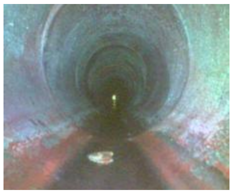
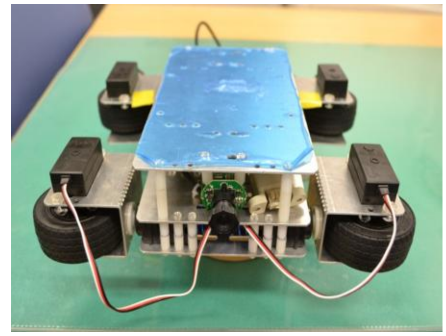


Pipe Inspection Robots for Structural Health Monitoring



Pipe Inspection Robots for Gas and Oil Pipe-lines

Almost all the energy related utilities like fuel, gas or oil supply lines and power generation sources such as nuclear and thermal power plants and so forth require an extensive network of pipelines for various transportation purposes. These pipelines, however, have limited life cycles due to various types of static and dynamic loads originated from both inside and outside the pipe; as well as, due to natural processes of degradation such as oxidation and corrosion of the pipe-surface, and joint failures due to abrasion. The presence of internal defects/corrosions in a gas pipeline is generally detected by:

- Visual examination using Inspection Dig
- External measurement such as Electrical Survey
- Examination of corrosion coupons or probes placed inside the pipeline
- Use of in-line inspection tool to identify areas of pitting or metal loss

In this course, we will deal with various technologies developed specifically for in-line inspection.

The concept of Structural Health Monitoring (SHM) is immensely applicable in these fields to improve the lifespan of the pipelines and prevent catastrophic failures. As it is nearly impossible to equip the entire pipeline with distributed array of sensors, a better strategy that has been envisaged is to monitor the condition of the inner surface of the pipe with the help of a surveillance robot. Couple of decades ago this technique was first introduced in nuclear power-plants with the help of cable drawn wheeled carts having a camera recorder at their apex. However, with the advent of sensors and actuators, fully autonomous robots based on various motion generation systems and integrated with multiple sensors are being developed today. Some of these robots travel hundreds of kilometers inside the pipelines to record the surface condition and location of damages. Hence, a considerable research funding is allocated worldwide to find newer and cheaper ways of monitoring the pipe-lines to ensure safety and high performance of the system.

Application of SHM in Sewarge Systems

Sewer is a pipe (an artificial subterranean conduit or tunnel) that collects and transports waste and drainage water (e.g. surface runoffs like storm water, rainwater and groundwater). Sewage collection systems are an extensive and vital part of any country's infrastructure.

In Japan, in 2007, the total length of sewer pipes was over 400,000 kilometers (about 10 times of the circumference of the earth). However, a report released by the Japan Sewage Works Association (JSWA) suggests that over 7000 kilometers of the sewer pipes (nearly one-seventh of the total length of sewer pipes in Japan) have been well over their service lives (more than 50 years) [1]. Consequently, the aging problem of the sewer pipes is being taken into serious consideration.

A major part of sewer pipe deterioration and corrosion is attributed to aging, traffic load and chemical reactions due to which inflows such as groundwater and rainwater seep into the pipe systems. Regional city government reports state that this inflow amounts to approximately 30% of the total flow. In addition to these inflows into the sewer pipes, outflow from damaged systems also occur, thereby contaminating the surrounding environment and posing a greater threat. The primary cause of such problems is the lack of in-depth knowledge about the condition of the pipelines. And as a consequence, many countries across the world have been spending a huge amount of their budget on emergency repairs of sewers. The need for emergency repairing of subterranean pipes can be significantly reduced if critical sections of it could be identified and repaired before a catastrophic failure occurs. On the other hand, the requirements of rebuilding the sewer pipes and the laying of optical fibers in them are also increasing. Hence it is essential to investigate the sewer pipes before their construction. To put it briefly, the effective inspection system for sewer pipes is gradually gaining importance and is even considered a mandatory procedure before any construction. This requires a convenient operational environment, a short investigation time and an accurate fault detection system.

Also, the key to developing this system is to find a fast and accurate fault detection method for the sewer pipes.

The primary objectives of the course are as follows:

i) **Generate Motivations and Interest in the field of Pipe Crawling Robots,**
ii) **Provide exposure to practical design and demonstration of Pipe Crawling Robots,**
iii) **Provide applicants the fundamentals of Structural Health Monitoring,**
iv) **Provide exposure to the field of communication system design,**
v) **Introduce practical aspects of Video based Sensing and image processing.**

Modules and Dates	**Module A: Pipe Inspection Robots for Sewerage Lines and Gas Pipe-Lines** Dates: 27.2.2016-29.2.2016 *Lecture 1* Introduction, Broad Overview of Sewrage System, Need for Accurate Determination of Damage in Sewer Pipes *Lecture 2* Introduction, Broad Overview of Gas-Pipe System, Nature of Failure of Gas-pipes *Lecture 3-5*: Various Sewer Inspection Techniques, Pipe Condition Assessment Protocols. *Tutorial 1.* Need Assesment, Conceptual Design of Pipe Inspection Robots

Modules and Dates	
	Module B: Basic Design of Crawler Robots Dates: 29.2.2016-2.3.2016 *Lecture 6-10* : Introduction to Pipe-Crawling Robots, Single and Multi-Axis Crawling Robots, Basic Locomotion Systems, Sensors and Actuators, *Tutorial 2*. QFD and Selection of Design **Module C: Communication Design for Crawling Robots** Dates: 2.3.2016-3.3.2016 *Lecture 11-15* : Transmission test in steel pipe, Transmission test in ceramic pipe, Tansmission loss measurement, Wireless Pipe-Inspection System, Wireless communication system. *Tutorial 3*. Embodiment Design, Basic Design calculations. **Module D: Structural Health Monitoring** Dates: 3.3.2016-4.3.2016 *Lecture 16-20*: Introduction to Smart Sensors, Piezoelectric Sensing using PVDF, Bimorph Sensors, Modelling and Design of Sensor Embedded Probes, Filtering and Signal Processing. *Tutorial 4* PVDF Sensing Probe Fabrication at the SMSS Lab, IIT Kanpur. *Tutorial 5* Sensor Testing and Evaluation.

	Module E: Sensing and Image Processing, System Development Dates: 4.3.2016-6.3.2016 *Lecture 21-25*: Video based sensing, Hardware environment, Imapge Processing Algorithms, FFT Transform, Hough Transform Method, Introduction to Image Filtering, Preprocessing and Testing *Tutorial 6* Testing and Evaluation. Duration: 27 February - 6 March
You Should Attend If…	• Executives, Engineers and Researchers from Oil, Water and Gas Transportation Organizations like GAIL, ONGC, Reliance, CPWD and related R&D laboratories. • Student at all levels (BTech/MSc/MTech/PhD) or Faculty from reputed academic institutions and technical institutions.
Fees	The participation fees for taking the course is as follows: **Participants from abroad**: US $500 **Industry/ Research Organizations:** Any two modules: Rs. 25000/- All modules : Rs. 30000/- **Academic Institutions:** All modules: Rs. 15000/- The above fee includes all instructional materials, lab use for tutorials and free internet facility. The participants will be provided with single bedded accommodation on payment basis.

Faculty

Prof. Harutoshi Ogai is Doctorate of Engineering from Tokyo Institute of Technology, Japan. Before joining the IPS-Waseda University, he had worked as one of the Chief Executives with Nippon Steel Company for about two decades and had seminal contribution in the field of Modelling and Optimal Control of Complex Systems like Blast Furnace.

He is currently working in the following research areas:

- Complex Process Modelling and Control
- Design and Development of Autonomous Electric Vehicle
- Process Analysis and Simulation
- Bridge Damage Diagnosis and
- Automotive Control

He has developed Process modeling and Java-based process simulator for some very large scale processes or complex processes and developed strategies for optimal control. A Typical Example: a blast furnace is a complicated and nonlinear system. The process analysis and operational guidance for such systems are researched by ICA (Independent Component Analysis), LOM (Large scale data on-line modeling), and SOG (Simulation based on-line guidance). Prof. Ogai and his team have developed many such hardware in loop systems for industrial applications.

Dr. Bishakh Bhattacharya is Dr. and Mrs. G. D. Mehta Chair Professor in Mechanical Engineering at IIT Kanpur. He has been involved in modeling and development of hybrid composite laminate activated by smart materials like Terfenol-D alloy and found its application in controlling vibration of flexible rotating members like helicopter rotor. He has subsequently expanded the composite system to include nano-particle reinforced composite layer for better broad band damping. In the field of micro and mini-actuators, he has modeled and developed Ionic Polymer Matrix Composite system for vibration control of flexible open and closed link systems. The technique is further expanded for modeling and development of Shape Memory Alloy based smart muscle and applied for trajectory control of multi-link actuators. Based on this work, a new technology is developed for shape control of continuous structure which has ushered in the development of space-born reconfigurable parabolic antenna system for Indian Space Research Organization (ISRO). Another application of his work on smart flexible link system has taken place in developing a new vehicle for Pipe Health Monitoring which is currently under development for the Gas Authority of India Limited (GAIL).

Professor Bhattacharya has published more than ninety papers in the international journals and proceedings. He is a recipient of Department of Science and Technology (DST) Young Scientist award 2001 and Young Scientist Award from the Systems Society of India in 2006. He has developed strong international collaborations with UK, Sweden and Japan. He was awarded DST-UK India Research Award (UKIERI) and UKIERI Award in 2009 and 2012 respectively. He was a visiting professor in the University of Sheffield in 2010, 2012 and 2013 where he carried out research on Structural Health Monitoring of Complex Autonomous Systems with a team of students from IIT Kanpur. He also visited IPS, Waseda University of Japan and was a visiting professor in 2009-2011 and 2013 for jointly developing Pipe Health Monitoring robots. Prof. Bhattacharya is recently awarded DBT-VINNOVA collaborative project for developing Seamless Affordable Assistive Technology for Health (SAATH) jointly with IISc Bangalore, and KTH Sweden.

From 2003, Prof. Bhattacharya has taken part in coordinating and developing a new post graduate academic programme for interdisciplinary studies in the field of Design. This is a unique programme in the country which is developed based on a balanced integration of functional, aesthetic and ergonomic aspects of design. Apart from developing and teaching new courses in this direction, his research focus is on technology enabled design especially in the field of design of intelligent system. Prof. Bhattacharya has received six patents with his students and four patents are under review at present. He has also mentored several successful student groups for national and international competitions in Design including Nokia Bhasha 2011 and Yahoo Design Challenge 2008. He is currently empanelled as Eminent Design Expert in National Manufacturing Competitiveness Program.

Professor Bhattacharya has completed guidance of five PhD theses and five are under progress. He has also guided forty eight M. Tech thesis and 23 M. Des thesis. He has been reviewer of several archival journals at the International level. Journal of Sound and Vibration, Journal of Vibration Control, Journal of Vibration and Acoustics, Journal of Intelligent Structures and Materials, Smart Materials and Structures, Physica Scripta, and Transactions of Magnetics to name a few among them. He is in the editorial board of Journal of Low Frequency Noise, Vibration and Active Control and Journal of ISSS.

Among other activities, he was the Head of Design Programme from 2011-2013. He is now coordinating the Space Technology Cell of the Institute. He is also coordinating three UG and PG laboratories from 2010: Applied Dynamics and Vibration, Automation and Control and Smart Materials and Systems Laboratory. He is active in creating Web based course material and contributed significantly in the national initiative called National Program on Technology Enhanced Learning (NPTEL). He is also selected as Academic Representative for the Mentor Council of DGET in Industrial Automation & Instrumentation.