Culturally Sensitive Social Robotics for Africa

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1 Project Objectives

Culturally Sensitive Social Robotics for Africa (CSSR4Africa) is a three-year research project to equip social robots with the ability to interact sensitively and politely with people in Africa; see Fig. 1. The objectives of the project are (i) to identify the verbal and non-verbal social and cultural norms of human interaction that are prevalent in countries in Africa, (ii) to encapsulate them in the behavioral patterns of social robots so that they can engage with African people in a manner that is consistent with their expectations of acceptable social interaction, and (iii) to demonstrate these culturally-sensitive social robot behaviors in two use cases: one for giving a tour of a university laboratory, and one for assisting and giving directions to visitors at the reception of a university. In order to ensure that the project objectives can be achieved in the time available, we restrict the scope of the project to the cultures and social practices that are prevalent in Rwanda and South Africa.

2 Recent Progress

2.1 Overview

As we approach the end of the second year, the project is progressing well, assiduously following the work plan and updating it when necessary. This has resulted in the publication of 32 deliverables on the CSSR4Africa website `www.cssr4africa.org`, four ROS packages and 11 ROS nodes (not including unit tests) on the CSSR4Africa software respository on GitHub site, and publications in the form of three abstracts, five posters, five presentations, and five peer-reviewed papers: (Zantou & Vernon, 2023; Akinade et al., 2023; Vernon, 2024; Akinade, Barros, & Vernon, 2025; Akinade, Barros, Danso, et al., 2025); see details in Section 4.

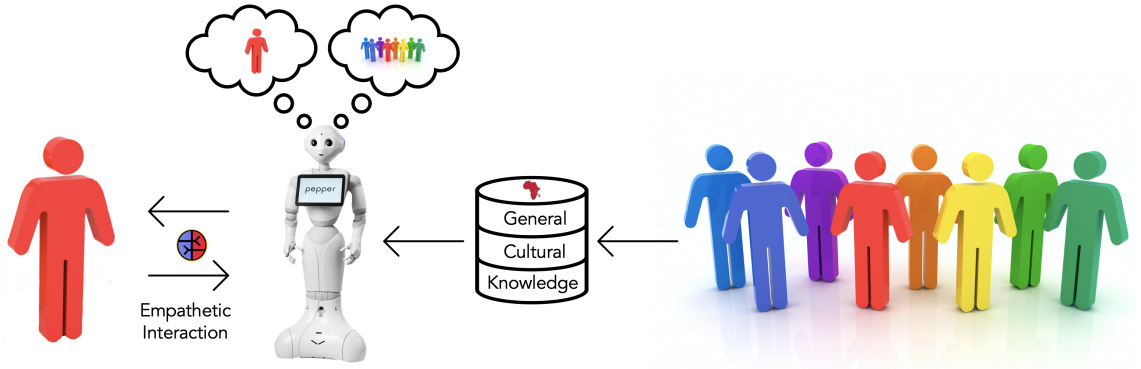

Figure 1: Based on surveys to acquire cultural knowledge about acceptable modes of communication, the CSSR4Africa project is equipping social robots, e.g., Pepper, with the ability to interact sensitively and politely with people in Africa.

2.2 Work Plan Updates

In the CSSR4Africa work plan, 23 of the 51 tasks are assigned to the University of the Witswatersrand. However, due to extensive delays in the delivery of the Pepper robot to the University of the Witswatersrand, no significant progress had been made on six tasks that were crucial for the integration of a complete system and the ability to execute a robot mission. The six deliverables are as follows.

D5.4.1 Cultural Knowledge Ontology & Culture Knowledge Base.

D5.4.2 Robot Mission Language.

D5.4.3 Robot Mission Interpreter.

D5.5.2.1 English Text to Speech Conversion.

D5.5.2.4 Integrated Text to Speech Conversion.

D6.1 Use Case Implementation.

D6.2 Use Case Evaluation.

Consequently, Carnegie Mellon University Africa agreed to take joint responsibility for these deliverables. Since this involved a significant amount of additional, unplanned effort, only one use case, the laboratory tour, has been implemented to date, leaving the second use case, the receptionist, to be implemented next year, along with the use case evaluation.

2.3 Submitted Deliverables

Table 1 lists the 32 deliverables that have been submitted to date. For more details, please refer to the deliverable reports on the CSSR4Africa website, also linked from the deliverable number in Table 1. The full list of deliverables due over the lifetime of the project, their due dates, their submission dates, and their revision dates, are available on the CSSR4Africa website. In the following, we summarize the work done to date, organized by work package topic.

2.4 African Cultural Knowledge

Deliverable D1.2 comprises a compendium of population-based cultural knowledge regarding behaviors, activities, actions, and movements that are either culturally sensitive or insensitive. This knowledge is formalized in the cultural knowledge ontology and knowledge base in Deliverable D5.4.1. The cultural knowledge has been gathered by developing a detailed questionnaire and using it to survey a cross-section of Rwandan citizens. The survey is available online in Kinyarwanda and English.

2.5 Use Case Scenario Specification

Deliverables D2.1, D2.2, and D2.3 together present a detailed scenario definition for the two use cases — lab tour guide and receptionist — along with the associated robot behavior specification, and the visitor behavior specification. The layout of the environment in which the scenarios are set is specified by the environment knowledge base detailed in Deliverable D5.4.2.

2.6 Systems Engineering

Deliverable D3.1 specifies the CSSR4Africa system architecture, identifying the component subsystems, the modules (i.e., ROS nodes) comprising each subsystem, and the information exchanged between subsystems and modules. The architecture itself is implemented in ROS using ROS nodes developed and documented in deliverables in work packages 4 and 5, i.e., Deliverables 4.2.1 – D4.2.4 and Deliverables D5.2 – D5.5.4.

Deliverables D3.2, D3.3, D3.4, and D3.5 provide the software engineering foundation for the implementation of the CSSR4Africa system: a reference manual of software engineering standards, a comprehensive installation manual, the procedures used to validate and test software

D1.2	Rwandan Cultural Knowledge, version 1
D2.1	Use Case Scenario Definition
D2.2	Robot Behavior Specification, version 1
D2.3	Visitor Behavior Specification, version 1
D3.1	System Architecture, version 1
D3.2	Software Engineering Standards Manual
D3.3	Software Installation Manual
D3.4	System Integration and Quality Assurance Manual
D3.5	System Integration and Quality Assurance
D4.1	Sensor Tests
D4.2.1	Person Detection and Localization
D4.2.2	Face & Mutual Gaze Detection and Localization
D4.2.3	Sound Detection and Localization
D4.2.4	Robot Localization
D4.3.2	Speech Event
D5.1	Actuator Tests
D5.2	Animate Behavior Subsystem
D5.3	Attention Subsystem
D5.4.1	Cultural Knowledge Ontology & Culture Knowledge Base
D5.4.2	Robot Mission Language
D5.4.3	Robot Mission Interpreter
D5.5.1.1	Gesture Execution
D5.5.1.2	Programming by Demonstration
D5.5.2.1	English Text to Speech Conversion
D5.5.2.3	Kinyarwanda Text to Speech Conversion
D5.5.2.4	Integrated Text to Speech Conversion
D5.5.3	Environment Map Generation
D5.5.4	Robot Navigation
D6.1	Use Case Implementation
D7.1	Online Presence
D7.3	Open-Source Software Repository
D8.1.3	Progress Report

Table 1: CSSR4Africa deliverables submitted to date; click on the deliverable number to see the full report.

developed by the partners prior to integration into the CSSR4Africa software repository, and current progress in integrating the software modules and adding them to the software repository on GitHub.

2.7 Robot Sensing

Deliverable D4.1 comprises a suite of unit tests to verify that sensor data is successfully acquired on each sensor topic. The functionality encapsulated in this deliverable forms the basis for all the sensory ROS nodes in the CSSR4Africa system architecture, i.e., Deliverables D4.2.1– D4.3.2.

Deliverable D4.2.1 documents a ROS node, `personDetection`, which detects and localizes people under various conditions. Deliverable D4.2.2 documents a ROS node, `faceDetection`, that detects and localizes human faces under various conditions and determines whether mutual gaze is established between the Pepper robot and the human user through head pose estimation. Deliverable D4.2.3 documents a ROS node, `soundDetection`, to detect and localize conspicuous sounds within a robot's hearing range. It provides two outputs:(a) the direction of arrival (DoA)

of the sound, and (b) a filtered audio signal. It interfaces with the `speechEvent` ROS node and the `overtAttention` ROS node, facilitating automatic speech recognition (ASR) and enabling the robot to focus its attention on sound sources. Deliverable D4.2.4 documents a ROS node, `robotLocalization`, that estimates the pose of the Pepper robot in a Cartesian world frame of reference. The module achieves this through a combination of relative and absolute position estimation techniques, including odometry, IMU data, and triangulation using visually detected ArUco marker visual landmarks. Deliverable D4.3.2 documents a ROS node, `speechEvent`, which deploys a speech-to-text model using deep neural networks that enables speech utterances in Kinyarwanda and English languages captured by Pepper's microphones to be transcribed into written text.

2.8 Robot Behaviors

Mirroring Deliverable D4.1, Deliverable D5.1 comprises a suite of unit tests to verify the accurate and reliable functioning of the actuators: head, arms, hands, legs, and wheels. The functionality encapsulated in this deliverable forms the basis for all the ROS nodes in the CSSR4Africa system architecture that control the actuators, i.e., Deliverables D5.2, D5.3, D5.5.1.1, D5.5.4, in addition to D5.5.1.2 which operates separately in a stand-alone mode.

Deliverable D5.2 documents a ROS node, `animateBehaviour`, which enhances the robot's lifelike appearance by generating subtle body movements to flex the robot's hands and slightly rotate its base around the Z-axis. Deliverable D5.3 documents a ROS node, `overtAttention`, which implements of the attention subsystem, enabling the robot to dynamically direct its attention towards salient features in its environment, primarily during social interactions, and to scan its surroundings when not actively engaged. The attention subsystem integrates several processes, including face and sound detection, saliency map generation, and gaze control, allowing the robot to engage in more human-like behaviors. Deliverable D5.5.1.1 documents a ROS node, `gestureExecution`, which enables the Pepper robot to perform a range of body and hand gestures: deictic, symbolic, and iconic hand gestures, and bowing and nodding body movements. Hand gestures are executed so that they exhibit biological motion, since this has been shown to enhance people's engagement when interacting with the robot (Akinade, Barros, & Vernon, 2025). The node interfaces with the `robotLocalization` node, so that deictic gestures accurately indicate the location of points of interest in the robot's environment. Additionally, it interfaces with the `overtAttention` node to control the head during diectic gestures toward a location. Deliverable D5.5.1.2 provides the robot with the ability to learn gestures through manual teleoperation or human demonstration, employing RGB-D camera technology to map human skeletal movements onto the robot's joint system, i.e., Programming by Demonstration. Deliverable D5.5.4 documents a ROS node, `robotNavigation`, enabling the Pepper robot to traverse its environment autonomously. It too interfaces with the `robotLocalization` node, continuously updating its pose with real-time data to ensure the navigation path is registered with the robot's environment.

Deliverables D5.4.1, D5.4.2, and D5.4.3 together provide the core functionality for executing a robot mission. Deliverable D5.4.2 documents the formal methodology — behaviour trees — for specifying a robot mission based on the use case scenarios documented in Deliverables D2.1, D2.2, and D2.3, and enact them in a culturally sensitive manner using the culture knowledge base and an environment knowledge base. This deliverable also documents and implements the environment knowledge base with the information required to complete the robot mission. Deliverable D5.4.3 documents the Robot Mission Interpreter, implemented as a ROS node, `behaviorController`, a central component in the CSSR4Africa system architecture, which interprets and executes the robot mission specifications defined in Deliverable D6.1. The `behaviorController` node interfaces with eight ROS nodes: `animateBehavior`, `overtAttention`, `gestureExecution`, `textToSpeech`, `robotNavigation`, `tabletEvent`, `speechEvent`, and `faceDetection`. Finally, Deliverable D5.4.1 formalizes the Rwandan modes of social inter-

action documented in Deliverable D1.2. It presents a cultural knowledge ontology and, based on this ontology, a simple representation of the cultural knowledge documented in Deliverable D1.2, in the form of the cultural parameter values that can be used by the robot to emulate these polite and respectful behaviours, activities, actions, and motions.

Deliverables D5.5.2.1, D5.5.2.3, and D5.5.2.4 together provide the functionality for converting English and Kinyarwanda text to speech, all encapsulated in the `textToSpeech` ROS node.

2.9 Use Case Demonstration and Evaluation

Deliverable 6.1 formalizes the use case scenarios in Deliverables D2.1, D2.2, and D2.3 using the robot mission specification methodology documented in Deliverable D5.4.2, i.e., using behavior trees. The resultant behavior tree provides the input to the `behaviorController` ROS node documented in Deliverable D5.4.3.

2.10 Dissemination and Impact

Deliverable D7.1 takes the form of a website, a wiki, and a report. The website is primarily a forum for disseminating information about the project to a broader audience, while the wiki is primarily a forum for exchanging information among the partners in the project consortium. The website domain name is www.cssr4afrcia.org and is hosted on GitHub. The wiki is also hosted on GitHub and it is linked from the website. The ROS nodes described above are available on the CSSR4Africa software repository, documented in Deliverable D7.3.

2.11 Project Management

Six-monthly progress reports are provided in Deliverable D8.1. To date, there are three versions D8.1.1, D8.1.2, and D8.1.3. The agendas and minutes of the weekly CMU-Africa team meetings are available on the CSSR4Africa wiki.

3 Next Targets

With the departure of the PI, David Vernon, on 30 June 2025, the project will be concluded by the co-PIs at the University of the Witwatersrand. During the final year, and as anticipated in the work plan, most of the work will focus on assessment and enhancement of the ROS software to improve the performance of the Pepper robot in culturally-sensitive social interaction, in addition to completing the outstanding deliverables for which the University of the Witwatersrand is responsible. Finally, the behavior tree specification of the robot mission for the receptionist scenario use case has yet to be written and tested using the ROS `behaviorTree` node and the `cssr_africa` ROS package as a whole.

4 Peer-Reviewed Publications Resulting from this Project

Akinade, A., Barros, D., Danso, M., Haile, Y., Birhan, E., Shimelis Girma, B., ... Vernon, D. (2025). Culturally sensitive social robotics for Africa. In Proceedings of the 2nd international workshop on cultural robotics: Diversified sustainable practices. Springer LNAI, in press.

Akinade, A., Barros, D., & Vernon, D. (2025). Biological motion aids gestural communication by humanoid social robots. International Journal of Humanoid Robotics, Vol. 22, No. 02.

Akinade, A., Haile, Y., Mutangana, N., Tucker, C., & Vernon, D. (2023). Culturally competent social robots target inclusion in Africa. Science Robotics, 8(85).

Vernon, D. (2024). An African perspective on culturally competent social robotics: Why DEI matters in HRI. IEEE Robotics and Automation Magazine, 31(4), 170–200.

Zantou, P. & Vernon, D. (2023). Culturally-sensitive human-robot interaction: A case study with the pepper humanoid robot. In Proceeding of IEEE Africon, Nairobi, Kenya.