NRI: FND: Natural Power Transmission through Unconstrained Fluids for Robotic Manipulation

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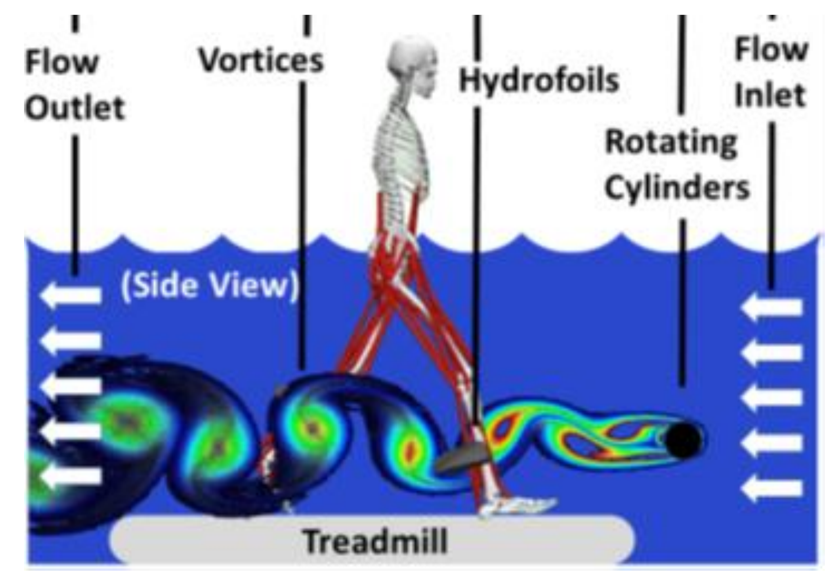
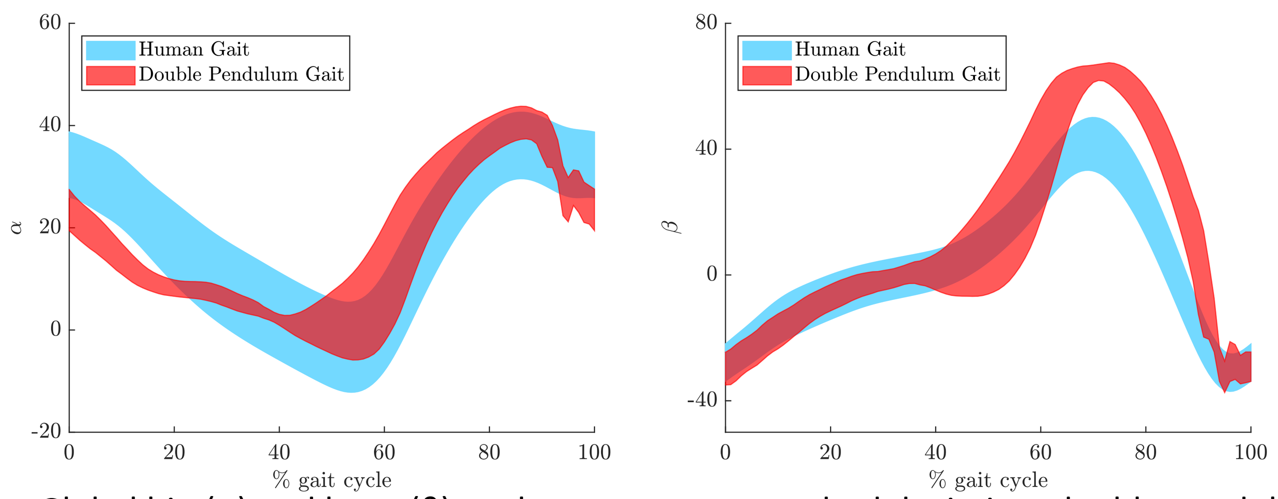
OVERVIEW

GOAL: Manipulate a body in fluid by controlling the transmission of power from a robot through a fluid environment to the object to be manipulated

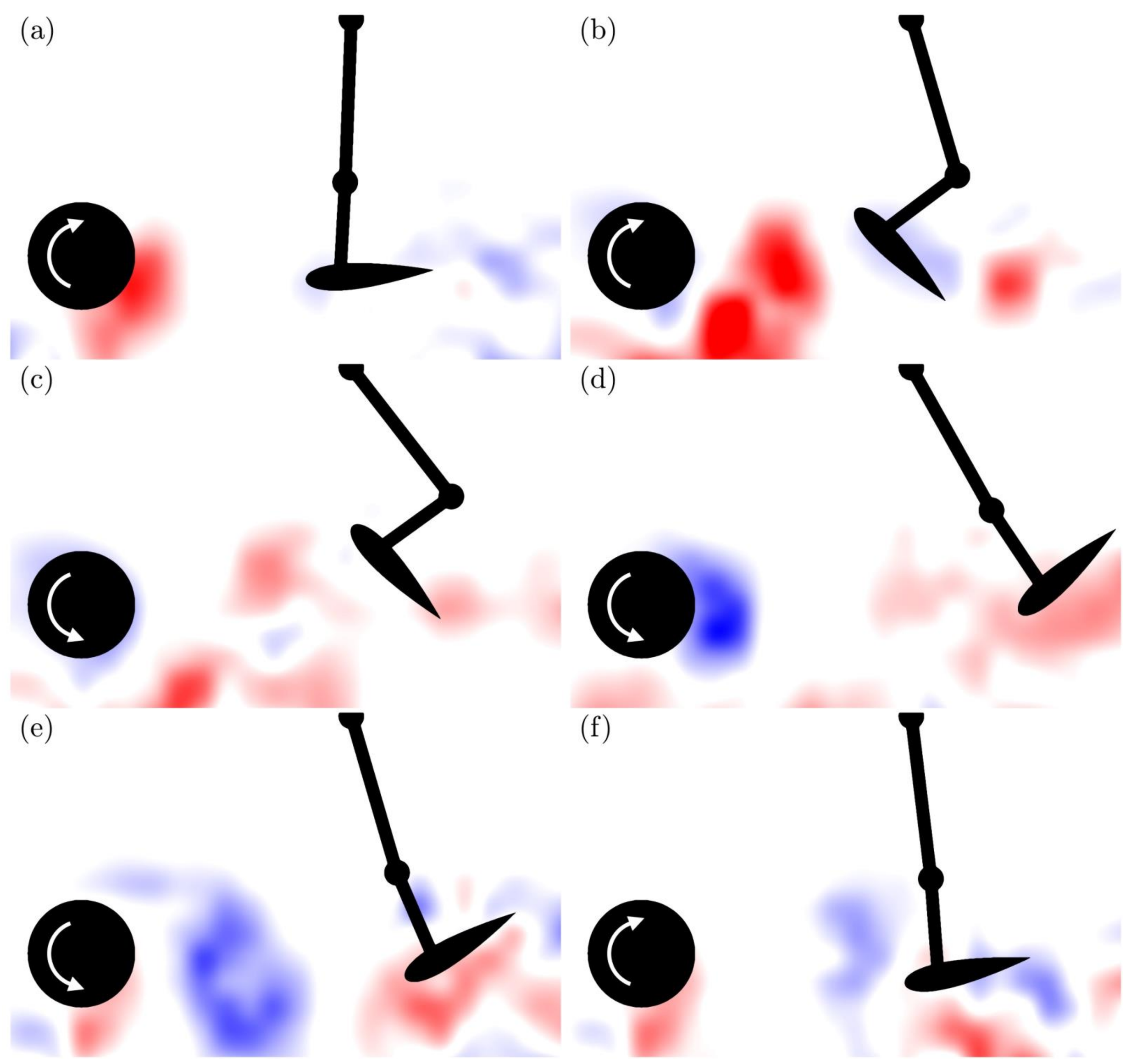
AIM: Use controlled vortex shedding to develop a novel fluid-powered human gait assistance system to enable a fully compliant assistive gait system for rehabilitation.



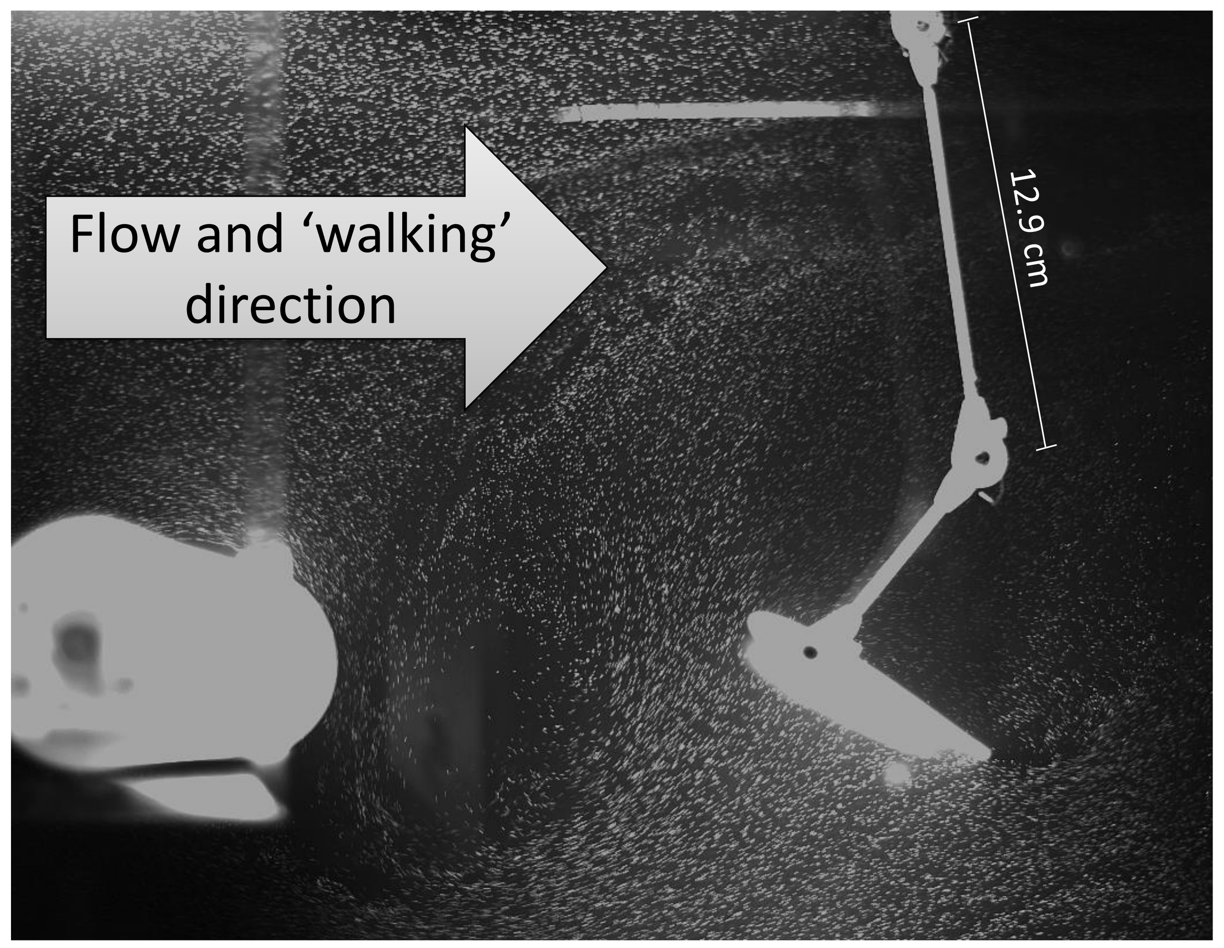
SMALL-SCALE TRAJECTORY EXPERIMENTS



Global hip (α) and knee (β) angle mean ± one standard deviation, double pendulum angles in red and human mo-cap data in blue



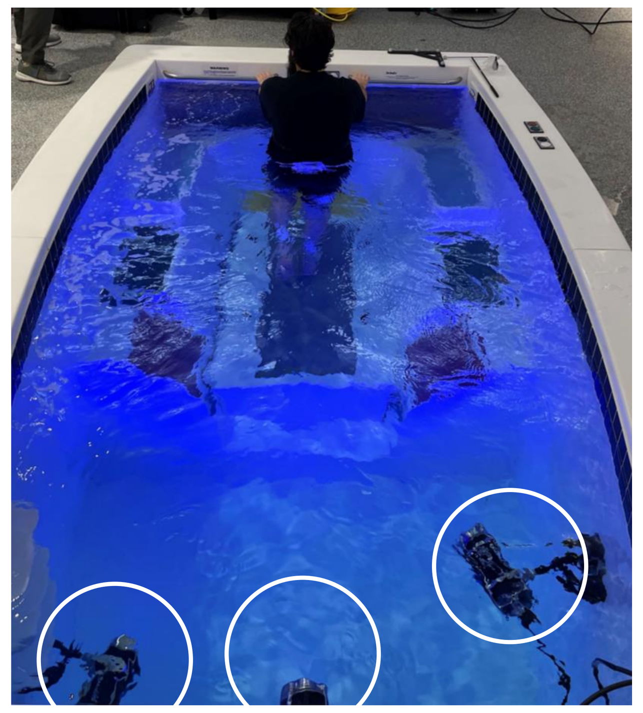
Vorticity data at multiple instances during one gait cycle, with positive rotation in red and negative in blue. Values calculated using particle image velocimetry



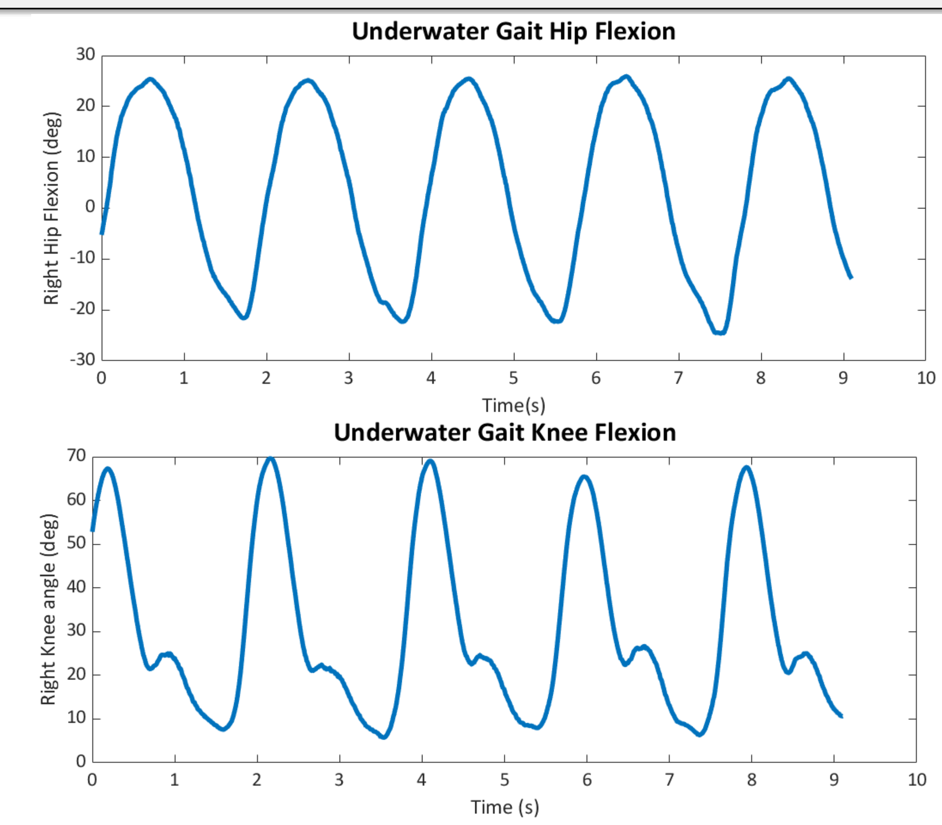
Water tunnel experiments where flow comes from left and passes the rotating cylinder. Switching cylinder rotation direction sheds a vortex, as seen between the cylinder and hydrofoil. Vortex interacts with hydrofoil and induces motion in the double pendulum

- Passive double pendulum used to replicate the kinematics of a human leg; hydrofoil attached at a point corresponding to the mid shank
- Pendulum placed in wake of a periodically rotating cylinder with controllable frequency to influence the structure of the wake
- Wake-hydrofoil interactions influence the motion of the hydrofoil and in turn the double pendulum, and a human gait-like motion can be induced in the double pendulum

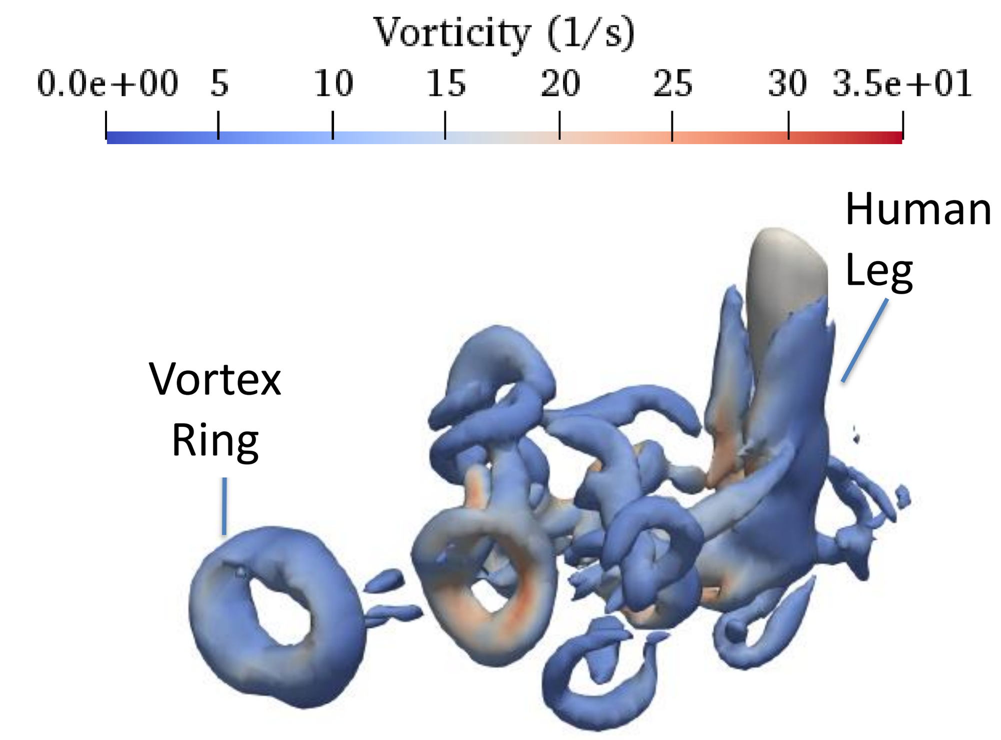
TRANSFERRING TO HUMAN GAIT



3-Camera Underwater MoCap System



Capturing kinematics of normal unassisted underwater treadmill walking gait of healthy subjects using underwater motion capture system.

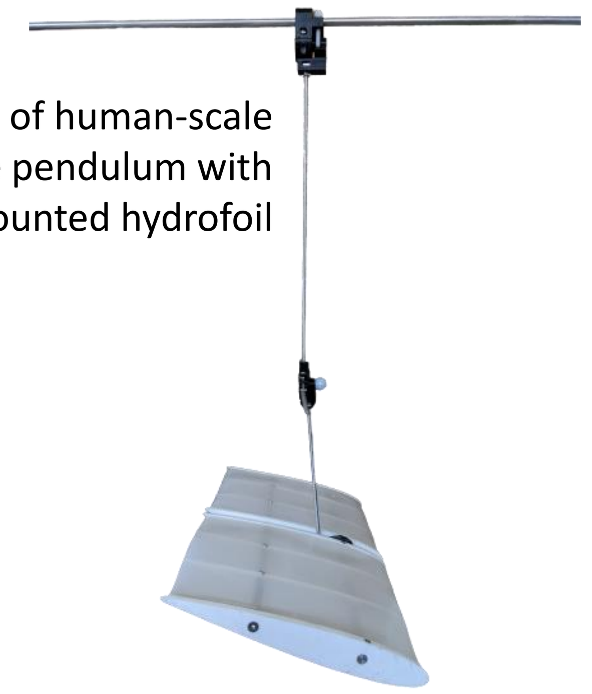


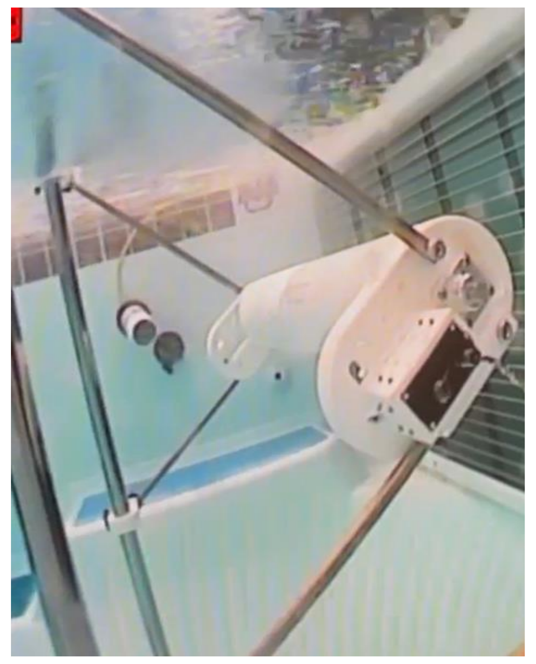
- Computational fluid dynamics simulation using immersed boundary method studies the flow around the leg during a gait cycle in still water with joint kinematics provided as an input.
- Iso-surfaces of vorticity show that a vortex-ring is formed between toe-off and heel-strike stages when the fluid is pushed upstream of the leg.

NEXT STEPS

- Human-scale double pendulum to recreate small-scale results observed in water tunnel.
- Testing controllability of human-scale hydrofoil motion via cylinder rotations
- Explore controllability of the model and create control laws to achieve desired performance in both upstream and downstream flow conditions.
- Transfer principles to human-in-the-loop experiments

Sideview of human-scale double pendulum with mounted hydrofoil





Human-scale vortex generator

IMPACTS

- Enable a new type of manipulation strategy, which does not involve direct contact or coupling with the object being manipulated
- Basis for novel method of natural gait training for persons recovering from stroke or injury
- Extensions to manufacturing and underwater robotics for fluid-based non-contact material handling and manipulation
- Creating an underwater robotics outreach program for K-12 students to demonstrate the physics as well as the beauty in engineering systems

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