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Data Descriptor

Dataset for Collaborative Robotics

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Abstract

This dataset represents the physical interactions collected by the robot's sensors during a collaborative effort between humans and robots. The experiment was conducted at the Sheffield Robotics laboratory at the University of Sheffield, UK, utilizing a KUKA LBR iiwa 7 R800 serial manipulator. Thirty participants, consisting of 14 males and 16 females, participated, including both students and faculty members. Participants were instructed to guide the robot's end effector through a two-dimensional maze situated on a horizontal plane. Each participant performed the same task 15 times, resulting in 450 complete interaction sequences. All data files are provided in CSV (comma-separated values) file format, which allows data to be stored in a table-structured format. The complete dataset is publicly available via the Mendeley Data repository (DOI: 10.17632/4fr33dkrjt.3).

Dataset: https://data.mendeley.com/datasets/4fr33dkrjt/3

Dataset License: Creative Commons Attribution (CC BY 4.0)

Keywords: collaborative robot; cybersecurity of robots; human–robot interaction; biometric authentication; KUKA LBR iiwa; force-torque sensing

1. Introduction

Collaborative robots (cobots) are increasingly utilized in manufacturing as well as service environments, working alongside humans without safety boundaries. This close interaction between humans and robots engenders significant safety, usability, and security challenges [1]. To enhance the efficacy of robots, it is essential to design user-friendly controls and ensure their safe operation, demanding an understanding of human–robot physical interaction.

Despite the increasing significance of research on human–robot interaction (HRI), there is a lack of publicly accessible information illustrating the physical interactions between humans and collaborative robots. Existing datasets frequently have a limited number of participants or restricted interaction patterns, limiting the development of robust models of human behavior in robotic usage. Table 1 provides a systematic comparison of publicly available physical HRI datasets, illustrating the gaps this dataset addresses.

As shown in Table 1, the present dataset is distinguished by its larger participant count (30), the highest number of repeated trials per participant (15), comprehensive multi-modal sensor data (forces, torques, full joint angles), and unrestricted public availability under

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a CC BY 4.0 licence. These features make it particularly suitable for studying individual differences, behavioural consistency, and biometric authentication in collaborative robotics.

Table 1. Comparison of publicly available physical human–robot interaction datasets.

Dataset	Participants	Trials	Sensor Data	Interaction Type	Task	Robot Platform	Public Access
This dataset	30	450 (15/participant)	Forces, torques, end-effector position, joint angles (10 Hz)	Physical guidance	2D maze navigation	KUKA LBR iiwa 7 R800	Yes (CC BY 4.0)
HRI Handover Dataset [2]	10	240	RGB-D video, object pose	Object handover	Object transfer	UR5	Yes
CORSMAL [3]	5	180	RGB-D, audio, IMU	Object manipulation	Container pouring	Baxter	Yes
Physical HRI Benchmark [4]	12	∼300	Forces, positions	Physical assistance	Lifting, guiding	PR2	Partial
Collaborative Assembly [5]	8	160	RGB video, object tracking	Collaborative assembly	IKEA furniture	Franka Emika	Yes
HRI Handshaking [6]	20	200	Forces, positions, EMG	Physical greeting	Handshaking	Custom 1-DOF	Yes

This paper presents a comprehensive dataset of human–robot physical interactions collected during collaborative manipulation tasks. The dataset addresses several gaps in current HRI research:

1. Scale: : With 30 participants each performing 15 trials, the dataset provides 450 complete interaction sequences.
2. Rich sensor data: The dataset includes synchronized measurements of forces, torques, and positions at the robot's end-effector and positions of all seven joints, captured at 10 Hz during task execution.
3. Demographic diversity: Participant information, including gender, handedness, and height, enables research into ergonomic factors and individual differences in robot operation.
4. Security applications: The dataset was designed to support research in biometric authentication and continuous user verification for collaborative robots [7].

The data were collected using a KUKA LBR iiwa 7 R800 lightweight collaborative manipulator. Participants guided the robot through a 2D maze task that requires sustained physical interaction, providing naturalistic data on human manipulation strategies and force application patterns.

This dataset was originally collected to support our investigation of behaviour-based biometrics for continuous user authentication to industrial collaborative robots, as reported in our prior work [7]. The present data descriptor provides comprehensive documentation of the complete dataset to facilitate its reuse by the broader research community for applications beyond the original authentication study.

This dataset is valuable to multiple research communities, including robotics (for developing adaptive control algorithms), human factors (for studying ergonomics and individual differences), machine learning (for behavior modeling and classification), and cybersecurity (for biometric authentication systems). All data are publicly accessible via the Mendeley Data repository, ensuring reproducibility and enabling comparative studies.

The remainder of this paper is organized as follows: Section 2 describes the dataset structure and content; Section 3 details the experimental methods and data collection procedures; Section 4 provides guidance for data users; and Section 5 concludes with a summary of the dataset's potential applications.

2. Data Description

2.1. Participants

The data were collected from 30 healthy adults (16 females and 14 males) who were students and faculty members at the University of Sheffield. Their average height was 170 cm (range: 154–190 cm), and approximately 90% of the participants were right-handed. Table 2 provides detailed demographic information for all participants. All participants were volunteers who provided informed consent before participating in the study.

Table 2. Participant demographic information.

ID	Gender	Handedness	Height (cm)
User 1	Female	Right	178
User 2	Male	Right	170
User 3	Male	Right	190
User 4	Male	Left	171
User 5	Female	Right	155
User 6	Male	Right	175
User 7	Female	Right	170
User 8	Male	Right	181
User 9	Female	Right	156
User 10	Female	Left	167
User 11	Female	Right	174
User 12	Male	Left	183
User 13	Female	Right	164
User 14	Male	Right	182
User 15	Male	Right	175
User 16	Female	Right	174
User 17	Male	Right	170
User 18	Female	Right	159
User 19	Female	Right	159
User 20	Female	Right	160
User 21	Female	Right	168
User 22	Female	Right	160
User 23	Male	Right	178
User 24	Female	Right	160
User 25	Female	Right	154
User 26	Male	Right	174
User 27	Female	Right	161
User 28	Male	Right	170
User 29	Male	Right	173
User 30	Male	Right	173

2.2. Data Files and Structure

The dataset contains 30 CSV files, one for each participant, with each file containing data from 15 trials. In addition, an Excel file is included containing the participants' demographic information shown in Table 2. Each CSV file is named according to the participant ID (e.g., "User_1.csv", "User_2.csv", etc.).

The total dataset comprises

- Thirty participant files(CSV format);
- One demographic information file(Excel format);
- One original maze file (PNG format);
- A total of 450 trials (30 participants × 15 trials each).

2.3. Data Format and Variables

Each participant's CSV file contains time-series data recorded at 10 Hz (every 0.1 seconds) during each trial. Table 3 describes all variables included in the dataset.

Table 3. Description of variables in each CSV file.

Variable	**Description**
Task_No	Task iteration number (1–15)
Time	Timestamp of the data reading (seconds)
OperationMode	Robot operating mode: T1 (Manual Reduced Velocity), T2 (Manual High Velocity), or AUT (Automatic) (see Section 3 for calibration and operation mode details)
isCollision	Boolean flag indicating if a collision was detected by the robot controller's internal model-based algorithm (a value of `true` indicates unexpected external forces exceeding predefined thresholds; see Section 3.5 for the collision condition definition)
isCompliance	Status of the robot's compliance mode
isReadyToMove	Boolean flag indicating whether the robot controller has completed motion planning and is ready to accept new movement commands (`true` = ready to execute; `false` = still processing or safety conditions not yet satisfied)
ToolPosition	Position of the tool/end-effector in Cartesian space [X, Y, Z, A, B, C] where X, Y, Z are coordinates in mm and A, B, C are orientation angles in degrees
ToolForce	External forces applied to the tool/end-effector [X, Y, Z] in Newtons, estimated via calibrated joint torque sensors and the robot's dynamic model
ToolTorque	External torques applied to the tool/end-effector [X, Y, Z] in Newton-metres, estimated via calibrated joint torque sensors and the robot's dynamic model
JointPosition	Robot joint angles [A1, A2, A3, A4, A5, A6, A7] in degrees for all seven joints
Tool_Velocity	End-effector velocity value
Tool_Acceleration	End-effector acceleration value

To guarantee uniform experimental conditions for all participants and trials, velocity and acceleration were fixed. This enabled the analysis to concentrate on the dynamics of human–robot interaction rather than fluctuations in motion parameters. The data are stored in raw format with no filtering or preprocessing. This enables researchers to set up their data processing pipelines that are best for their areas of study.

Note that the 10 Hz sampling rate is adequate for behavioural and ergonomic observation; however, researchers should be aware that this frequency has limited resolution for developing low-level force/impedance control models that typically require higher sampling rates (e.g., 100 Hz or greater).

3. Materials and Methods

3.1. Experimental Setup

The experiment was conducted in the Sheffield Robotics laboratory at the University of Sheffield, UK (Latitude: 53.3826° N, Longitude: 1.4777° W). The primary equipment consisted of a KUKA LBR iiwa 7 R800 (KUKA Roboter GmbH, Augsburg, Germany) serial manipulator, a seven degree-of-freedom lightweight collaborative robot designed for safe human–robot interaction [8]. The robot specifications include the following:

- Payload capacity: 7 kg;
- Reach: 800 mm;
- Weight: 23.9 kg;

- Repeatability: ±0.1 mm;
- Joint torque sensors: Integrated in all seven joints;
- Control interface: KUKA Sunrise.Workbench with ROS Kinetic (Open Robotics, Mountain View, CA, USA) integration.

A custom experimental apparatus was designed for the data collection task. A two-dimensional maze (approximately 600 mm × 840 mm) as shown in Figure 1 was printed on paper and affixed to a horizontal work surface within the robot's workspace. The maze featured a single solution path with multiple turns and dead ends, requiring participants to navigate through several corridors and decision points. Red and green circles marked the start and end points, respectively, as shown in the experimental setup (Figure 2).

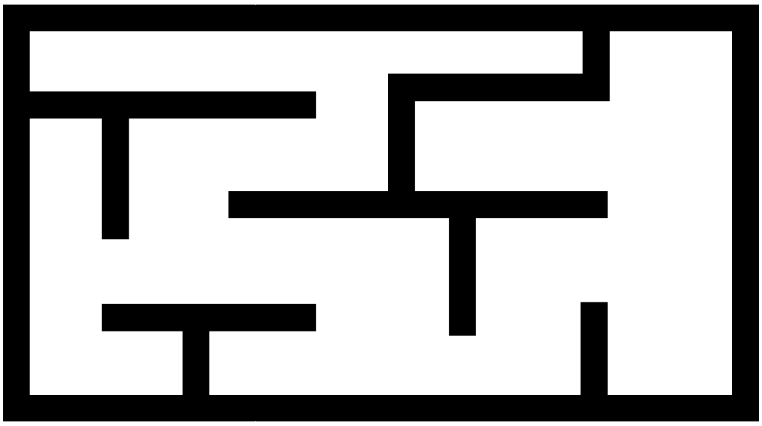

Figure 1. Maze layout used in the collaborative navigation task. Participants guided the robot's end-effector through the maze from start to finish.

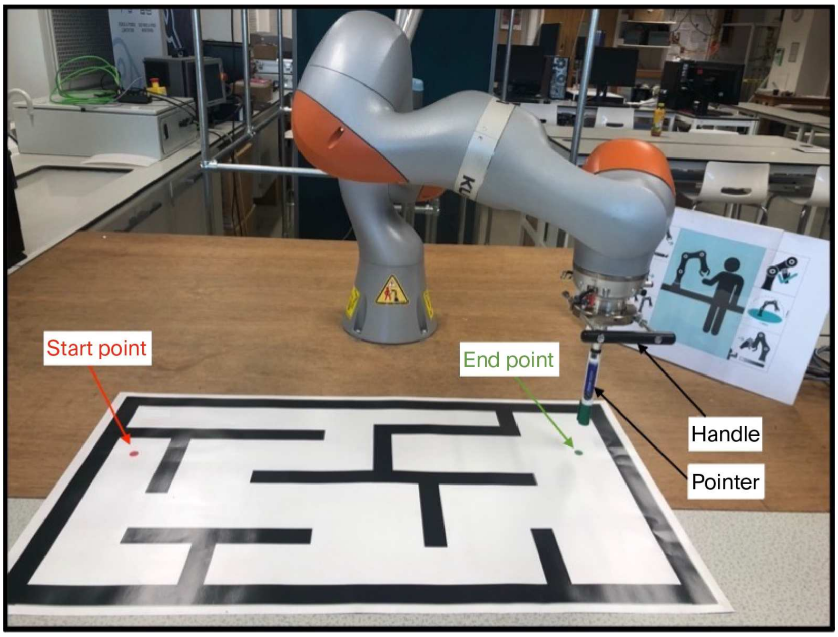

Figure 2. Experimental setup showing the KUKA LBR iiwa 7 R800 collaborative robot, 2D maze task, and custom handle/pointer attachment. The red circle indicates the start point and the green circle indicates the end point of the maze [7]

To provide an intuitive interaction method, a custom handle and pointer were attached to the robot's end-effector. Participants could easily hold and control the robot with its U-shaped handle (Figure 3). The pointer was a cylindrical marker that they used to trace the path through the maze.

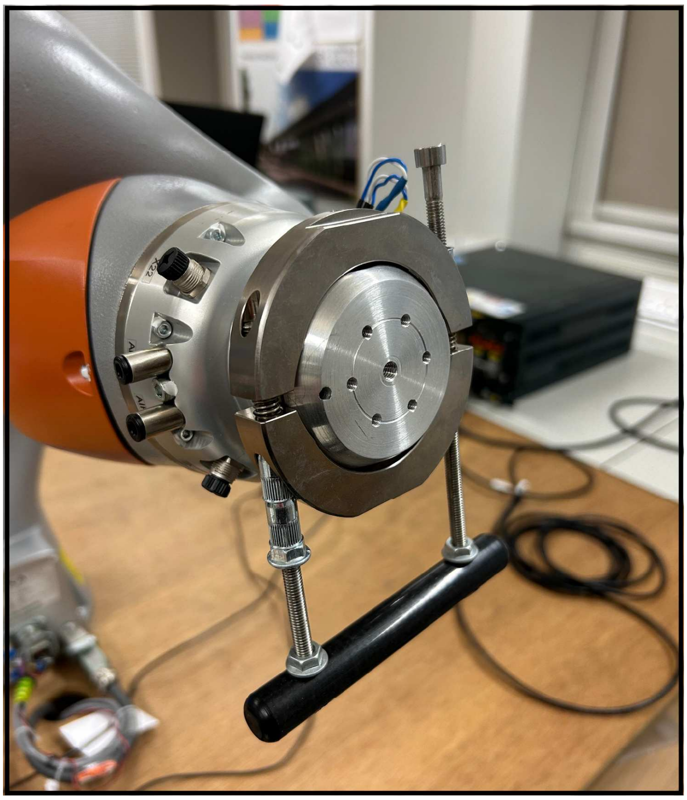

Figure 3. Modified end-effector handle with a U-shaped handle, allowing participants to easily hold and control the robot during the experimental task.

3.2. Data Collection Procedure

Data collection followed a standardized protocol for all participants:

1. Briefing: Participants were given a brief introduction to the study purpose and shown the experimental setup. They were informed that they would be guiding the robot through a maze and that their interaction data would be recorded.
2. Consent: All participants read an information sheet and signed a consent form. They were informed of their right to withdraw at any time without consequences.
3. Practice trials: Each participant performed three practice runs to familiarize themselves with the robot's behavior and the maze layout. Data from practice trials were not recorded.
4. Participant instructions: To ensure consistency, all participants received standardized instructions: (a) complete the maze at a comfortable, natural pace with no time limit; (b) guide the pointer along the centre of the maze path as accurately as possible; and (c) avoid contact with the maze walls where possible, though occasional wall contact was acceptable and did not invalidate the trial.
5. Data collection: Participants completed 15 recorded trials of the maze task. For each trial,
    - The robot was positioned at the start point (red circle);
    - The participant grasped the handle and guided the pointer through the maze;
    - Data recording began when the participant moved the end-effector from the start point;
    - Recording continued throughout the maze traversal;
    - Recording stopped when the pointer reached the end point (green circle);
    - The robot autonomously returned to the start point for the next trial (not recorded).

The entire data collection session for each participant lasted approximately 30–45 min, including briefing, practice, and all 15 trials.

3.3. Equipment and Software

Data acquisition was facilitated by the KUKA iiwa ROS-integrated application programming interface (API) [1], which provides real-time access to the robot's internal sensors. The robot was operated in compliance (impedance control) mode, which allows the user to move the robot by applying physical forces while the robot actively compensates for its own weight and inertia.

Operation mode: The robot was operated in T1 mode (Manual Reduced Velocity) during all participant trials, ensuring safe low-speed interaction. The Cartesian impedance was configured to enable compliant and safe interaction.

The data collection system consisted of the following:

- Robot controller: KUKA Sunrise Cabinet with Sunrise.Workbench software;
- ROS middleware: Robot Operating System (ROS) Kinetic ROS (Open Robotics, Mountain View, CA, USA) running on Ubuntu 16.04 (Canonical Ltd., London, UK);
- Custom ROS node: Python-based data logger developed using Python 3.x (Python Software Foundation, Wilmington, DE, USA) that subscribed to robot state topics and wrote data to CSV files;
- Sampling rate: 10 Hz (100 ms between samples).

All sensor data were timestamped and synchronized using ROS time. The system logged data continuously during each trial, resulting in variable-length recordings depending on how quickly participants completed the maze (typical duration: 30–90 s per trial).

3.4. Sensor Calibration

The KUKA LBR iiwa 7 R800 is equipped with factory-calibrated joint torque sensors in all seven axes. The robot used in this study was within its calibration validity period during data collection. The external forces and torques reported at the end-effector (`ToolForce`, `ToolTorque`) are estimated by the robot controller using the calibrated joint torque measurements combined with the robot's dynamic model, accounting for gravity, inertia, and friction. End-effector Cartesian positions are derived from factory-calibrated optical encoders with a repeatability of ± 0.1 mm. No additional external calibration procedures were applied; all measurements represent the robot's internal sensor outputs as reported through the ROS interface.

3.5. Collision Condition Definition

The KUKA LBR iiwa uses a model-based collision detection algorithm that compares measured joint torques with predicted values from the robot's dynamic model. A collision (`isCollision = true`) is flagged when the torque residual exceeds a joint-dependent threshold, upon which the robot stops and enters a compliant state. The algorithm runs at 1 kHz, independently of the 10 Hz data logging rate.

3.6. Data Processing and Quality Control

The data were stored in raw format without filtering or preprocessing. However, several quality control measures were implemented during collection:

1. Visual monitoring: An experimenter observed each trial to ensure proper execution of the task and data recording.
2. Trial completion verification: Only trials where participants successfully navigated from start to end were included in the dataset.

3. Anonymization: All participant data were anonymized immediately after collection. Participants were assigned numerical IDs (User 1 through User 30) without personally identifiable information retained beyond the demographic data in Table 2.

All 450 trials (30 participants, × 15 trials) were successfully recorded with complete sensor data and no technical errors.

4. User Notes

4.1. Accessing the Data

The complete dataset is publicly available through the Mendeley Data repository [9]:

- Repository: Mendeley Data;
- DOI: 10.17632/4fr33dkrjt.3;
- Direct URL: https://data.mendeley.com/datasets/4fr33dkrjt/3 (accessed on 8 April 2026);
- License: CC BY 4.0 (Creative Commons Attribution).

Users can download the entire dataset or individual participant files as needed. The repository includes the following:

- A total of 30 CSV files (one per participant);
- One Excel file with demographic information;
- One original maze file in PNG format.

4.2. Loading and Analyzing the Data

The CSV format allows easy import into most data analysis software packages. Example code for loading the data in Python using pandas is as follows:

```
import pandas as pd

# Load data for a single participant
user_data = pd.read_csv('User_1.csv')

# Access specific trial
trial_1 = user_data[user_data['Task_No'] == 1]

# Extract force data
forces = trial_1[['ToolForce_X', 'ToolForce_Y', 'ToolForce_Z']]
```

4.3. Potential Applications

This dataset can be used for various research purposes:

1. Biometric authentication: Develop user identification/verification systems based on interaction patterns [7];
2. Behavior modeling: Study individual differences in robot manipulation strategies;
3. Ergonomics research: Analyze the effects of gender, handedness, and height on force application;
4. Control algorithm development: Design adaptive controllers that respond to user intentions;
5. Machine learning: Train classifiers for user recognition, skill assessment, or anomaly detection (including deep learning approaches such as CNNs, LSTMs, and transformers);
6. Human factors: Investigate learning effects across trials and fatigue patterns;
7. Safety research: Analyze force profiles for developing safety guidelines.

4.4. Limitations and Considerations

Users should be aware of the following limitations:

1. Task specificity: Data were collected during a specific maze-navigation task and may not generalize to all collaborative manipulation scenarios. While the maze structure constrains movement sequences, the underlying behavioural characteristics (e.g., force modulation, movement smoothness) have been shown to carry individual-specific signatures suitable for biometric authentication within the same task context [7]. Generalization to substantially different collaborative tasks should be validated empirically.
2. Participant population: All participants were from a university setting and may not represent broader populations.
3. Single robot platform: Data are specific to the KUKA LBR iiwa 7 R800 and may not directly transfer to other robot models.
4. Controlled environment: Data were collected in a laboratory setting without the distractions and variations of real-world environments.
5. Limited training: Participants had only three practice trials, so the data primarily capture novice-to-intermediate skill levels.
6. Sampling rate: The 10 Hz sampling rate is adequate for behavioural and ergonomic observation but has limited resolution for high-fidelity force/impedance control modelling. Future data collection efforts may benefit from higher sampling rates (e.g., 100 Hz or greater).

The dataset is a baseline for many HRI research applications, and, despite these limitations, it offers useful insights into human–robot physical interaction.

5. Conclusions

This research provides a detailed dataset of human–robot physical interactions gathered during collaborative manipulation activities. The dataset comprises 450 full interaction sequences, generated by 30 people each conducting 15 trials, with extensive sensor data that includes forces, torques, and positions collected at a frequency of 10 Hz. For studies involving human–robot interaction, this dataset fills an important gap in the public domain. It is particularly beneficial for fields including cybersecurity, biometric identification, and ergonomics.

The data have already proven valuable in our research on behavior-based biometrics for continuous user authentication to industrial collaborative robots [7]. We expect the dataset will enable adaptive control algorithm development, human factors investigations, and machine learning user modeling and skill evaluation.

The Mendeley Data repository provides public access to all data under a Creative Commons Attribution license. This makes it possible for various research groups to use the data and compare their results. We invite academics to utilize this dataset and welcome partnerships to expand data collecting to more activities, robotic platforms, or participant demographics.

In future research, this work could be extended to include a wider range of participants, the ability to record additional physiological signals like eye tracking and muscle activity, and the addition of more common collaborative manipulation tasks like assembly and pick-and-place to the task repertoire. We believe this dataset may serve as a starting point to enhance the security, usability, and safety of collaborative robotic systems.

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Supervision, Writing—review. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was approved by the Ethics Committee of the University of Sheffield (Reference no: 024354).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. All participants were informed about the data collection procedure and possible future data release to other researchers. They were required to read an information sheet and sign a consent form before beginning the experiment.

Data Availability Statement: The dataset is publicly available at Mendeley Data repository: https://data.mendeley.com/datasets/4fr33dkrjt/3 (DOI: 10.17632/4fr33dkrjt.3), accessed on 9 May 2026.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HRI	Human–Robot Interaction
ROS	Robot Operating System
CSV	Comma-Separated Values
DOI	Digital Object Identifier
API	Application Programming Interface

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