Shadow Robot

Shadow Teleoperation System

Technical Specification

September 2025

Table of Contents

1. Overview

The Shadow Teleoperation System combines state-of-the-art robotics and user interface technologies in order to mimic human arm and hand movements and allow highly intuitive human-level dexterity at a distance.

The system is built by two 6-degree-of-freedom (DoF) robotic arms, each fitted with our 20 DoF (24 joint) Dexterous Hand, for a combined total of 52 DoF (60 joints). While the 6 DoF arms allow the system to mimic any position and orientation of the user's forearms, the Dexterous Hands' humanoid kinematics allow accurate reproduction of the user's hand movements, including wrist angles.

The main user interface is the Shadow Glove, which tracks the user's forearm, palm and fingertips in 6 DoF each, using a combination of optical and magnetic sensors. The state of the system is controlled by a foot pedal, allowing the user to start, stop and reset the system. Its main function is that of a "clutch", expanding the workspace of the robot beyond that of the user.

The system has been designed to provide movement precision comparable to that of the human performance level. It has the potential to not only reduce travel costs and eliminate skill shortages, but remove humans from dangerous situations entirely.

To summarise, a standard Shadow Teleoperation System includes:

- Robots and control systems:
    - Two Shadow Dexterous Hands
    - Two Universal Robots UR10e 6-DoF arms
    - Two Shadow stands for UR10e
    - A dedicated robot control NUC, running a real-time kernel
    - A main computer, running main teleoperation processes
    - A gigabit router connecting all networked devices
- User interface:
    - Two Shadow Gloves, including interfaces and adaptors
    - An HTC Vive Pro with 2 Vive Trackers (v.3) and 4 Vive Base Stations (v.2)
    - A 3-button USB control pedal
    - 2 emergency stop buttons and 1 emergency stop pedal
- Shadow Teleoperation software and documentation are installed on the above computers.
- All necessary power supplies, cabling, etc.

2. Mechanical Profile

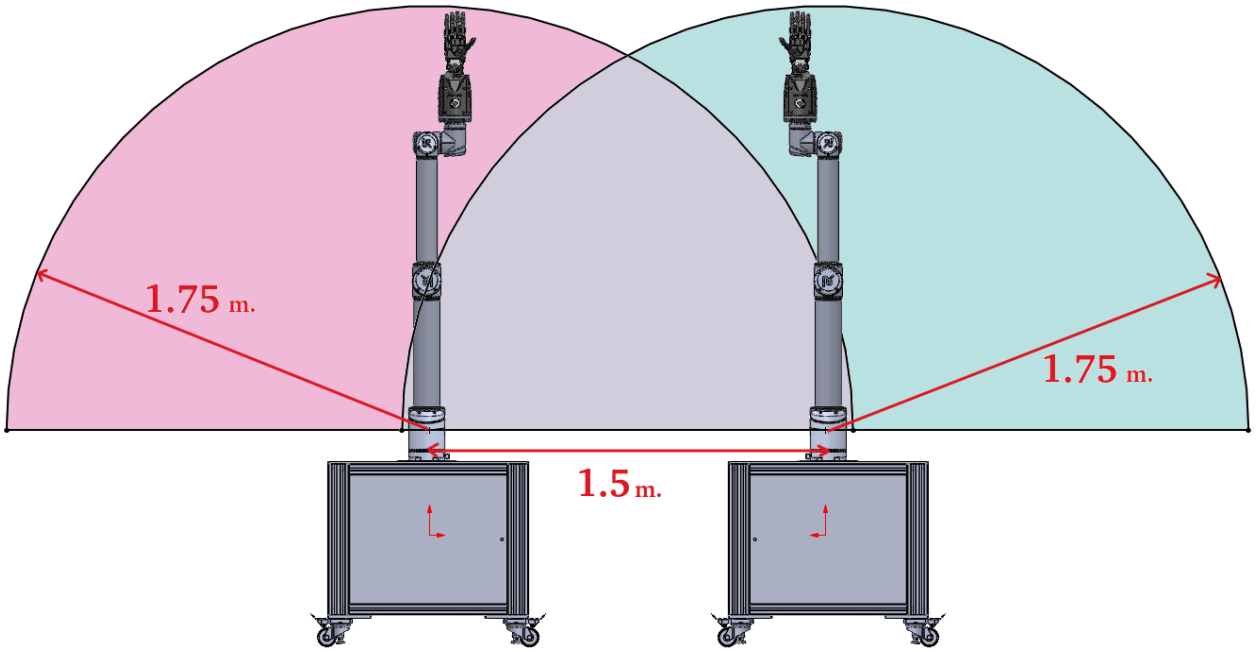
2.1 Robot kinematic structure

2.1.1 Arms

The Shadow Teleoperation System kinematics are optimised to be as close as possible to the kinematics of the human upper limbs. Each arm is fixed to a heavy stand that elevates the base of the robot arm to 83cm above the floor and keeps the system stable. The standard distance between both robot arms is 1.5 meters; it can be adapted according to requirements.

Joint	Working Range		Max Speed (*)
	Min	Max	
Arm Wrist 1	-360º	360º	180º/s
Arm Wrist 2	-360º	360º	180º/s
Arm Wrist 3	-360º	360º	180º/s
Arm Elbow	-360º	360º	180º/s
Arm Shoulder	-360º	360º	120º/s
Arm Base	-360º	360º	120º/s

(*) Joint maximum speeds are based on factory tuning and control parameters; the values listed here are indicative. Speeds will vary if tuning and control parameters are changed.



It should be noted that the manipulation range of the hand and arm is reduced at full arm extension (there is less available range of movement for the arm), and the practical workspace of the arm is, in fact, slightly smaller than indicated.

2.1.2 Hands

The Dexterous Hand kinematics are optimised to be as close as possible (within engineering constraints) to the kinematics of the human hand.

Joint(s)	Working Range		Notes
	Min	Max	
Finger Distal Flexion & Extension (F1)	0	90	Coupled
Finger Middle Flexion & Extension (F2)	0	90	
Finger Base Flexion & Extension (F3)	-15	90	
Finger Base Abduction &Adduction (F4)	-20	20	
Little Finger Palm Flexion & Extension (LF5)	0	45	
Thumb Distal Flexion & Extension (TH1)	-15	90	
Thumb Middle Flexion & Extension (TH2)	-40	40	
Thumb Middle Abduction &Adduction (TH3)	-12	12	
Thumb Base Flexion & Extension (TH4)	0	70	
Thumb Base Rotation (TH5)	-60	60	
Wrist Flexion & Extension (WR1)	-40	28	
Wrist Abduction &Adduction (WR2)	-28	8	

The thumb has 5 degrees of freedom and 5 joints. Each finger has 3 degrees of freedom and 4 joints.

The distal joints of the fingers are coupled in a manner similar to a human finger, such that the angle of the middle joint is always greater than or equal to the angle of the distal joint. This allows the middle phalange to bend while the distal phalange is straight. The little finger has an extra joint in the palm provided to allow opposition to the thumb.

All joints except the finger distal joints are controllable to +/- 1° across the full range of movement.

2.2 Tracking

By combining the below data, the Shadow Teleoperation System software establishes the room-scale positions and orientations of the user's forearm, palm, fingers and thumb.

2.2.1 Vive Tracker ⇉ Arms

The user's palms are tracked using an HTC Vive laser tracking system, which reports the positions of trackers attached to the Shadow Glove. The Vive system uses 4 base stations, each with a 120º field of vision, to provide room-scale tracking with minimal occlusions. The base stations can be reconfigured to suit the user's workspace and typical range of movement, but this is usually unnecessary.

2.2.2 Haptx G1 Glove ⇄ Dexterous Hand (Haptic System)

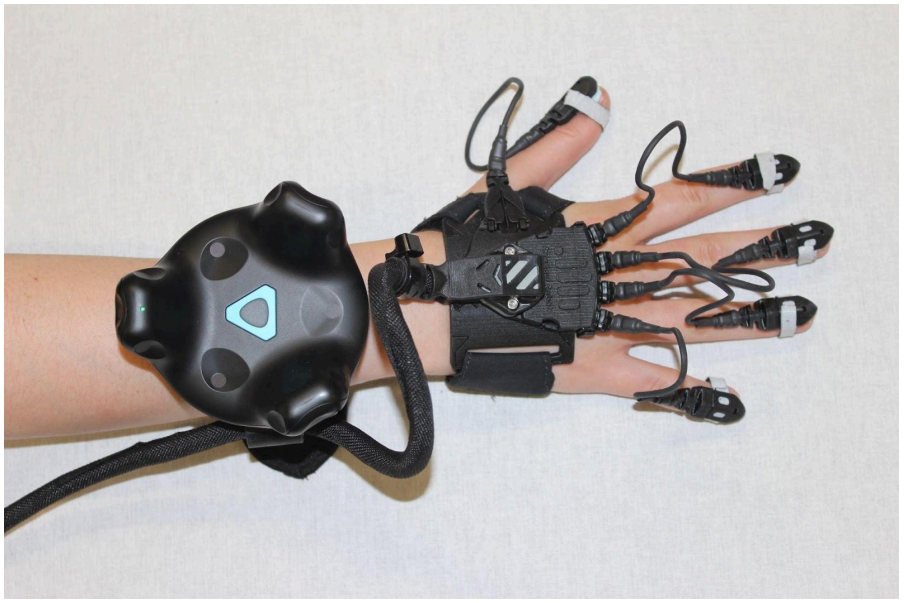
The Haptx Gloves G1 deliver incredibly realistic touch sensations through their unique microfluidic system. This system intelligently directs compressed air to 135 tiny tactile actuators embedded in each glove. These actuators precisely inflate at specific locations, gently displacing your skin to simulate the feeling of contact with virtual objects.

Furthermore, each glove accurately tracks hand movements with 36 degrees of freedom and an impressive positional resolution of 0.3 mm RMS. This precise tracking is achieved using six 6DoF (degrees of freedom) electromagnetic motion trackers integrated into each glove – one at each fingertip and one on the forearm. This ensures highly accurate and repeatable tracking of both finger and forearm position and orientation relative to the palm.

Designed for comfort and unrestricted movement, the Haptx G1 Gloves accommodate a wide range of hand sizes. You'll experience full, unencumbered finger movement, allowing you to perform any grasp or gesture naturally while wearing them.

2.2.3 Shadow Glove ⇉ Dexterous Hand (Non-Haptic System)

In contrast, the Non-Haptic system features Shadow Gloves, designed specifically to capture the user's finger movements. Like their haptic counterparts, these gloves prioritise comfort for a variety of hand sizes and ensure complete freedom of finger motion, enabling any grasp or gesture. They also precisely track hand movement with 36 degrees of freedom, utilising six 6DoF electromagnetic motion trackers per glove—one at each fingertip and one on the forearm—to deliver accurate and repeatable data on finger and forearm position and orientation relative to the palm.



2.3 Weight and Payload

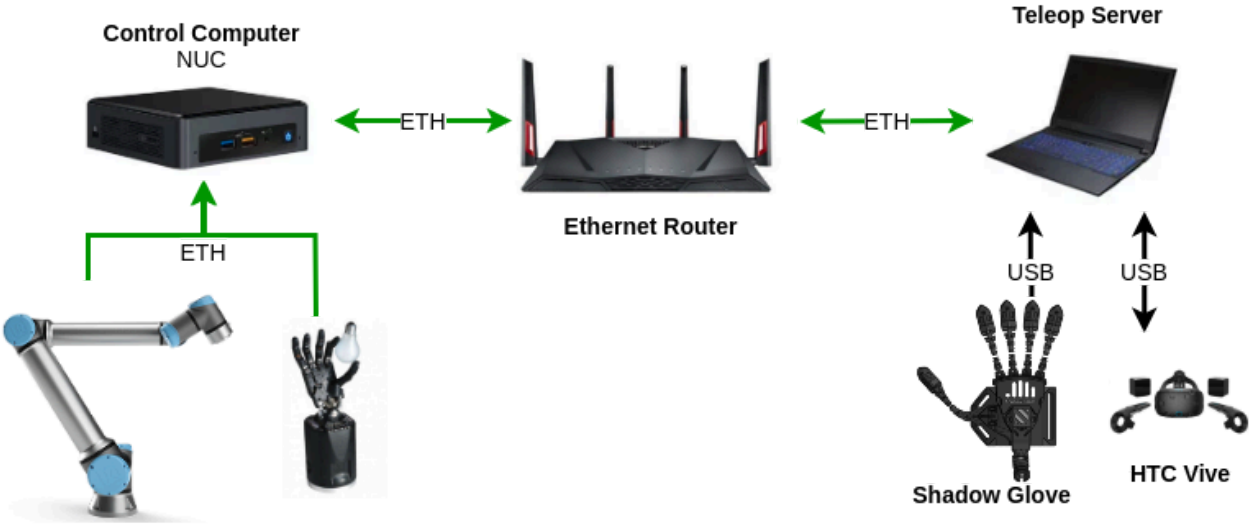
Component	Mass	Quantity	Total Mass
UR10e Arm	33.5 Kg	2	67 Kg
UR10e Control Box	12 Kg	2	24 Kg
Shadow Dexterous Hand	5 Kg	2	10 Kg
UR10e Stand	75 Kg	2	150 Kg
Stand Ballast	75 Kg	2	150 Kg
Total			**401 Kg**

The Shadow Teleoperation System (excluding the ballast) has a total weight of 251kg. An additional 75kg will have to be added per stand if the system cannot be bolted to the floor. The system allows the operator to lift and manipulate objects up to 3kg, although this is heavily dependent on grasp shape.

2.4 Safety

Despite being designed for remote teleoperation, the Shadow Teleoperation System is safe even when the robot is sharing a workspace with humans. The Universal Robots UR10e is a collaborative robot, built from the ground up to safely share a workspace with humans. The Shadow Dexterous Hand is (configurably) compliant, and constantly monitors and limits tendon forces.

3. Communications



4. Computer and Software

The system is supplied with a multi-core discrete-GPU laptop running Ubuntu, a NUC for robot control and a router to connect them. The router allows later reconfiguration for remote teleoperation. Shadow Teleoperation software is installed on both computers. The software is based on the ROS meta-operating system.

The system is delivered pre-configured; teleoperation can be initiated using the graphical interface on the main computer. Users can also launch fully or partially simulated teleoperation systems, run demonstrations, etc.

For customers wishing to adapt or extend the Shadow Teleoperation System, the open nature of the infrastructure of the system lends itself to such projects. They should know that:

- The software is separated into ROS nodes, launched using launch files, communicating via ROS topics, services etc.
- Launch files can be modified, node arguments and parameters modified.

- Topics can be subscribed to, remapped, etc.
- The software is containerised using Docker, affording it an isolated environment to run in, and protecting it from, e.g. environmental changes that may be necessary for additional customer software.
- Source code for our open-source software is included. Some software is proprietary and closed-source, but all communication between nodes is exposed via ROS.
- Source code for the dexterous hand micro-controllers and schematics for the electronics subsystems are available on request under Non-Disclosure Agreement (NDA).
- Example code, along with documentation, is provided, along with access to e-mail support from Shadow.
- 3D models and kinematic data are supplied via ROS.
- Collision scenes, robot models, etc., are all defined using ROS-standard methods (MoveIt! scene files, URDFs, etc.) and can be modified.

5. Specification Summary

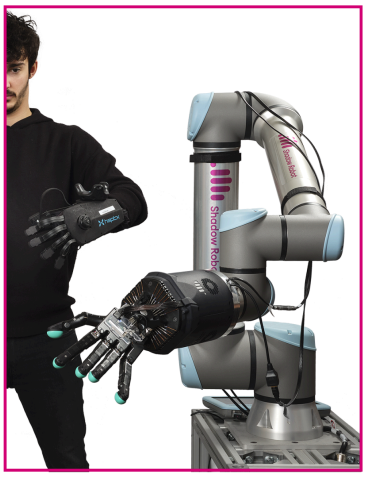
Item	Value
System Total Mass (not including stand ballast)	251 Kg
Stand Ballast Mass (per stand if it's not bolted to the floor)	75 Kg
Single Hand Payload	3 Kg
Hand Max Speed	~1 Hz (Fully open to fully clenched)
Arm Max Speed	1 ms^{-1}
Power Peak	2.3 KW
Input Voltage	110 - 240 V
User-Robot Latency (movement start-to-start)	50 ms
Single Hand DOF	20 motors
Single Arm DOF	6 motors
System Total DOF	52 motors
Operating Temperature Range	10 - 40 °C
Operating Relative Humidity (non-condensing)	0 - 90 %

6. Options

The following options may be selected at the time of ordering.

8.1 Unimanual Right or Left System

For those interested in single-hand teleoperation, Shadow offers Unimanual Teleoperation Systems. These can be manufactured on demand as either a right or left-hand system, specifically tailored to your project requirements.

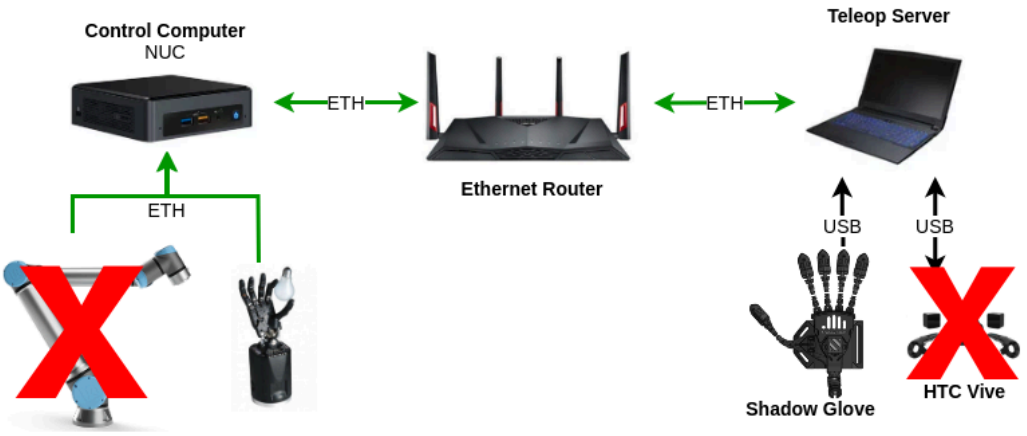


8.2 Haptic or Non-Haptic

Our teleoperated robotic systems offer two distinct glove options to suit your specific research needs. You can choose between a high-fidelity haptic experience for immersive tactile feedback (See reference on section **2.2.2 Haptx G1 Glove ⇄ Dexterous Hand, Haptic System**) or a non-haptic solution focused purely on precise motion capture (See reference on section **2.2.3 Shadow Glove ⇉ Dexterous Hand, Non-Haptic System**). Both options are designed for comfort and exceptional tracking accuracy.

8.3 Hand + Glove Teleoperation

This streamlined version of our full teleoperation system enables hand control via the non-haptic Shadow Glove, but excludes arm teleoperation. It's an ideal choice for research groups focused on building their own teleoperation stack who prefer to avoid the initial deep complexity of controlling a highly articulated robot hand.



Shadow Robot Company
Unit 31, Spectrum House
32-34 Gordon House Rd
London NW5 1LP
United Kingdom
+44 (0)20 7700 2487

www.shadowrobot.com
hand@shadowrobot.com