you have sufficient resources for laboratory courses?	05	02	
	Sufficient	Inadequate	
Is the library/journal/e-connection support adequate?	07	00	
	Definitely	May be	No
Would you like to have common (TEQIP) repository of course material?	06	01	00
Would you like to visit IITK to participate in and develop course material (existing or new)?	05	02	00

Would you like to participate in creation of the repository material (course files/lab. Manuals/question bank/etc)	05	02	00	
	<i>e-courses</i>	<i>Workshop</i>	<i>Content</i>	<i>none</i>
How can IITK effectively help you prepare for teaching?	04	04	02	
How can TEQIP help improve your teaching?	<ul style="list-style-type: none"> • By adopting different teaching style • More workshops and short term courses can be arranged to get to know about the modern sensing & control techniques. • To learn more advance topic to improve quality of teaching himself and helpful to our students. • By conducting more. • The style and method of lectures under TEQIP workshop is useful to me in improving the teaching method. 			

Research

<i>Questions</i>	<i>Definitely</i>	<i>Maybe</i>	<i>No</i>
Would you like to visit an IIT for a visiting-faculty/ post-doctoral fellow, if offered (via TEQIP)?	06	00	00
Would you like to share/use research infra-structure at IITK, if made available?	06	00	00
Would you like to conduct collaborative research with IITK?	05	01	00
Would you like lectures by experts (Indian and international) on niche research areas/topics?	06	00	00
Do you want special-topic conferences?	05	01	00

How can TEQIP help improve your research?

- Learning advanced version & different topic and recent research work.
- Research grants may be given for aspiring short term projects.
- Visit to eminent research lab may be arranged to bridge the gap in research.
- Industries which focus on modern sensing & control techniques, visit to there is also required where we will get to know the requirement of the moment.
- By giving these opportunities here.
- Obviously the topic of lecture session has diversified the outline of future research can be diverted.

SUMMARY OF STUDENT FEEDBACK

Workshop

<i>Questions</i>	<i>Excellent</i>	<i>Good</i>	<i>Ordinary</i>
Clarity of communication about	08	08	00
Organization of the sessions	07	09	00
Quality of lectures	06	10	00
Effectiveness of discussions	03	13	00
Effectiveness of learning experience	07	07	00
		<i>Short</i>	<i>Long</i>
Duration of workshop	15	00	01
	<i>Definitely</i>	<i>Maybe</i>	<i>No</i>
Would you like to have more such	12	04	00
Would you like e-lectures by experts on special topics?	15	00	00
Suggest specific topic that you would like additional expert lectures on	<ul style="list-style-type: none"> • Multiple model adaptive control. • Control techniques in the field of Robotics, Electric Motors, and in the area of power electronics. • Machine Dynamics Robotics. • Manufacturing Systems. • Multiple model adaptive control • Lectures based on modelling like as AJM, ECM and CNC machines • On production engineering topics like AFM, AWJM (machining) • On Industrial Engineering • Flatness based differential control. • Variable structure control • Contraction Theory • Triggered Control • Process Control (Chemical Reactor Modelling) • Intelligent Control 		
Additional Suggestions	<ul style="list-style-type: none"> • Please provide all soft copy materials so that one can know about that. • As my field is industrial engineering so most of the lectures were out of my field but I enjoyed. 		

Learning

<i>Questions</i>	<i>Yes</i>	<i>No</i>	
Do you get enough class projects?	13	02	
Is the learning adequate?	15	01	
Do you have sufficient resources for	07	08	
What is your area of specialization	<ul style="list-style-type: none"> • Adaptive Control • System Identification • Non-linear control • Robotics • Industrial Engineering • Control Theory & Applications to aerospace systems • Production and Industrial Engineering. • Production Engineering • Dynamic Modelling & Control • Robotics, Control Systems. • Control applications in renewable energy system. • Nonlinear systems & intelligent control • ICE 		
	<i>Sufficient</i>	<i>inadequate</i>	
Is the library/journal support/e-connection adequate?	10	06	
	<i>Definitely</i>	<i>Maybe</i>	<i>No</i>
Would you like to have common (TEQIP) repository of course	14	02	00
Would you like to visit IITK to attend specialized courses?	16	00	00
Would you like MOOCS/e-resources	14	00	00

How can TEQIP help improve your learning?

- TEQIP organize a large number of different workshop fellowship programme, exchange program etc.
- By organizing more workshops
- Studying through their class room programs will enhance our knowledge.
- TEQIP should conduct workshop outside the IIT also.
- TEQIP gave me all data so I requested to TEQIP please inform me every time when workshop is conducted.
- By arranging the talk by different researchers.
- By conducting workshops, expert lectures and conferences.
- Financial support to attend and/or conduct workshop/seminar etc.
- If TEQIP is organizing under one department then topics should also be under the same department. In this workshop some topics were from aerospace engg. but organizing under electrical department.

Research

<i>Questions</i>	<i>Definitely</i>	<i>Maybe</i>	<i>No</i>
Would you like to visit an IIT for a short visit /internship/post- doctoral stint, if offered (via TEQIP)?	16	00	00
Would you like to share/use research infra- structure at IITK, if made available?	14	02	00
Would you like to conduct collaborative research with IITK	16	00	00
Would you like lectures by experts (Indian and international) on niche research areas/topics?	16	00	00
Do you want special-topic conferences?	16	00	00
How can TEQIP help improve your research?	<ul style="list-style-type: none"> • I am extremely looking forward to have a collaborative work with aerospace dept. of IITK. • Organize exchange programme, such as someone take course work research work etc. • By giving the opportunities to attend workshop on the research topic. • Studying through lectures will enhance knowledge & thereby will improve quality of research. • This kinds of workshops increase thinking of mine. The topic and thoughts which are choosing by me helps me out to conduct the lectures. So it is useful for me. • It increases my knowledge meet different kind of people so its help me out. • Providing more fund and research activity. • By getting the exposure the specific areas of our research expert. Provide sufficient concepts. • Basics concepts are improved with different seminars workshops etc. organized by TEQIP • TEQIP sponsored seminars/workshops helps us to improve our area of research and basic concepts of the different techniques. • If there is any project (research) related process control TEQIP can help me to do work on that project related (Chemical Reactor Process) • By organizing expert talks on challenges in different research areas. 		

OUTCOME

- Participants gathered research-based strategic learning and teaching practices in this field.
- They met experts in this field and discussed problems they face in their teaching and research.
- Participants were acquainted with challenges involved in flight control systems, basics of linear and nonlinear systems, state estimation and various popular control techniques.
- The workshop familiarized participants to advance control techniques, system identification methods, and their applications to aerospace system through presentations and discussions led by multiple experts.

Organizer's Report

Report on TEQIP Workshop on “Control Techniques and Applications” held between 19th to 23rd September 2016 at PBCEC, VH, IIT Kanpur

Workshop coordinator: **Dr. Mangal Kothari and Dr. Soumya Ranjan Sahoo, IIT Kanpur**

Background:

Recently, there has been an increase in the attention towards the design and deployment of unmanned vehicles for various “dull, dirty and dangerous” jobs. This requires a complete package of understanding the challenges involved, choosing a proper control strategy and deploying the same in the actual system. Motivated by this the workshop was proposed to focus on making the target participants aware of the challenges involved in flight control systems, the notion of various modern control techniques that are available and the application of a few ideas to new designs of aerial vehicles.

The workshop was spread over five-days. During the workshop, experts from academia and industry shared their knowledge, experience and expertise with the participants. The details of the workshop has been presented in the latter half of the report.

Objectives:

Objectives of the workshop were to:

1. Introduce concepts of various state estimation methods and control techniques applicable to linear and non-linear continuous systems.
2. Introduce the challenges involved in Flight Control Systems
3. Introduce the applications of the control techniques for missiles, unmanned aircrafts.
4. Demonstrate the functioning of the control techniques on actual systems.

Course content:

Course content focused on the challenges involved in flight control systems, basics of linear and nonlinear systems, state estimation and various popular control techniques. The course content is listed as below:

- Control Systems Theory
 - Challenges in Flight Control Systems
 - Linear Control
 - State Estimation
 - Dynamic Inversion
 - Feedback Linearization
 - Lyapunov Theory and design
 - Adaptive control
 - Optimal Control
 - Backstepping and Intelligent Control
 - Fuzzy Logic Control
 - Model Predictive Control
 - Closed Rotation Sequences, and Rolling Cones and Attitude Trajectories.
- Applications
 - Design, dynamics and stability of variable-pitch quadrotor
 - Dynamic stability of Artillery Rockets

- Control of 4WS4WD Electric Vehicle
- Flight Control with backstepping

Contribution:

The workshop had lectures from experts in various fields of control theory. The workshop hosted a mix of experts from academia like IIT Kanpur, IIT Bombay, IIT Delhi, IISc, and from industry like CSIR-NAL, ADA, TCS. The list of experts who contributed to this workshop is:

- **Speakers from IIT Kanpur**
 - Dr. Mangal Kothari
 - Dr. Soumya Ranjan Sahoo
 - Dr. Abhishek
 - Prof. A.K. Ghosh
 - Prof. Laxmidhar Behera
 - Dr. Nishchal Verma
 - Dr. Gaurav Pandey
 - Dr. Ramprasad Potluri
- **Invited Speakers**
 - Dr. Vijay Patel, ADA Bangalore
 - Prof. Ravi N. Banavar, IIT Bombay
 - Dr. Shubhendu Bhasin, IIT Delhi
 - Dr. Radhakant Padhi, IISc Bangalore
 - Prof. Sachin Patwardhan, IIT Bombay
 - Dr. Sanjay Bhat, TCS Hyderabad
 - Dr. Abhay Pashilkar, CSIR-NAL Bangalore

The schedule of the workshop is in Annexure-I.

Key take-aways from the workshop for the participants

Participating in the program, we hope has enabled participants to:

- Understand the challenges involved in control systems.
- Appreciate and understand various control techniques and their possible applications.
- Gain knowledge about the recent advancements in design and deployment of control systems for aerospace applications.

Acknowledgements:

In the end, we sincerely thank the TEQIP team. They made an impeccable arrangement for the program and also took care of all the necessary details (posters, dinners, tags, etc). This workshop would not have been successful without their constant support.