TECHNISCHE UNIVERSITÄT DARMSTADT

Hybrid Electric-Pneumatic Actuator (EPA) for Legged Locomotion

Aida Mohammadi Nejad

Lauflabor

Goal of project

Design
a new hybrid actuator
to outperform existing actuators in efficiency and robustness
over the operational region required for human-like gaits

Goal of project

Design
a new hybrid actuator
to outperform existing actuators in efficiency and robustness
over the operational region required for human-like gaits

locomotor sub-functions

TECHNISCHE UNIVERSITÄT DARMSTADT

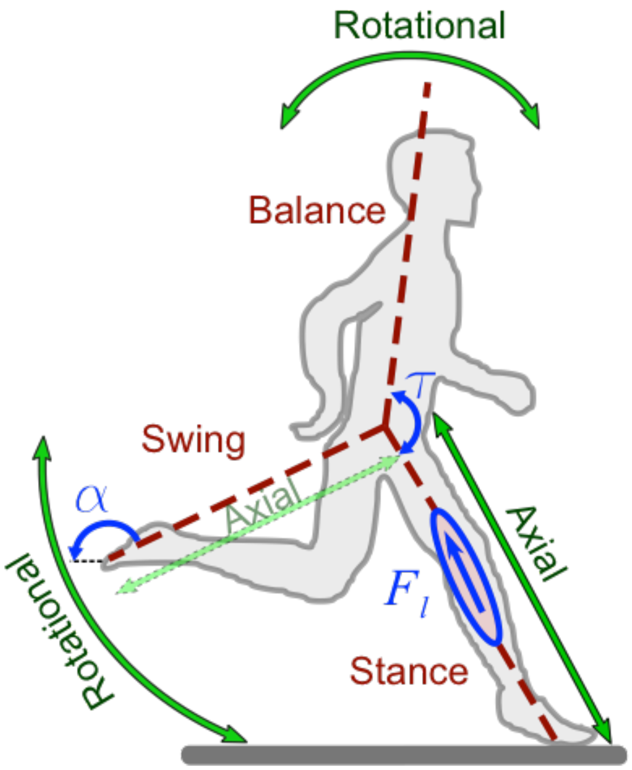
Bouncing (axial leg function)
describes the elastic rebounding of the stance leg (ground contact) to counteract gravity

Leg swinging
a rotational movement of the swing leg combined with a minor axial leg movement for ground clearance

Balancing (posture control)

we focus on **bouncing** as **the first locomotor sub-function** and how the new actuator can be advantageous for bouncing

Hopping in place



Lauflabor

Goal of project

TECHNISCHE UNIVERSITÄT DARMSTADT

Design
a new hybrid actuator
to outperform existing actuators in efficiency and robustness over the operational region required for human-like gaits

Different types of acctuators

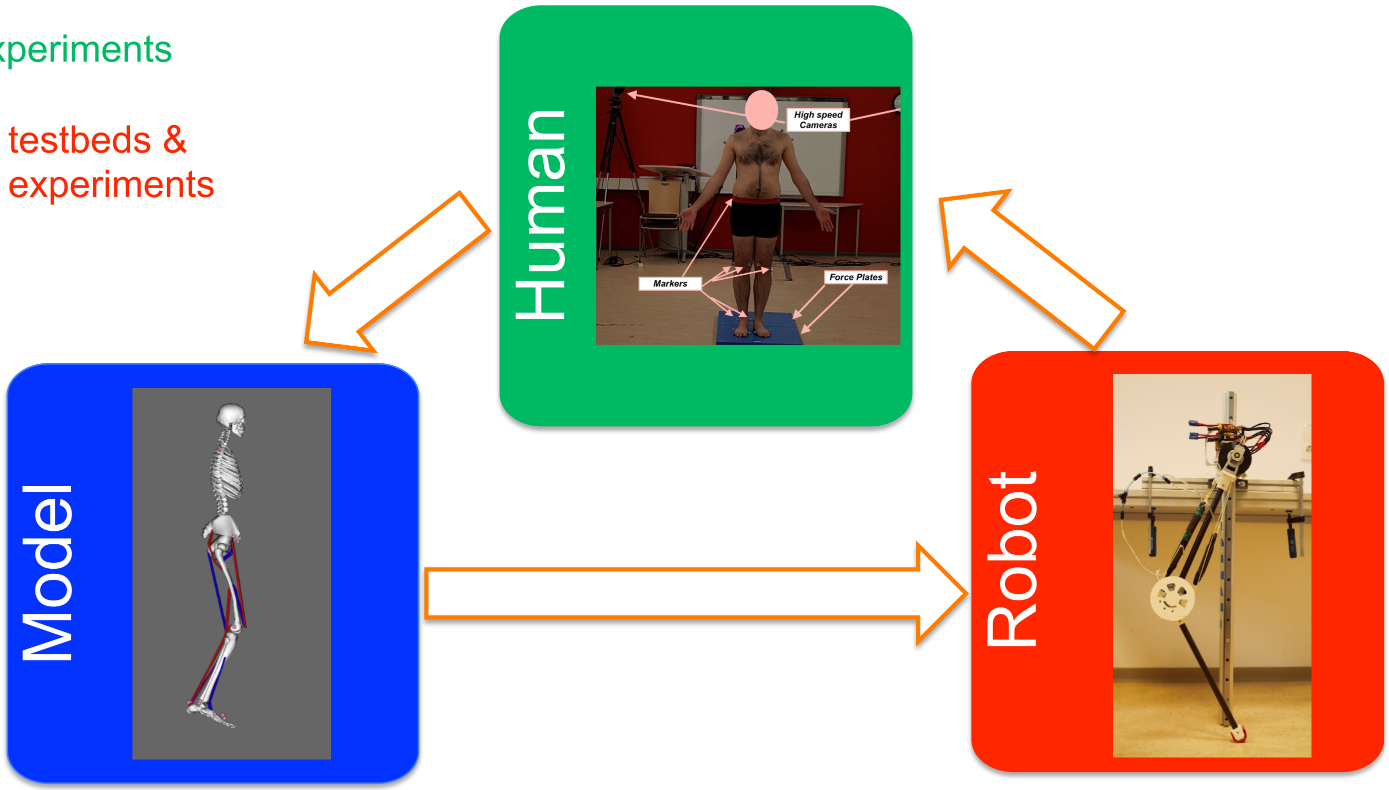
- **Pneumatic artificial muscles (PAM)**
- **Electric motors (EM)**
  - DDEM: direct drive electric motor
  - GEM: geared electric motor
- **Series elastic actuators (SEA)**
  - Variable impedance actuators (VIA)
- **Hydraulic actuators (HA)**
- **EPA: Combination the EM and PAM**

Properties	PAM	DDEM	GEM	SEA	HA	EPA
Bandwidth	low	high	high	low	high	high
Versatility in torque generation	medium	low	high	low	high	very high
Achievable range of motion	medium	high	high	medium	medium	very high
Achievable velocity	medium	high	medium	medium	high	high
Achievable torque	medium	medium	high	medium	very high	high
Efficiency	high	high	high	very high	very low	very high
Similarity to human actuators	high	very low	very low	medium	very low	very high
Robustness (impact resistance)	high	low	very low	high	high	high
Weight	very low	low	medium	medium	medium	low
Size	medium	low	medium	medium	medium	medium
Noise	high	very low	very low	very low	high	high
Price	very low	low	medium	medium	very high	low
User friendliness	very high	high	high	medium	medium	high
Intrinsic compliance	very high	very low	very low	very high	very low	very high
Backdrivability	high	very high	low	very high	very low	high
Position controllability	low	very high	very high	high	very high	high
directions of actuation	1	2	2	1	2	2

Our approach

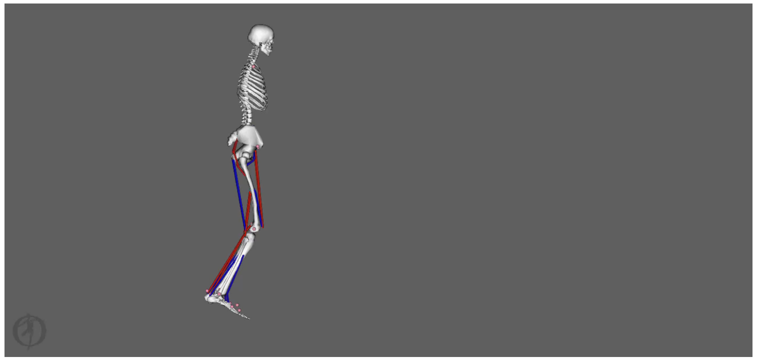
TECHNISCHE UNIVERSITÄT DARMSTADT

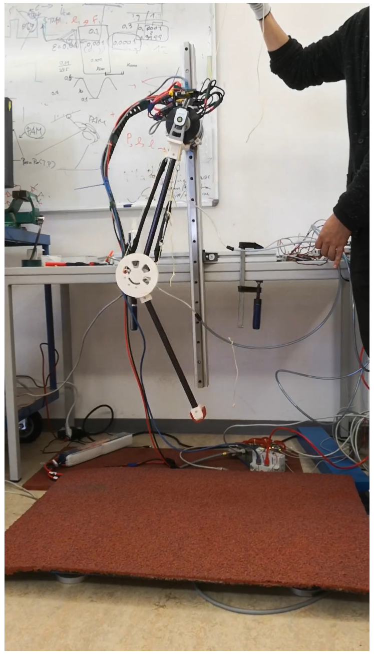
- Human experiments
- Modeling
- Hardware testbeds &
- Hardware experiments



Lauflabor

Our approach





Key question

What are the fundemental mechanical design and control principles in human hopping?

Mechanics: musculosketal system
Control: neular control

Experiment Suggestion
Measurements?

Previous Hopping Experiments

- 8 Subjects
- Hopping experiments:
  - ✓Preferred hopping height and frequency
  - ✓Hopping with maximum hopping height which is possible for subject
  - ✓One leg hopping: right leg and left leg
  - ✓Specified frequency hopping: 1 Hz, 2 Hz, 3 Hz
- Each experiment repeated 3 times
- Each experiment took 20 seconds

Some Suggenstion for new Experiments

TECHNISCHE UNIVERSITÄT DARMSTADT

- 8 more Subjects
- Hopping experiments:
  - ✓Preferred hopping height and frequency
  - ✓Hopping with maximum hopping height which is possible for subject
  - ✓One leg hopping: right leg and left leg
  - ✓Specified frequency hopping: 1 Hz, 2 Hz, 3 Hz ?
  - ✓Perturbed hopping, perturbation on one leg and both legs
- Each experiment repeated 3 times
- Each experiment: 25 seconds
- Measuring EMG at least for one leg
- Oxygen consumption