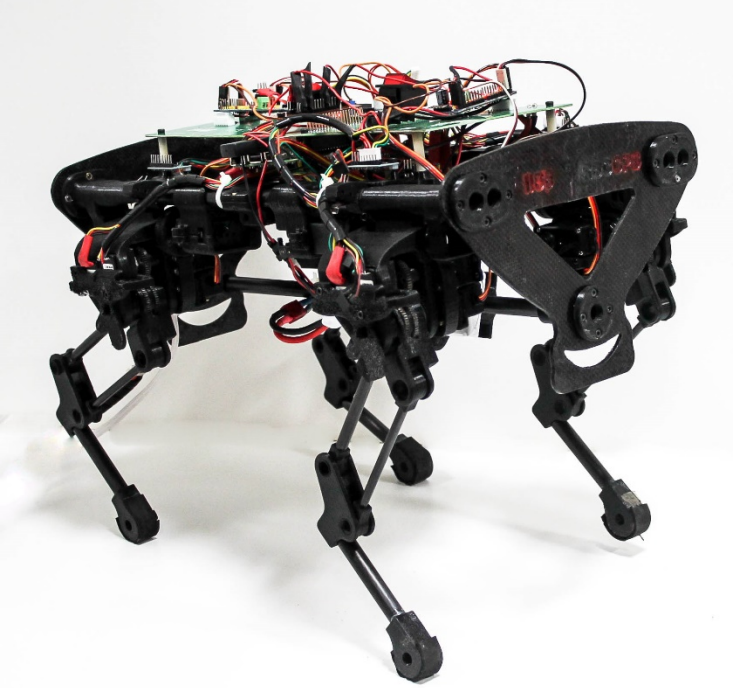
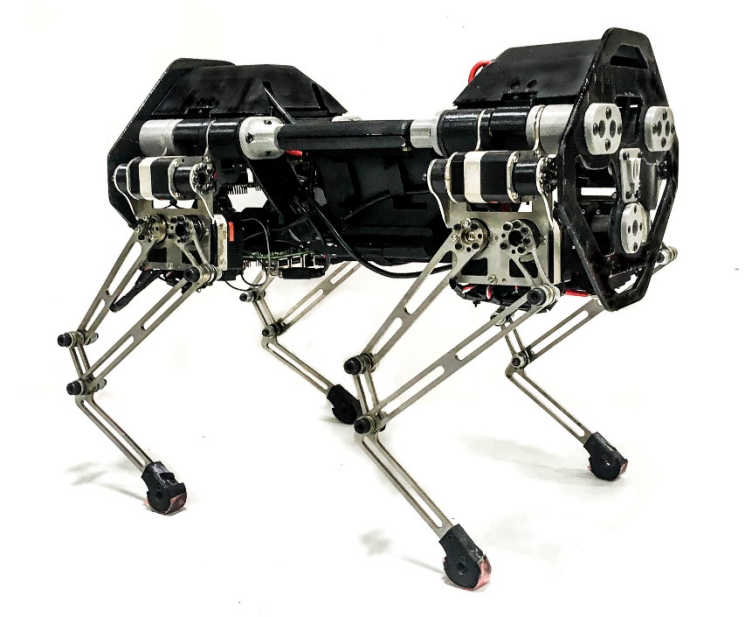




WALKING ROBOTS FOR ADVANCED MOBILITY

Shishir N Y Kolathaya

Assistant Professor

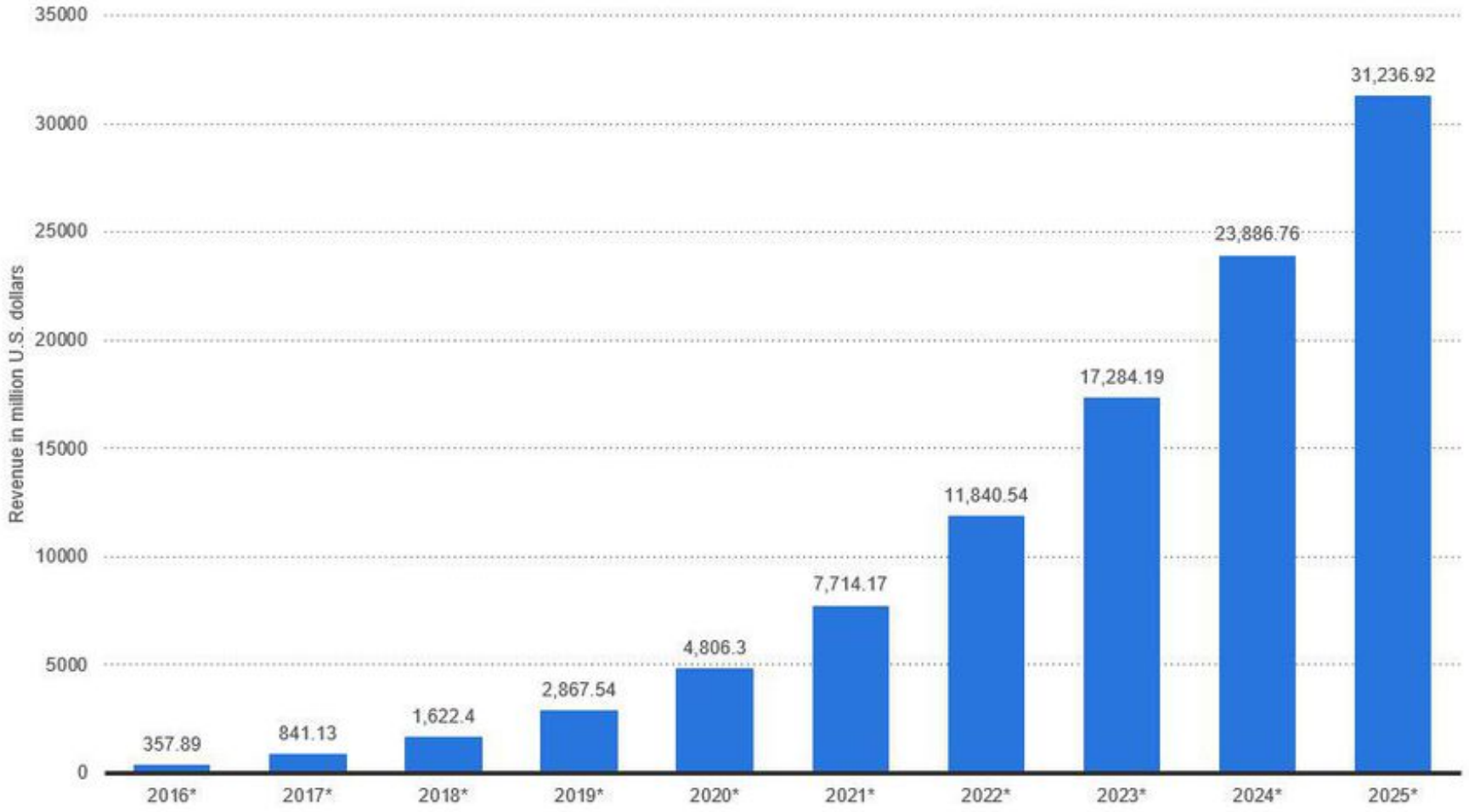
Robert Bosch Centre for Cyber Physical Systems

Computer Science and Automation

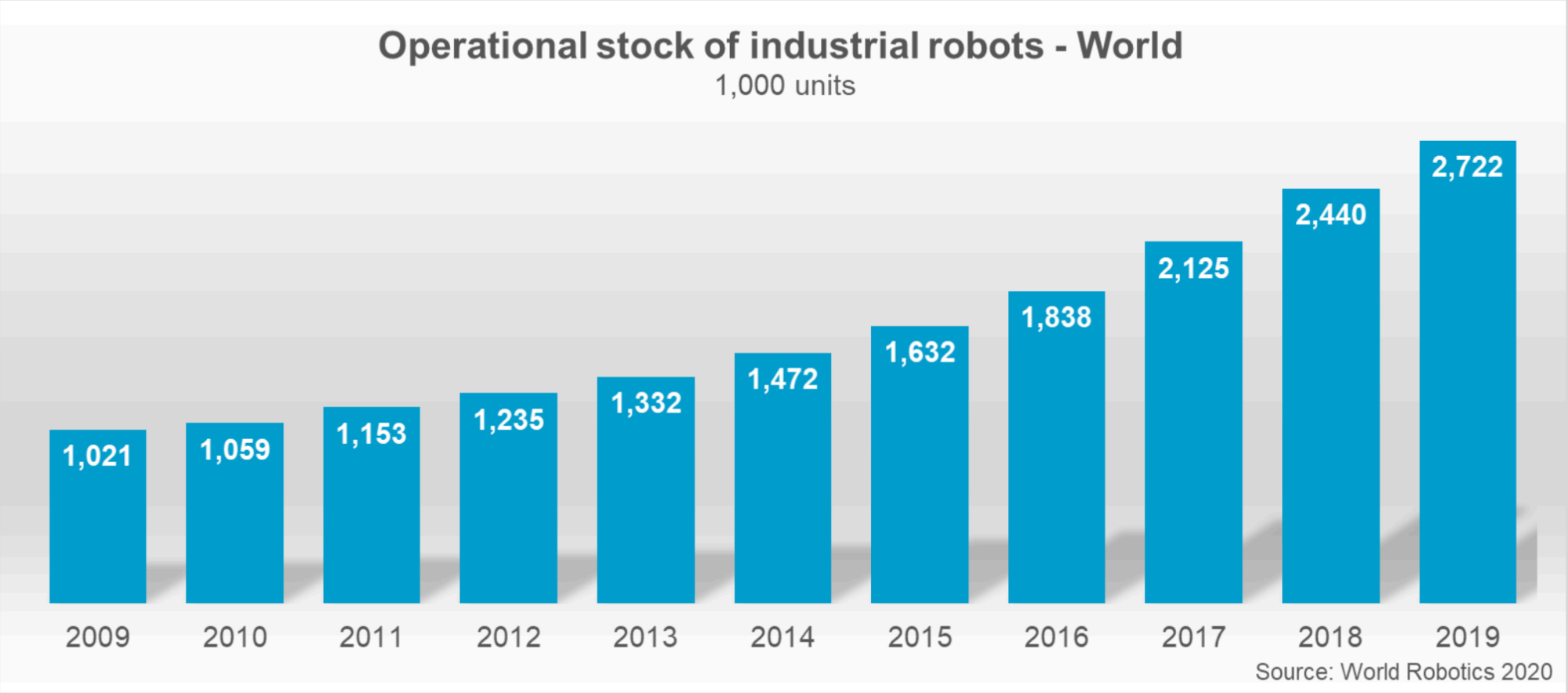
Indian Institute of Science, Bangalore

Enterprise artificial intelligence market revenue worldwide 2016-2025

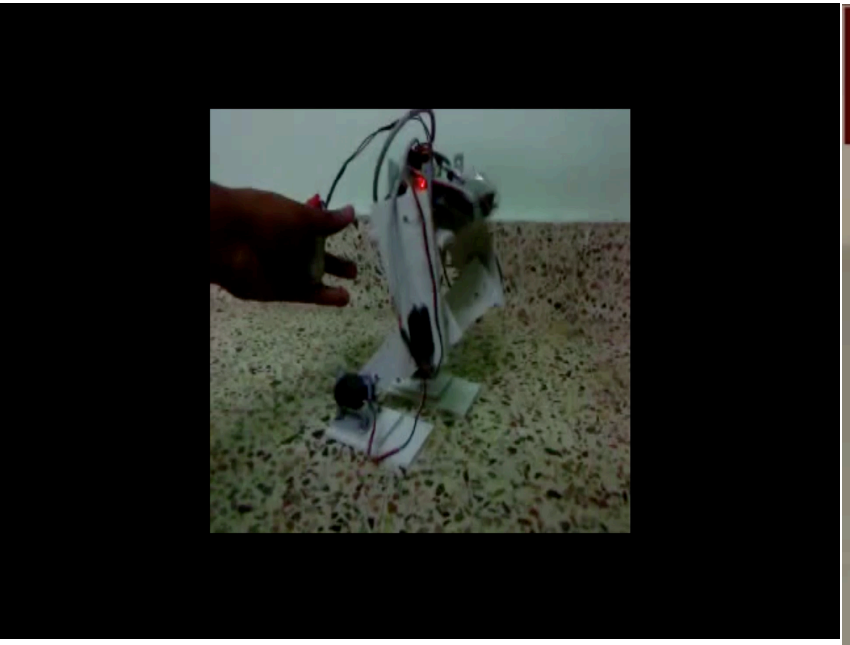
Revenues from the artificial intelligence for enterprise applications market worldwide, from 2016 to 2025 (in million U.S. dollars)



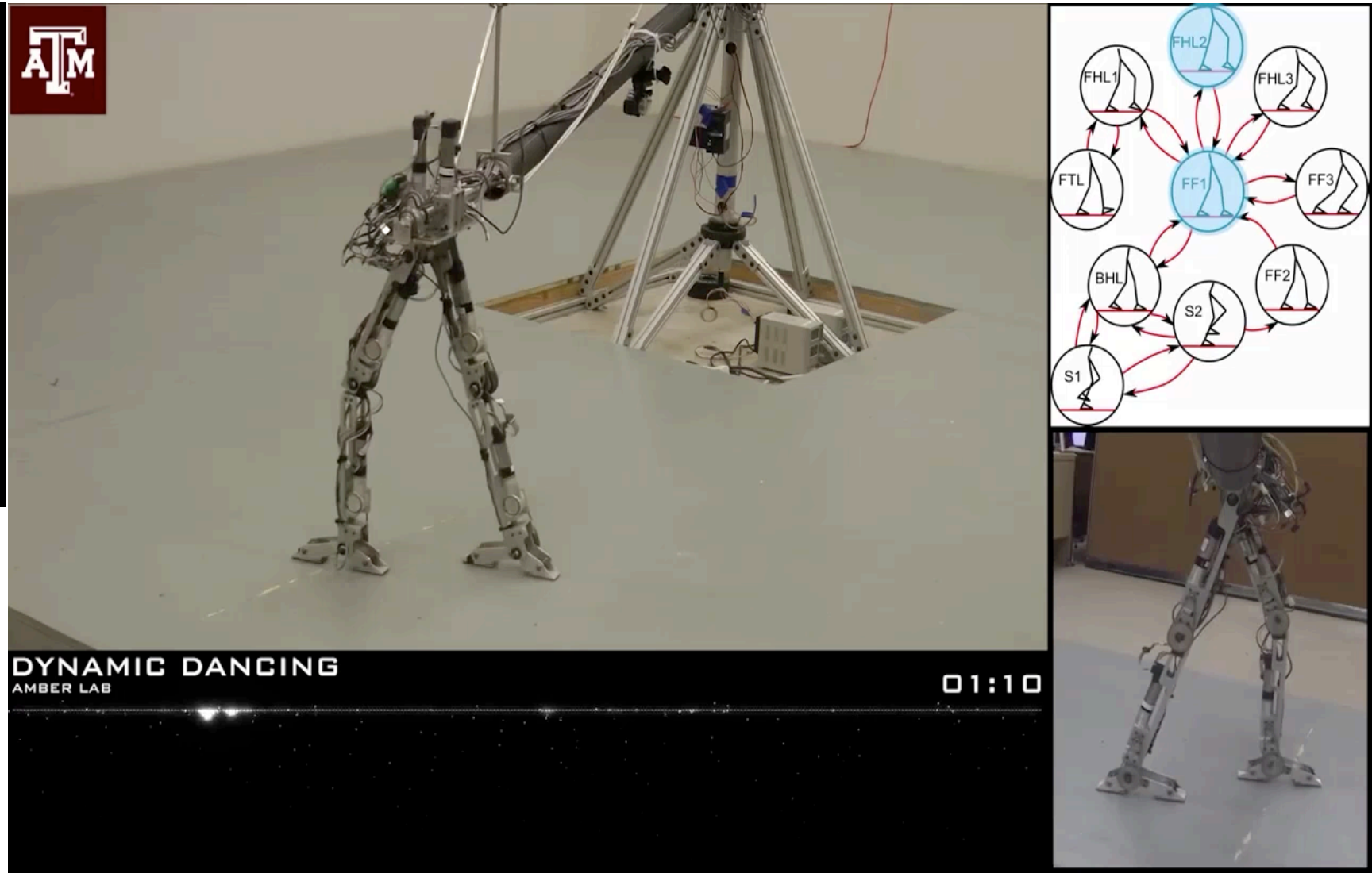
More robots deployed than ever



Background (before 2018)

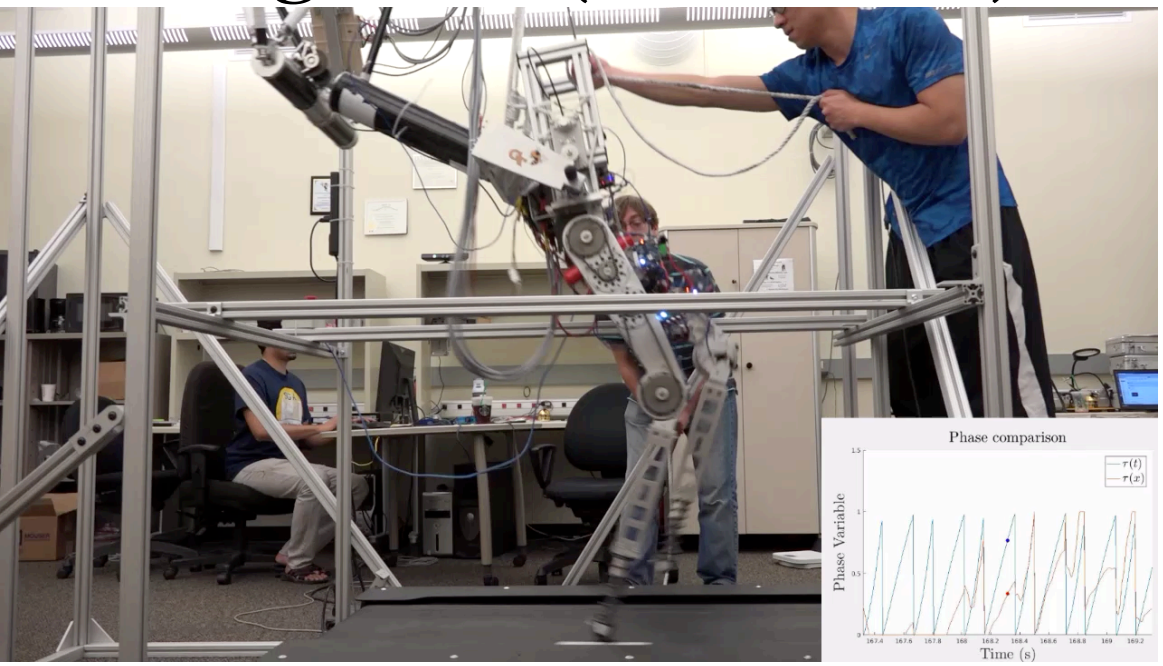


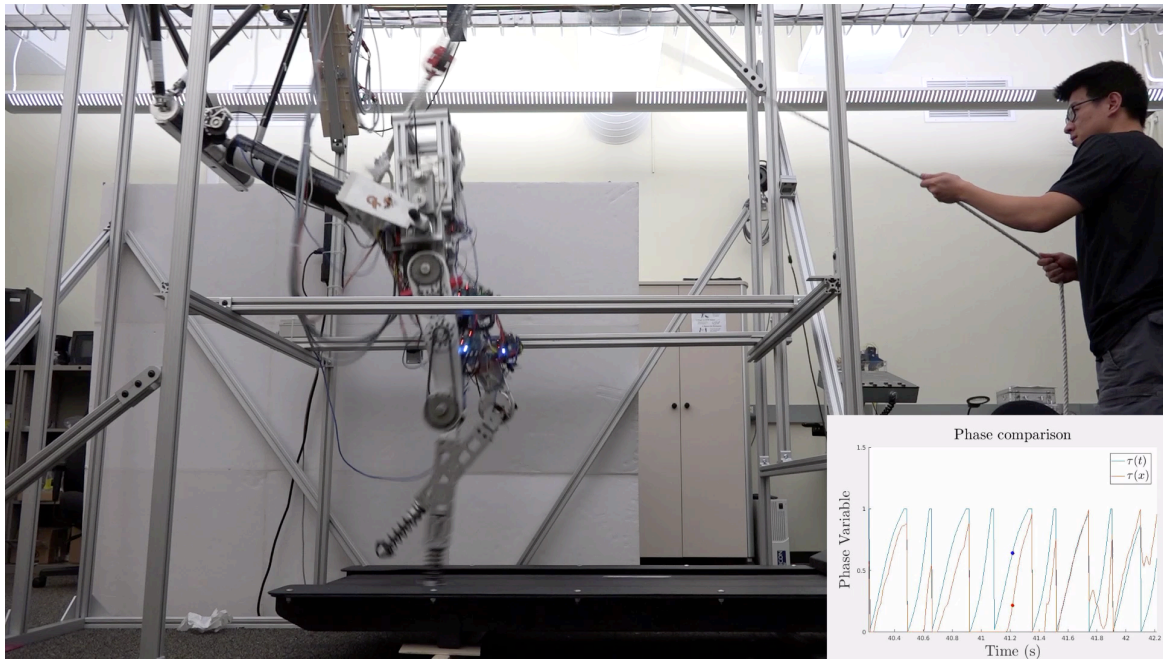
My humble beginnings…
Started working on bipeds
as an undergraduate

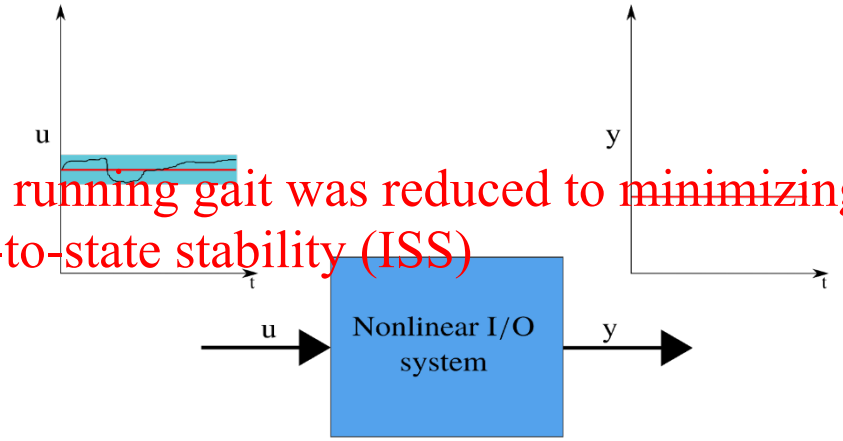


Shishir Kolathaya et.al., "Composing dynamical systems to realize dynamic robotic dancing", *Algorithmics Foundations of Robotics XI 2015*. *(<25% acceptance rate)*

Background (before 2018)







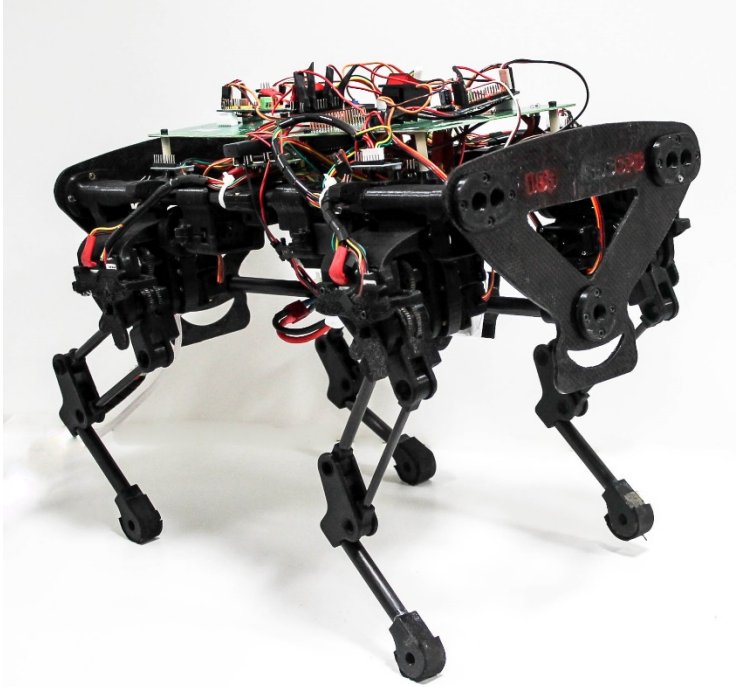
Problem of stabilizing the running gait was reduced to ~~minimizing~~ the phase uncertainty:
Using the notion of Input-to-state stability (ISS)

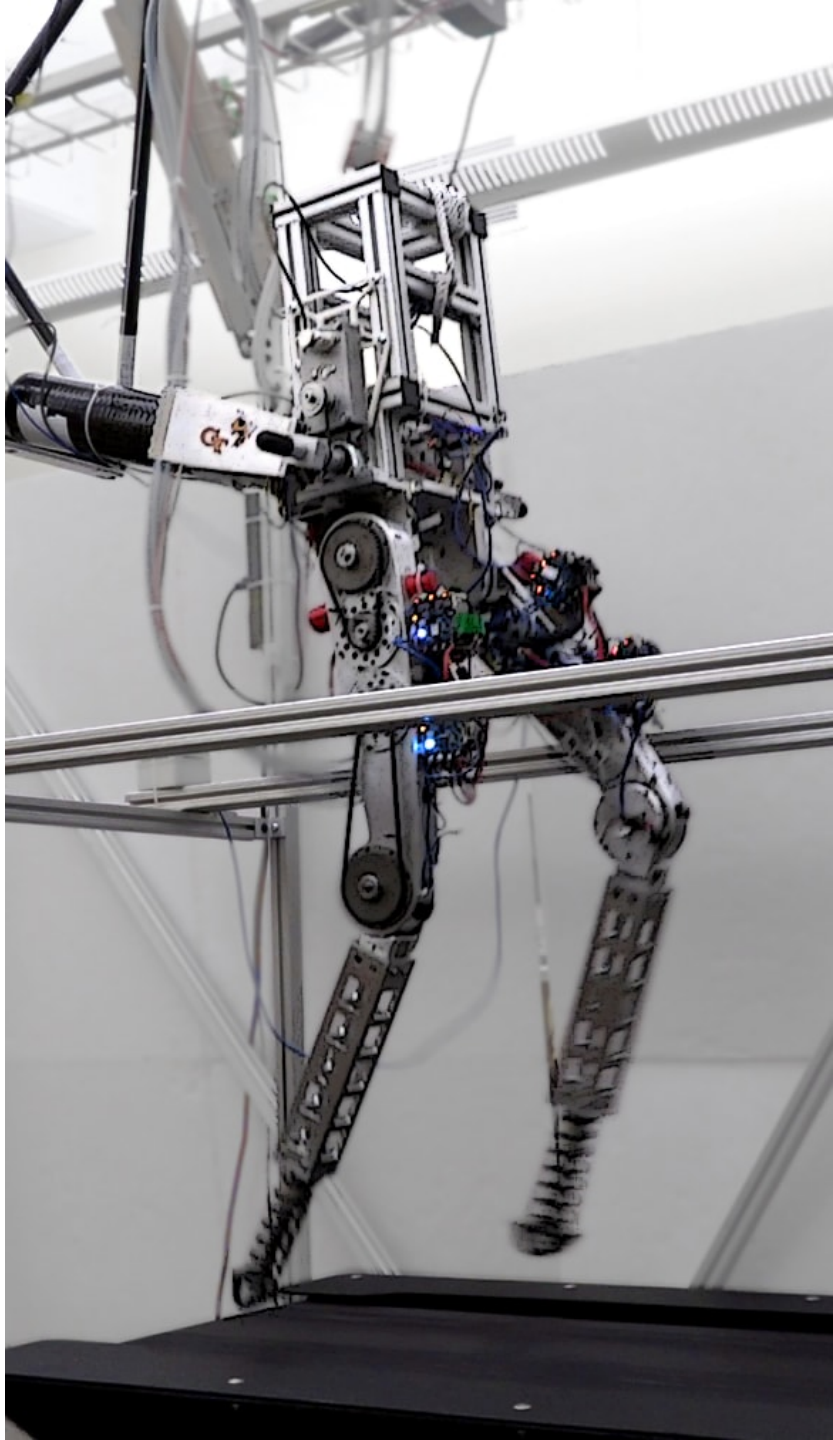
ACC 2016, ACC 2018, NAHS 2017, HSCC 2017, NAHS 2018

My background

Ph.D. from GeorgiaTech (2016)
Postdoctoral Scholar from Caltech (2017)
DST INSPIRE Faculty at IISc (2018-2020)

Worked with more than 7 different robotic platforms in 9 years.





Team Stoch (2018-current)

Faculty

Shishir Kolathaya
Assistant Professor

Bharadwaj Amrutur
Professor

Shalabh Bhatnagar
Professor

Ashitava Ghosal
Professor

Staff

Ashish Joglekar
Researcher

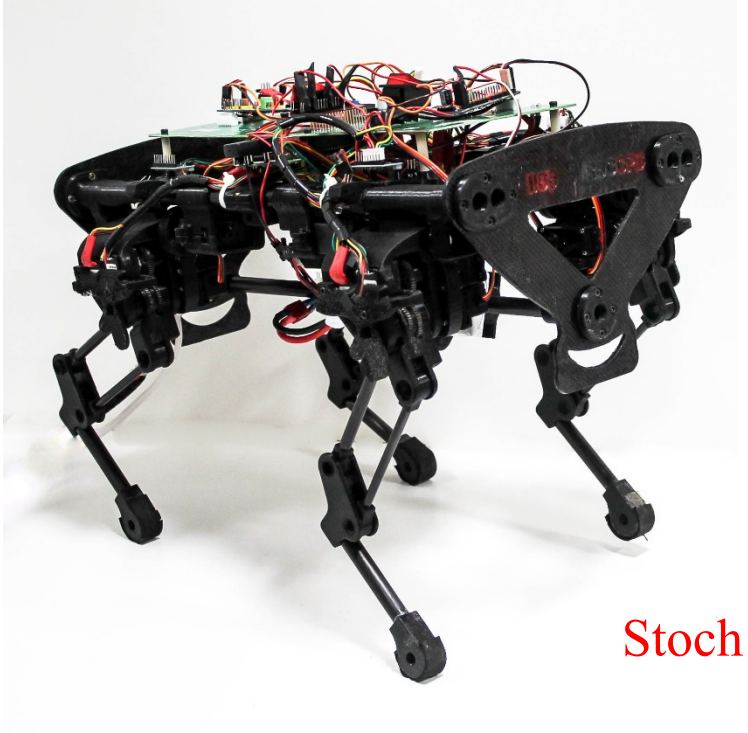
Aditya Sagi
Technical Associate

Alok Rawat
Technical Associate

Varun
Technical Associate

Kartik Paigwar
Project Associate

The project called the “Stoch walking platform” is operating under the philanthropic grant by Robert Bosch India.



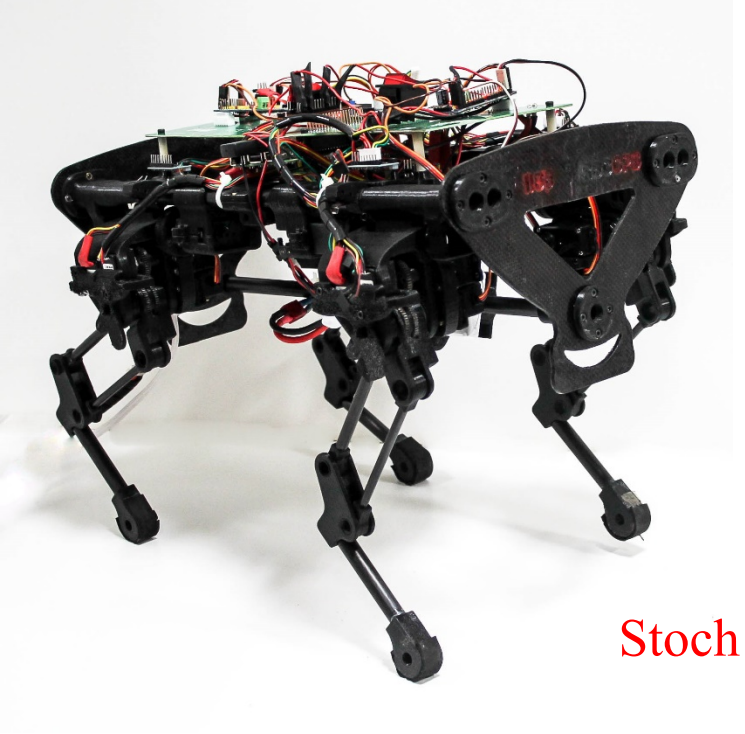
Stoch 1

Stoch 2

Stoch series (2018-current)

Salient features:

1. The quadrupeds **Stoch 1** and **Stoch 2** were indigenously developed in IISc
2. Cost < **5000$**
3. Can trot, turn, side-step etc
4. Powered by servo motors
5. Uses limited sensing like IMU, joint angles etc



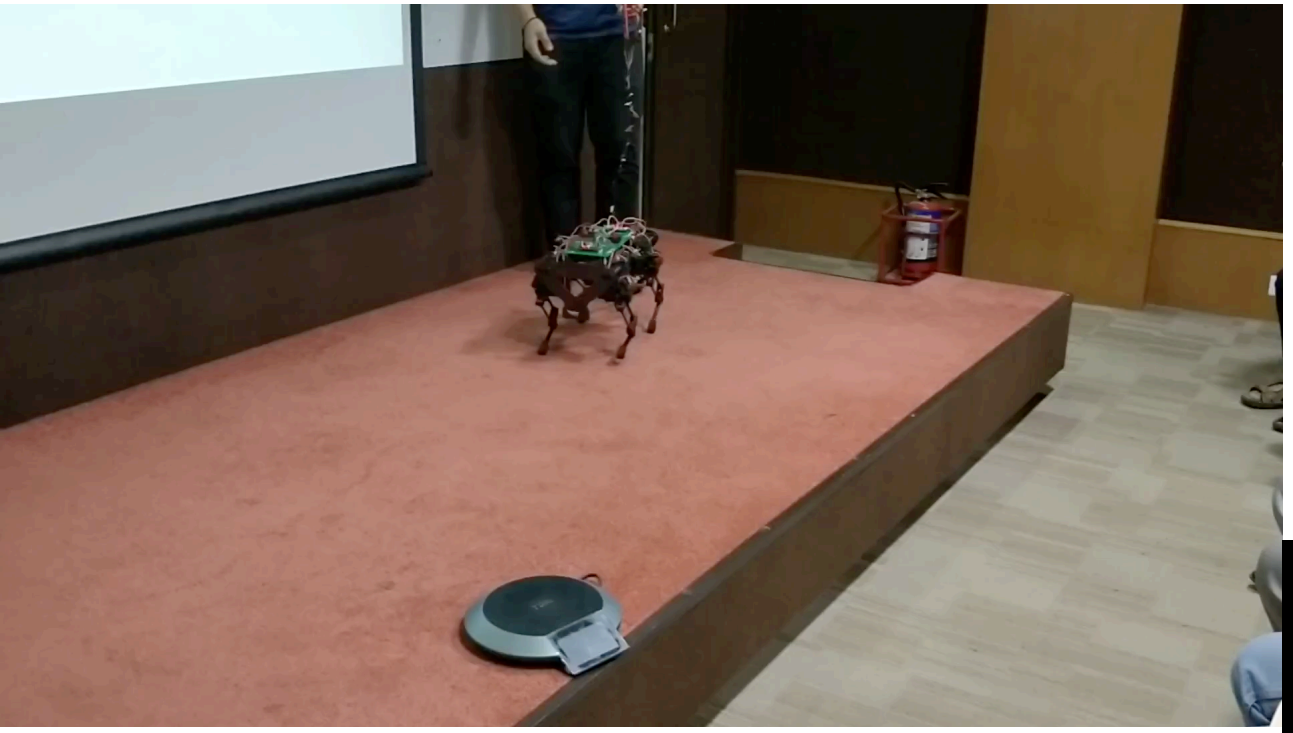
Stoch 1

Conference venues:

1. ICRA 2019
2. Ro-Man 2019, 2020
3. ICCAR 2019
4. CoRL 2020

Stoch 2

Stoch 1 was designed in 2018



Manually tuned, March 2018

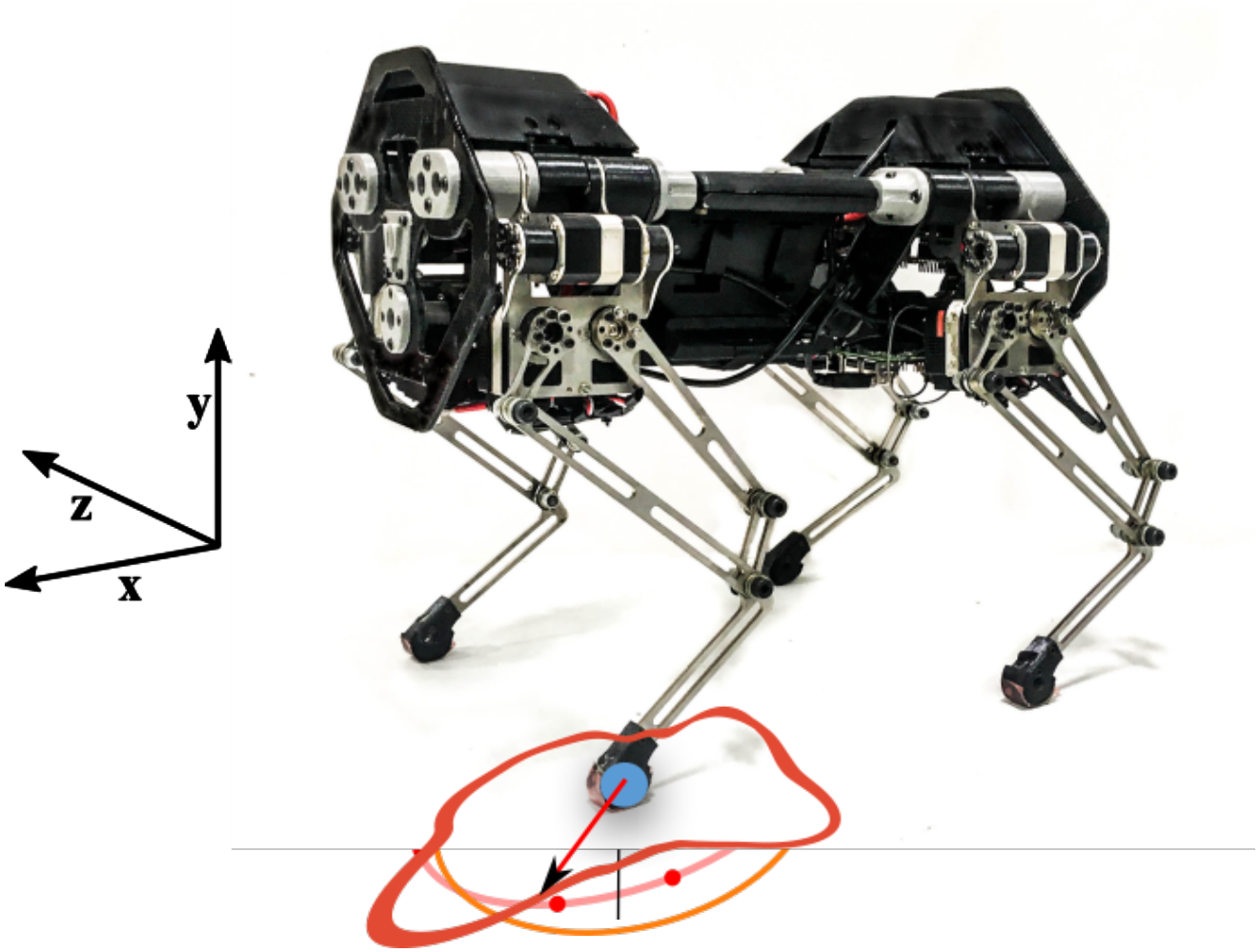
Learned, Sep 2018

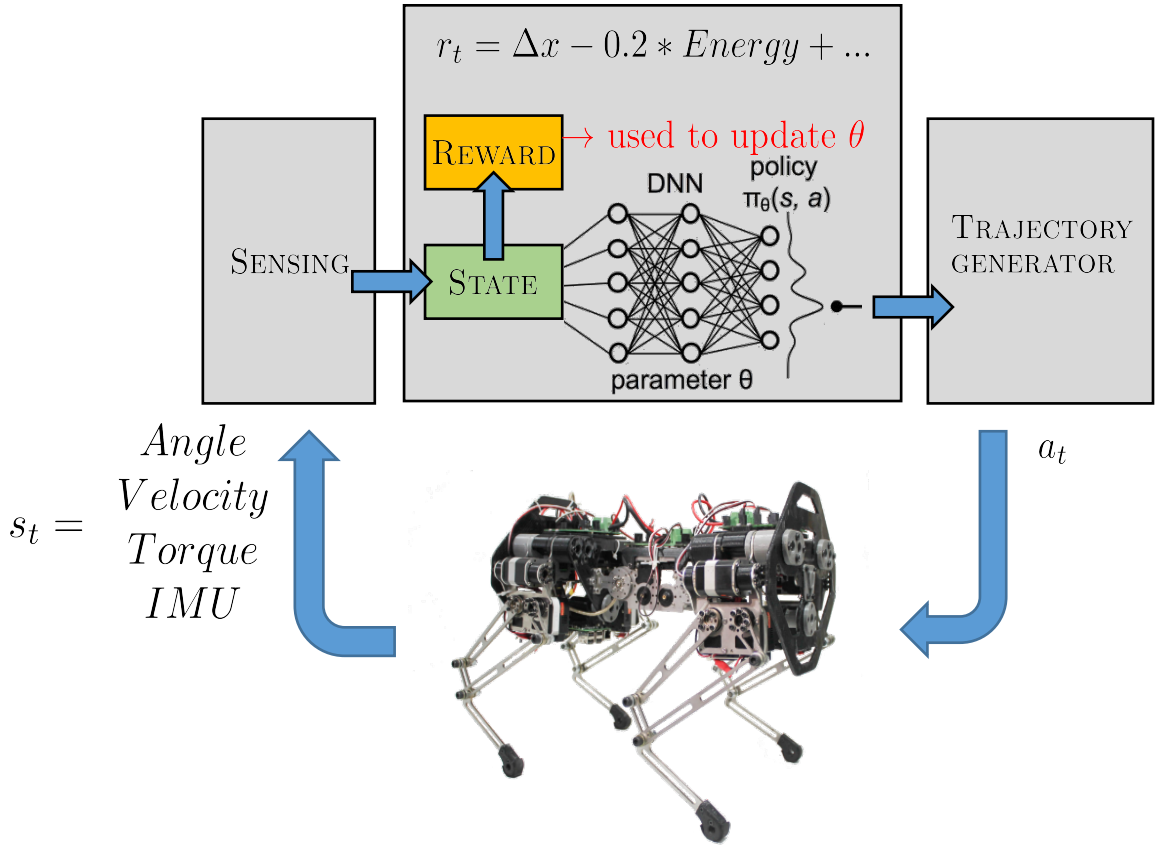
Realizing Learned Quadruped Locomotion Behaviors through Kinematic Motion Primitives

Abhik Singla, Shounak Bhattacharya, Dhaivat Dholakiya,
Shalabh Bhatnagar, Ashitava Ghosal, Bharadwaj Amrutur and Shishir Kolathaya

ROBERT BOSCH CENTRE for CYBER-PHYSICAL SYSTEMS
Indian Institute of Science, Bangalore-560012, India

Stoch 2 was designed in 2019

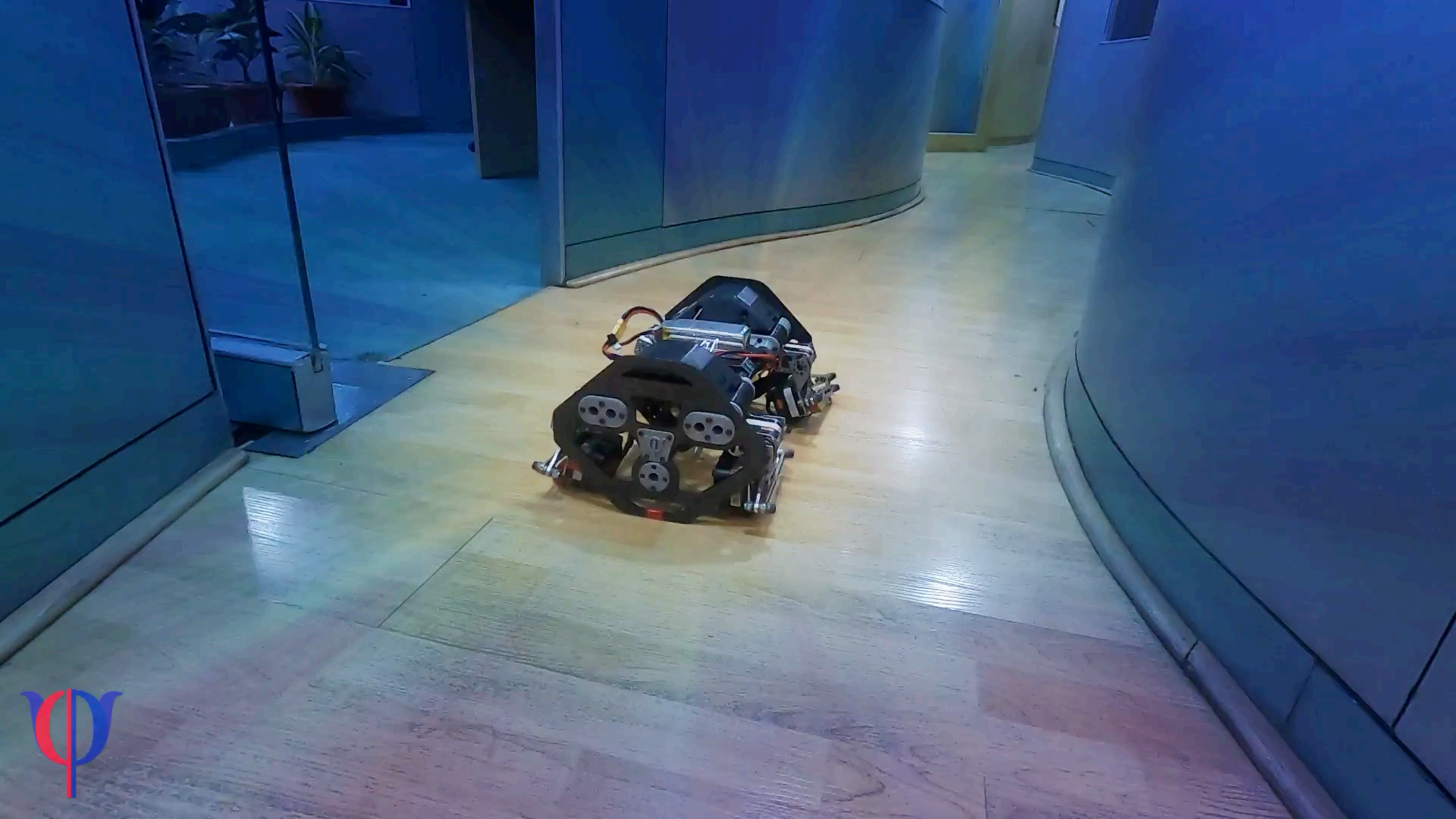




Research Staff: Aditya, Sashank, Kartik, Ashish, Ravi

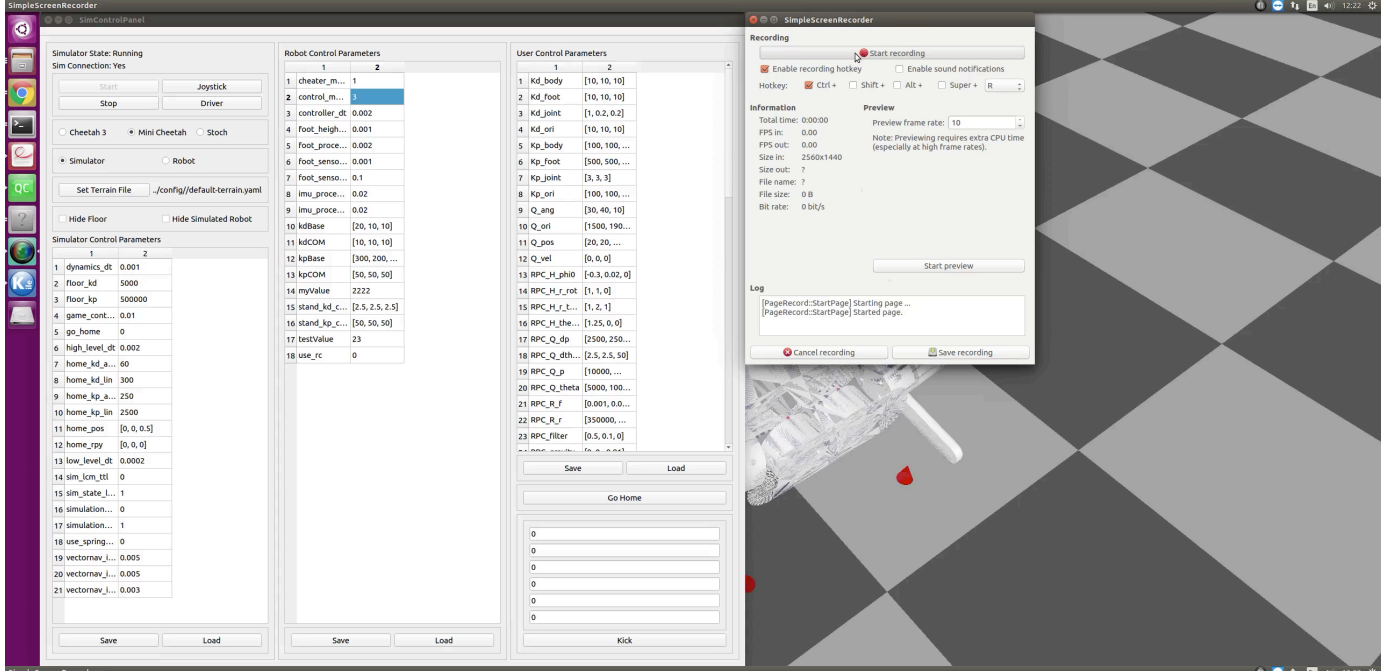
Collaborators: Bharadwaj, Shalabh, Ashitava

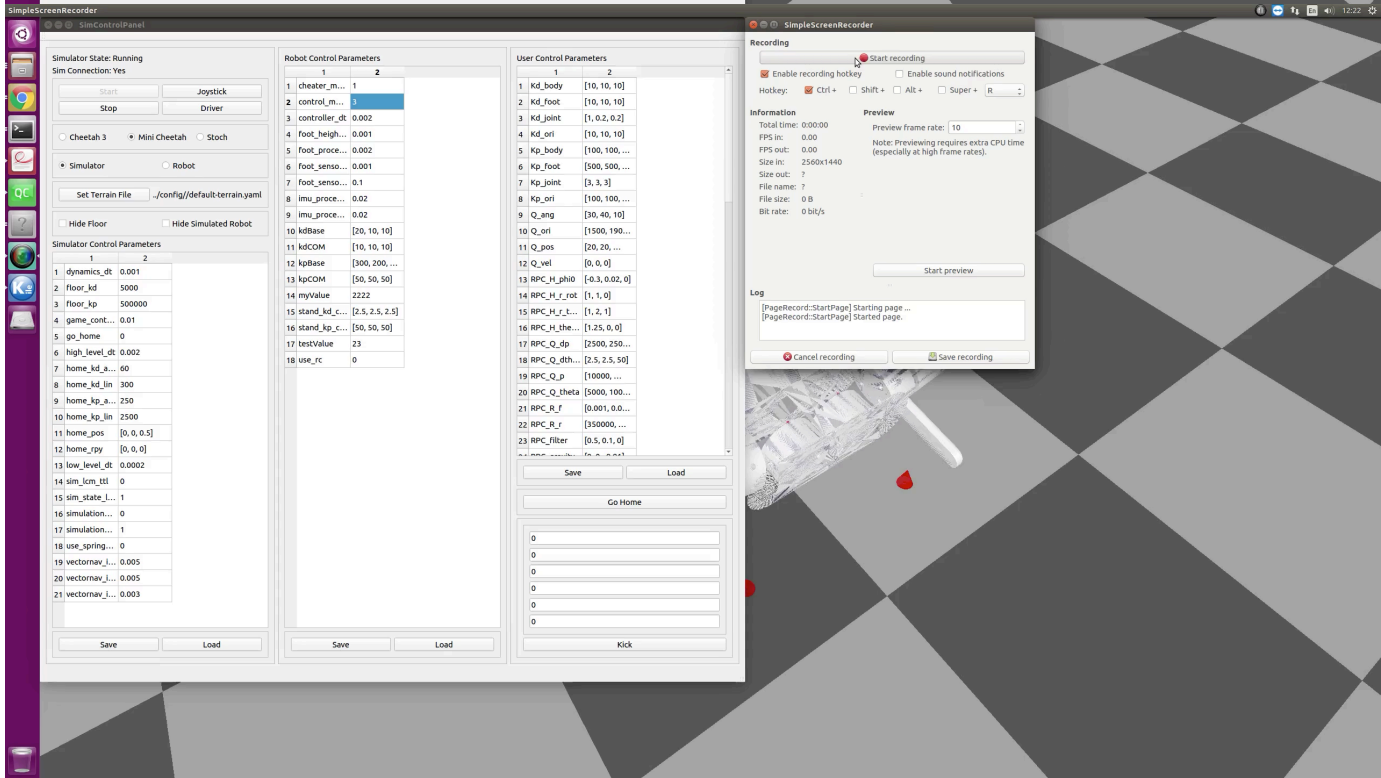
ICRA 2019, Ro-Man 2019 (2 papers), ICCAR 2019



Next steps: Stoch 3

We are developing a bigger stronger quadruped Stoch 3 in IISc.





Proposal: A “Mule” walking platform for extreme terrain and weather conditions

There is a growing requirement for indigenous development of a robust walking platform for extreme terrains

Proposal: A “Mule” walking platform for extreme terrain and weather conditions

Existing companies/research labs with walking robot platforms:

1. Boston dynamics (US): $ 100k for a quadruped
2. Agility robotics (US): $ 250k for a biped
3. Unitree robotics (China): $ 40k for a quadruped
4. Ghost robotics (US): $ 40k for a quadruped
5. ANYbotics AG (Switzerland, Europe)
6. Zhejiang university: $ 40k for a quadruped
7. Italiano Instituto Technologica (IIT, Italy)

There are NO walking robot companies in India!

Proposal: A “Mule” walking platform for extreme terrain and weather conditions

CHALLENGES:

1. The terrains in some parts of border are very extreme: steep inclines, freezing temperatures
2. Designing a walking controller is very complex. Research in walking > 30 years
3. Most of the parts required for building a walking robot are not manufactured in India: BLDC motors, gearboxes, batteries, cameras, on-board compute platform.
4. Indian engineers have the required skillset for software projects, but not for hardware projects.

Proposal: A “Mule” walking platform for extreme terrain and weather conditions

	Phases	Milestones
Stoch 3: We are currently in Phase I. Currently **FUNDED** by IISc.	I (1 - 1.5 years)	R&D phase, where robust controllers are developed, new designs are created and assembled, and walking is demonstrated in IISc in outdoor environments.
Mule walking platform: Phase II, III Can be completely focused on needs of the Army. Mule has other potential applications like space, agriculture.	II (1.5 - 2 years)	Pilot phase demonstrated in a suitable hilly region. Temperatures of 10 deg. C to 35 deg. C and slopes of up to 20 degrees are tested.
	III (2 - 2.5 years)	Development phase demonstrated in the field with temperatures of –45 deg. C to +45 deg. C and 45 degree slopes and a payload capacity of 20-25 kg.

Potential applications of Stoch 3 and Mule in the army

Stoch 3 will have partial autonomy. Can demonstrate mobility with joystick control in “not-so-extreme” environment conditions.

1. Mine detection (can send the robot with sensors attached a few meters ahead of the patrolling team).
2. Follow the leader (can capture videos, images of the scene).

Remarks:

1. This is purely an R&D effort. Our current team will be driving this effort.

Mule can have full autonomy. Can demonstrate mobility with map guided routes.

1. Patrolling in sensitive areas, and in extreme environment conditions.
2. Transportation of emergency equipment.

Remarks:

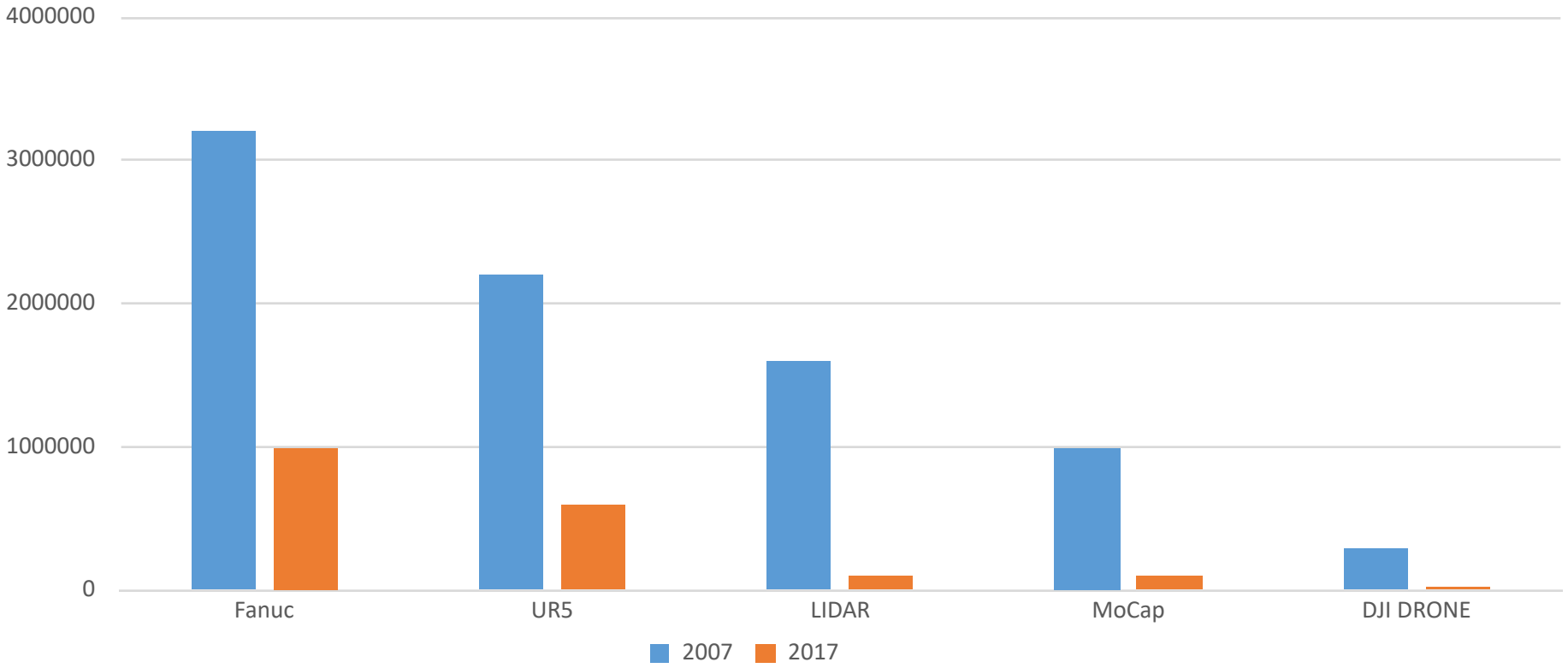
1. We will need to collaborate with a startup/industry to scale (transfer of technology). BEML, TIH (IISc) have shown interest. Similar transfers can be executed with other government organizations under MOD.

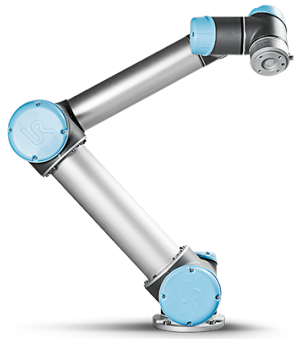
STOCH 3 specifications and estimated cost

Sr. No	Part	Description	Mass/item (kg)	Cost/item (in Lakh INR)	Numbers	Mass/robot kg	Spare Nos.	Total (in Lakhs)
1	Motors	Brushless DC motors, 24 V, output (after gear reduction): 100 rpm (~10 rad/s)	0.35	0.1	12	4.2	6	1.8
2	Gear Box	10:1 reduction	0.4	0.4	12	4.8	6	7.2
3	Motor drive	24 V, 1 kW per drive	0.05	0.1	12	0.6	6	1.8
4	Linkages (legs)	Linkages like calfs, thighs torso made of carbon-fibre/aluminium	1.5	0.5	4	6	2	3
5	Chassis	Structure	2.5	0.75	1	2.5	1	1.5
6	Sensors	IMU	0.05	0.5	4	0.2	2	3
7	Sensors	Joint encoders	0.05	0.05	12	0.6	12	1.2
8	Sensors	Ultrasonic sensors for terrain estimation	0.05	0.1	4	0.2	4	0.8
9	Vision	Stereo cameras (HD resolution)	0.2	0.25	4	0.8	2	1.5
10	Controllers	Trajectory generator QP solver etc. on-board	0.05	0.05	4	0.2	2	0.3
11	CPU	Intel i7 series (or better) or Nvidia Jetson Xavier	0.3	1	1	0.3	1	2
12	Battery	Lithium ion (only supports -10 to 25 deg C)	3	1	1	3	2	3
13	Charging	charging + charger	0.5	0.5	1	0.5	1	1
14	Docking Station	logging/debugging	0	0.15	1	0	0	0.15
15	Misc.	Wires, tools, T-slots and various other accessories required for testing	0	1	1	0	0	1
						23.9		**29**

Mule cost can be estimated based on the specifications

Robot Costs are Going Down!





Robot Costs are Going Down!

What Is the Real Cost of

insights.globalspec.com/article/4788/what-is-the-real-cost-of-an-industrial-robot-arm

How Much Do Industrial Robot Arms Cost?

The price of industrial robots has dropped more than 25 percent since 2014, and is expected to drop an additional 22 percent by 2025. Today, an industrial robotic arm can cost anywhere from

Best Drone for Money: $

time.com/money/4800984/drone-prices-decrease-spark-dji/

Money

EVERYDAY MONEY • TECH

Why High-End Drones Are Half the Price They Were a Year Ago

GM's Cruise acquires Str

Secure | https://techcrunch.com/2017/10/09/cruise-acquires-strobe-to-help-dramatically-reduce-lidar-costs/

Shishir

News Startups Mobile Gadgets Enterprise Social Europe Trending Amazon Tesla Microsoft

self-driving

strobe

cruise

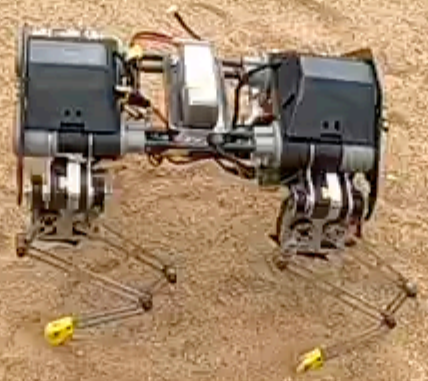
Cruise acquires Strobe to help dramatically reduce LiDAR costs

Posted Oct 9, 2017 by Darrell Etherington (@etherington)

Thank you

Collaborators:
Bharadwaj Amrutur, Professor, IISc
Shalabh Bhatnagar, Professor, IISc
Ashitava Ghosal, Professor, IISc

Funding Agencies (present and past):
Department of Science and Technology
Robert Bosch India
Yaskawa India



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