TEQIP Workshop on Dynamics and Control of Rotorcraft

February 02-06, 2018

Course Coordinators

Dr. Abhilshhek
Assistant Professor
Department of Aerospace Engineering
Indian Institute of Technology Kanpur

Dr. Mangal Kothari
Assistant Professor
Department of Aerospace Engineering
Indian Institute of Technology Kanpur

Dr. Ravi Banavar
Professor
Indian Institute of Technology Bombay

Venue

PBCEC Building IIT Kanpur

Organized by: Knowledge Incubation for TEQIP, IIT Kanpur
Knowledge Incubation for TEQIP
Indian Institute of Technology Kanpur

Dynamics and Control of Rotorcraft
02 - 06 February, 2018

More Pictures
Lecture Videos
ABOUT

This workshop gave the participants a broad overview of the field of dynamics and control of rotary wing aerial vehicles. Engineering faculty and students working in the area of control, robotics, aerospace, and personnel from industry and research organizations attended this workshop.

TOPICS DISCUSSED

- Introduction to rotary wing vehicles, helicopter rotor aerodynamics, momentum theory, Blade Element Theory (BET)
- Rotor blade dynamics and rotor loads calculation
- Fixed and variable pitch quadrotor dynamics
- Trim and rotor response to perturbations
- Linear and nonlinear flight dynamics models for rotary wing vehicle
- Minimum complexity helicopter model for real time simulation and control design
- Introduction to smooth manifolds
- The rotational rigid body equations in a coordinate-free framework
- Lyapunov stability and stabilization
- Lyapunov stability and stabilization on a manifold
- Tracking problems on a manifold
- Linear and non-linear control design for fixed and variable pitch Quadrotors
- Introduction to frequency domain based system identification for helicopters
1. **Dr. Abhishek**
   Assistant Professor
   Department of Aerospace Engineering
   IIT Kanpur
   [http://www.iitk.ac.in/aero/abhishek/](http://www.iitk.ac.in/aero/abhishek/)

2. **Dr. Mangal Kothari**
   Assistant Professor
   Department of Aerospace Engineering
   IIT Kanpur
   [https://www.iitk.ac.in/new/mangal-kothari](https://www.iitk.ac.in/new/mangal-kothari)

3. **Dr. Ravi Banwar**
   Professor
   Systems and Control Engineering
   IIT Bombay
   [http://www.sc.iitb.ac.in/~banavar/](http://www.sc.iitb.ac.in/~banavar/)
1. **Dr. Abhishek**  
   Assistant Professor  
   Department of Aerospace Engineering  
   IIT Kanpur  
   [http://www.iitk.ac.in/aero/abhishek/](http://www.iitk.ac.in/aero/abhishek/)

2. **Dr. Mangal Kothari**  
   Assistant Professor  
   Department of Aerospace Engineering  
   IIT Kanpur  
   [https://www.iitk.ac.in/new/mangal-kothari](https://www.iitk.ac.in/new/mangal-kothari)

3. **Dr. Ravi Banwar**  
   Professor  
   Systems and Control Engineering  
   IIT Bombay  
   [http://www.sc.iitb.ac.in/~banavar/](http://www.sc.iitb.ac.in/~banavar/)

4. **Mr. Nidish Raj**  
   PhD Student  
   IIT Kanpur
## Participating Institutes

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Institutes</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>DRDO</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>GBP UNI. Of AG. &amp; tech. Pantnagar</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>MMMUT Gorakhpur</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>Aligarh Muslim University, Aligarh</td>
<td>3</td>
</tr>
<tr>
<td>5.</td>
<td>Govt. Engineering college Bikaner (Raj.)</td>
<td>1</td>
</tr>
<tr>
<td>6.</td>
<td>BIT, Mesra</td>
<td>5</td>
</tr>
<tr>
<td>7.</td>
<td>Gaya college of Engineering, Gaya</td>
<td>1</td>
</tr>
<tr>
<td>8.</td>
<td>HBTU, Kanpur</td>
<td>4</td>
</tr>
<tr>
<td>9.</td>
<td>Govt. Engineering college, Ajmer</td>
<td>1</td>
</tr>
<tr>
<td>10.</td>
<td>IIT Bombay</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

## Statewise Participation

- **New Delhi**: 9%
- **Jharkhand**: 22%
- **Bihar**: 4%
- **Maharashtra**: 4%
- **Uttarakhand**: 4%
- **Rajasthan**: 9%
- **UP**: 48%
- **Rajasthan**: 9%
## WORKSHOP SCHEDULE

### Day -1

<table>
<thead>
<tr>
<th>Date/Day</th>
<th>Slot</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friday, 2 February</td>
<td>9:30- 10:00</td>
<td>Registration</td>
</tr>
</tbody>
</table>
|                | 10:00 – 11:30 | Introduction to rotary wing vehicles, helicopter rotor aerodynamics, momentum theory, Blade Element Theory (BET) (hover and forward flight)  
Dr. Abhishek |
|                | 11:30 – 11:45 | High Tea                                                              |
|                | 11:45 – 13:15 | Rotor blade dynamics and rotor loads calculation  
Dr. Abhishek |
|                | 13:15 – 14:30 | Lunch Break                                                           |
|                | 14:30 – 16:00 | Fixed and variable pitch quadrotor dynamics  
Dr. Mangal Kothari |
|                | 16:00 – 16:15 | Tea Break                                                             |
|                | 16:15 – 17:00 | Tutorial / Lab / Demo  
Dr. Abhishek |

### Day -2

<table>
<thead>
<tr>
<th>Date/Day</th>
<th>Slot</th>
<th>Topic</th>
</tr>
</thead>
</table>
| Saturday, 3 February | 10:00 – 11:30 | Trim and rotor response to perturbations  
Dr. Abhishek |
|                | 11:30 – 11:45 | Tea Break                                                             |
|                | 11:45 – 13:15 | Linear and nonlinear flight dynamics models for rotary wing vehicle  
Mr. Nidhish Raj |
|                | 13:15 – 14:30 | Lunch Break                                                           |
|                | 14:30 – 16:00 | Minimum complexity helicopter model for real time simulation and control design  
Dr. Abhishek |
|                | 16:00 – 16:15 | Tea Break                                                             |
|                | 16:15 – 17:00 | Tutorial / Lab / Demo  
Dr. Mangal Kothari |
### Day 3

<table>
<thead>
<tr>
<th>Date/Day</th>
<th>Slot</th>
<th>Topic</th>
</tr>
</thead>
</table>
| Sunday, 4 February | 10:00 – 11:30  | Introduction to smooth manifolds – I  

*Dr. Ravi Banavar*

<table>
<thead>
<tr>
<th>11:30 – 11:45</th>
<th>Tea Break</th>
</tr>
</thead>
</table>
| 11:45 – 13:15  | Introduction to smooth manifolds – II  

*Dr. Ravi Banavar*

<table>
<thead>
<tr>
<th>13:15 – 14:30</th>
<th>Lunch Break</th>
</tr>
</thead>
</table>
| 14:30 – 16:00  | The rotational rigid body equations in a coordinate-free framework  

*Dr. Ravi Banavar & Nidish Raj*

<table>
<thead>
<tr>
<th>16:00 – 16:15</th>
<th>Tea Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:15 – 17:00</td>
<td>Tutorial / Lab / Demo</td>
</tr>
</tbody>
</table>

### Day 4

<table>
<thead>
<tr>
<th>Date/Day</th>
<th>Slot</th>
<th>Topic</th>
</tr>
</thead>
</table>
| Monday, 5 February | 10:00 – 11:30  | Lyapunov stability and stabilization  

*Dr. Mangal Kothari*

<table>
<thead>
<tr>
<th>11:30 – 11:45</th>
<th>Tea Break</th>
</tr>
</thead>
</table>
| 11:45 – 13:15  | Lyapunov stability and stabilization on a manifold  

*Dr. Ravi Banavar*

<table>
<thead>
<tr>
<th>13:15 – 14:30</th>
<th>Lunch Break</th>
</tr>
</thead>
</table>
| 14:30 – 16:00  | Tracking problems on a manifold – I  

*Dr. Ravi Banavar*

<table>
<thead>
<tr>
<th>16:00 – 16:15</th>
<th>Tea Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:30 – 17:30</td>
<td>Tutorial / Lab / Demo</td>
</tr>
<tr>
<td>Date/Day</td>
<td>Slot</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Tuesday, 6 February</td>
<td>10:00 – 11:30</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11:30 – 11:45</td>
</tr>
<tr>
<td></td>
<td>11:45 – 13:15</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13:15 – 14:30</td>
</tr>
<tr>
<td></td>
<td>14:30 – 16:00</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16:00 – 16:15</td>
</tr>
<tr>
<td></td>
<td>16:15 – 17:00</td>
</tr>
</tbody>
</table>
SUMMARY of FACULTY FEEDBACK

Workshop

1. **Clarity of communication about workshop**

   ![Pie chart showing feedback distribution for clarity of communication.]

   - Excellent 100%
   - Good 0%
   - Ordinary 0%

2. **Organization of the sessions**

   ![Pie chart showing feedback distribution for organization of sessions.]

   - Excellent 50%
   - Good 50%
   - Ordinary 0%

3. **Quality of Lectures**

   ![Pie chart showing feedback distribution for quality of lectures.]

   - Excellent 50%
   - Good 50%
   - Ordinary 0%
4. Effectiveness of discussions

- Excellent: 17%
- Good: 83%
- Ordinary: 0%

5. Effectiveness of learning experience

- Excellent: 17%
- Good: 83%
- Ordinary: 0%

6. Workshop duration

- Appropriate: 100%
- Short: 0%
- Long: 0%
7. Would you like to have more such sessions?

8. Would you like e-lectures by experts on special topics?

9. Suggest Specific topic that you would like additional expert lectures on
   - Manufacturing, Automobile.
   - I would like additional experts from computer science so that I will get information in their fields.
   - Real time system
   - Non – liner systems
   - Controller Design

10. Additional Suggestions
    - Hydro power plant and working visit in sites.
1. **Do you have additional support for teaching (tutors, graders, teaching assistants, etc)?**

![Pie chart showing 60% Yes and 40% No.]

2. **Do you give class projects for UG classes?**

![Pie chart showing 100% Yes and 0% No.]

3. **Do you have sufficient resources for laboratory courses?**

![Pie chart showing 80% Yes and 20% No.]
4. Is the library/journal/e-connection support adequate?

5. Would you like to have common (TEQIP) repository of course material?

6. Would you like to visit IITK to participate in and develop course material (existing or new)?
7. Would you like to participate in creation of the repository material (course file/lab Manuals/question bank etc.)?

8. How can IITK effectively help you prepare for teaching?

9. Which Subject do you teach?
   - Manufacturing and production
   - Soft computing, Machine learning & subjects from computer science.
   - Computer science
   - Modelling simulation & evolutionary techniques

10. What is average student to teacher ratio in your institute?
    - 1:40
    - 30:1
    - 20:1

11. How TEQIP can improve your teaching?
    - New concept and ideas to is developed and help it.
    - By providing recourses & knowledge / approaches
Research

1. Would you like to visit an IIT for a short visit/internship/post-doctoral stint, if offered (via TEQIP)?

2. Would you like to share/use research infrastructure at IITK, if made available?

3. Would you like to conduct collaborative research with IITK faculty?
4. **Would you like lectures by experts (Indian and International) on niche research areas/topics?**

5. **Do you want special-topic conferences?**

6. **How can TEOIP help improve your research?**
   - More interaction with faculties of reputed institutions like IITs.
   - Expose the latest development in the research in my area if work.
   - By knowledge sharing interaction workshops & conferences on latest area.
SUMMARY of STUDENT FEEDBACK

Workshop

1. Clarity of communication about workshop

2. Organization of the sessions
3. **Quality of Lectures**

4. **Effectiveness of discussions**

5. **Effectiveness of learning experience**
6. **Workshop duration**

- Short: 36%
- Appropriate: 64%
- Long: 0%

7. **Would you like to have more such sessions?**

- Definitely: 64%
- Maybe: 27%
- No: 9%

8. **Would you like e-lectures by experts on special topics?**

- Definitely: 70%
- Maybe: 30%
- No: 0%
9. **Suggest specific topic that you would like additional expert lectures on**
   - Geometric control theory (Topology & JMP Tautological control systems)
   - Geometric control theory
   - Robotic artificial intelligent
   - Non-liner control, Optimal control
   - Adaptive control technologies, controlling of robotic manipulator
   - Back stepping
   - Sliding mode control
   - Optimal control
   - Adaptive control
   - Aerospace engineering
   - Robotics, power electronics, Geometry control theory
   - Power system
   - Wide area control
   - Some practical or experimental problem solving
   - Practical work

10. **Additional Suggestions**
   - Please video cast the lectures
   - Particular labs for designing & please video cast the lecture
   - All management are good if possible add non-veg to food.
   - Implement MATLAB for control and power system.
   - More lab and MATLAB section
   - MATLAB and lab view software

---

**Learning**

1. **Do you get enough class projects?**

   ![Pie chart showing 43% Yes and 57% No](image)
2. Is the learning adequate?

- Yes: 87%
- No: 13%

3. Do you have sufficient resources for laboratory?

- Yes: 0%
- No: 100%

4. Is the library/journal support/e-connection adequate?

- Sufficient: 25%
- Inadequate: 75%
5. Would you like have common (TEQIP) repository of course material?

6. Would you like to visit IITK to attend specialized courses?

7. Would you like MOOCs/e-resources based courses?

8. What is your area of specialization?
   - Control system
   - Control system
9. **How can TEQIP help improve your learning?**

- Introduced new topic
- Somehow the video lecture should be for previous TEQIP course (2015- control systems) are not available, please provide them.
- TEQIP can help us by providing video lecture like NPTEL, TEQIP should have a registered video gallery of the course provided by them.
- By providing E- lectures & provide some real time labs & project on which we are attending lectures / seminars.
- Hardware more than theory
- More workshops lab
- More practical work instead of theoretical part.
- Practical lab

---

**Research**

1. **Would you like to visit an IIT for a short visit/internship/post-doctoral stint, if offered (via TEQIP)?**

![Pie chart showing responses](image.png)
2. **Would you like to share/use research infrastructure at IITK, if made available?**

![Pie chart showing responses to share/use research infrastructure at IITK.]

- **Definitely**: 89%
- **Maybe**: 11%
- **No**: 0%

3. **Would you like to conduct collaborative research with IITK faculty?**

![Pie chart showing responses to conduct collaborative research with IITK faculty.]

- **Definitely**: 91%
- **Maybe**: 9%
- **No**: 0%
4. **Would you like lectures by experts (Indian and International) on niche research areas/topics?**

![Chart showing 91% definitely, 9% maybe, and 0% no]

5. **Do you want special-topic conferences?**

![Chart showing 60% yes, 40% maybe, and 0% no]

6. **How can TEQIP help improve your research?**
   - TEQIP should continue funding research which are theoretical and basic science related.
   - TEQIP should provide/continue and sponsorship for the theatrical and basic science related.
   - Conduct laboratories workshops with hardware interference so we can feel real machine environments.
   - There should be lab visit so that we can grab 100% on that topic.
   - Conducting more workshops like this.
   - Conducting mostly hardware projects more than theory.
   - For implementation code MATLAB and bring material
OUTCOME

Participants learned about following topics after attending this program:

- Helicopter aerodynamics
- The Euler equations for a rigid body and the dynamics of a helicopter
- Fixed and variable pitch quadrotor dynamics
- Minimum complexity helicopter model for real time simulation and control design
- Lyapunov stability and stabilization