Robotics in Africa Forum at IROS 2024

16th October 2024

Culturally Sensitive Social Robotics for Africa

David Vernon

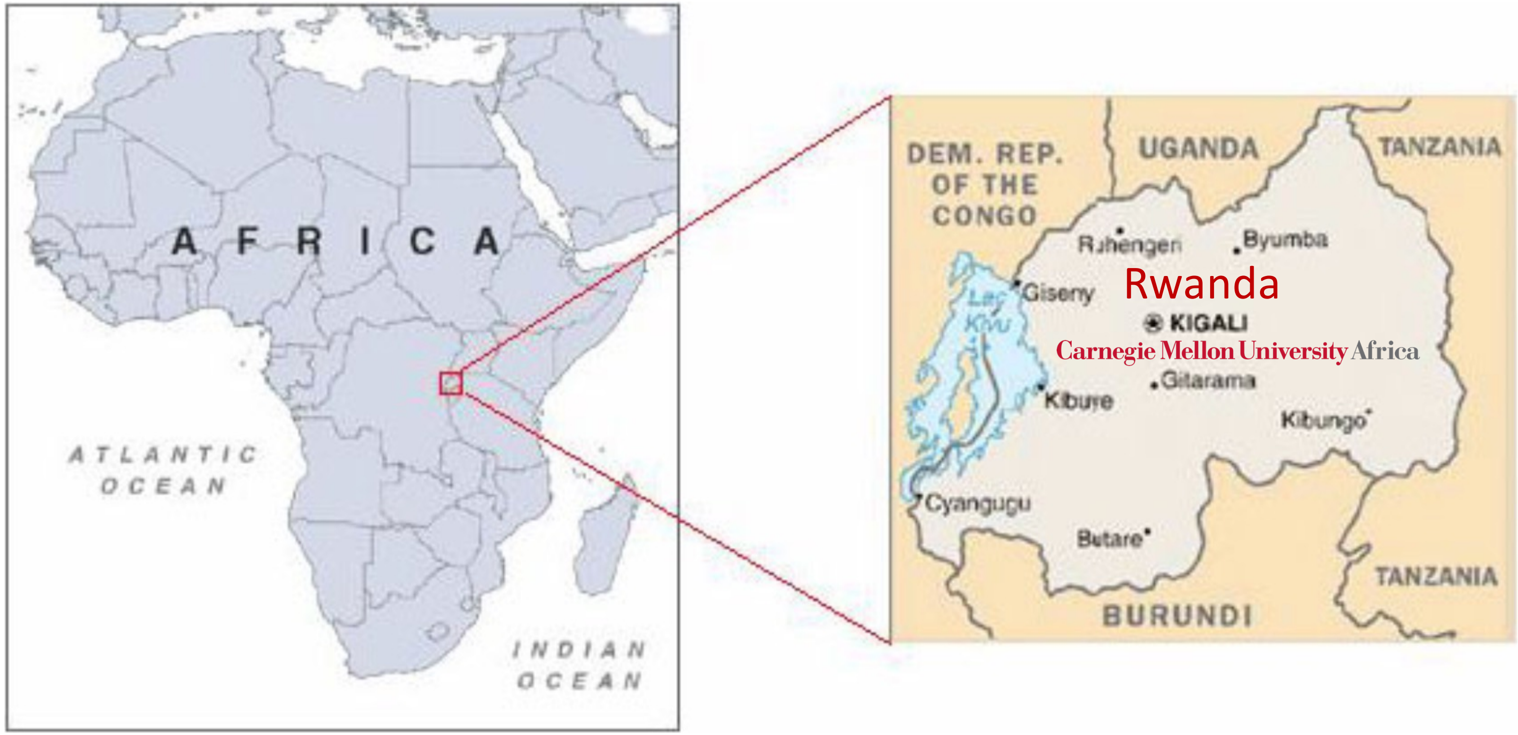
Carnegie Mellon University Africa

www.vernon.eu

IROS '24
ABU DHABI

www.africa.engineering.cmu.edu


02
TARTAN PRIDE


A F R I C A
ATLANTIC OCEAN
INDIAN OCEAN
DEM. REP. OF THE CONGO
UGANDA
TANZANIA
Ruhengeri
Byumba
Gisenyi
Rwanda
KIGALI
Carnegie Mellon University Africa
Gitarama
Kibuye
Kibungo
Cyangugu
Butare
TANZANIA
BURUNDI

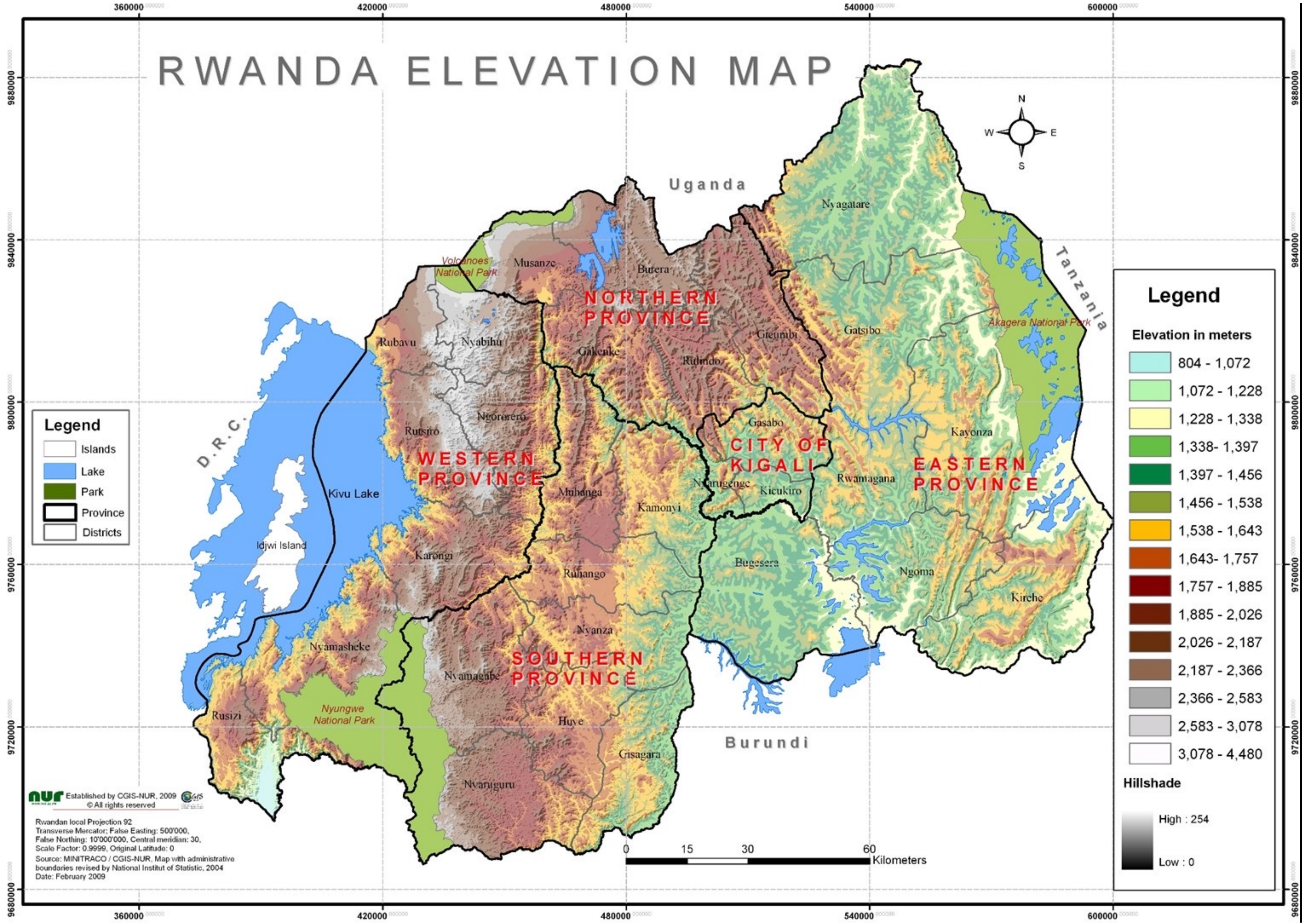

RWANDA ELEVATION MAP
Uganda
Tanzania
Burundi
D.R.C.
NORTHERN PROVINCE
WESTERN PROVINCE
SOUTHERN PROVINCE
EASTERN PROVINCE
CITY OF KIGALI
Volcanoes National Park
Akagera National Park
Nyungwe National Park
Kivu Lake
Idjwi Island
Musanze
Burera
Gakenke
Gicumbi
Rulindo
Rubavu
Nyabihu
Ngororero
Rutsiro
Karongi
Muhanga
Kamonyi
Ruhango
Nyanza
Nyamagabe
Nyamasheke
Rusizi
Huye
Gisagara
Nyaruguru
Gasabo
Nyarugenge
Kicukiro
Bugesera
Nyagatare
Gatsibo
Kayonza
Rwamagana
Ngoma
Kirehe
Legend
Islands
Lake
Park
Province
Districts
Legend
Elevation in meters
804 - 1,072
1,072 - 1,228
1,228 - 1,338
1,338- 1,397
1,397 - 1,456
1,456 - 1,538
1,538 - 1,643
1,643- 1,757
1,757 - 1,885
1,885 - 2,026
2,026 - 2,187
2,187 - 2,366
2,366 - 2,583
2,583 - 3,078
3,078 - 4,480
Hillshade
High : 254
Low : 0
0 15 30 60 Kilometers
N
S
E
W
360000
420000
480000
540000
600000
9880000
9840000
9800000
9760000
9720000
9680000
Established by CGIS-NUR, 2009
© All rights reserved
Rwandan local Projection 92
Transverse Mercator; False Easting: 500'000,
False Northing: 10'000'000, Central meridian: 30,
Scale Factor: 0.9999, Original Latitude: 0
Source: MINITRACO / CGIS-NUR, Map with administrative
boundaries revised by National Institut of Statistic, 2004
Date: February 2009

Photo credit: Tallis Woomert

Photo credit: Tallis Woomert

Photo credit: Tallis Woomert

UCI

NEWS CALENDAR TEAMS/RIDERS DISCIPLINES CYCLING FOR ALL

ROAD

04 MAR 2022

Globe Riders: Africa gearing up for 2025 UCI Road World Championships in Rwanda

COOKIE SETTINGS

https://www.uci.org/article/globe-riders-africa-gearing-up-for-2025-uci-road-world-championships-in/33uOYFn6vsVjs0oE6Jfwci

The Future of Work
Kigali, Rwanda

Africa is the youngest and fastest-growing continent in the world. By 2030, there will be 375 million young people in the job market in Africa. Within a few decades, this demographic boom will push Africa's workforce to more than a billion people, the largest in the world. There is a significant gap between the number of young people seeking work and the employment opportunities available to them. Young people will face challenges finding formal employment and a pathway out of poverty. The theme of this year's PARC is ***The Future of Work***. Students are challenged to create solutions for job creation and workforce innovation in Africa.

Download PARC Letter of Notice (English & French)

www.parcrobotics.org/

PARC 2024 : Senegal

The Pan-African Robotics Competition (PARC) 2024, held from July 22 to 29 in Senegal, continued its tradition of being the largest robotics competition in Africa.

This year's theme, "The Future is Now," challenged participants to develop technological innovations propel the African continent into 5th Industrial revolution. The Competition attracted 94 teams from 25 African countries. 33 of these talented teams came to Senegal for the final rounds from July 22 to July 29.

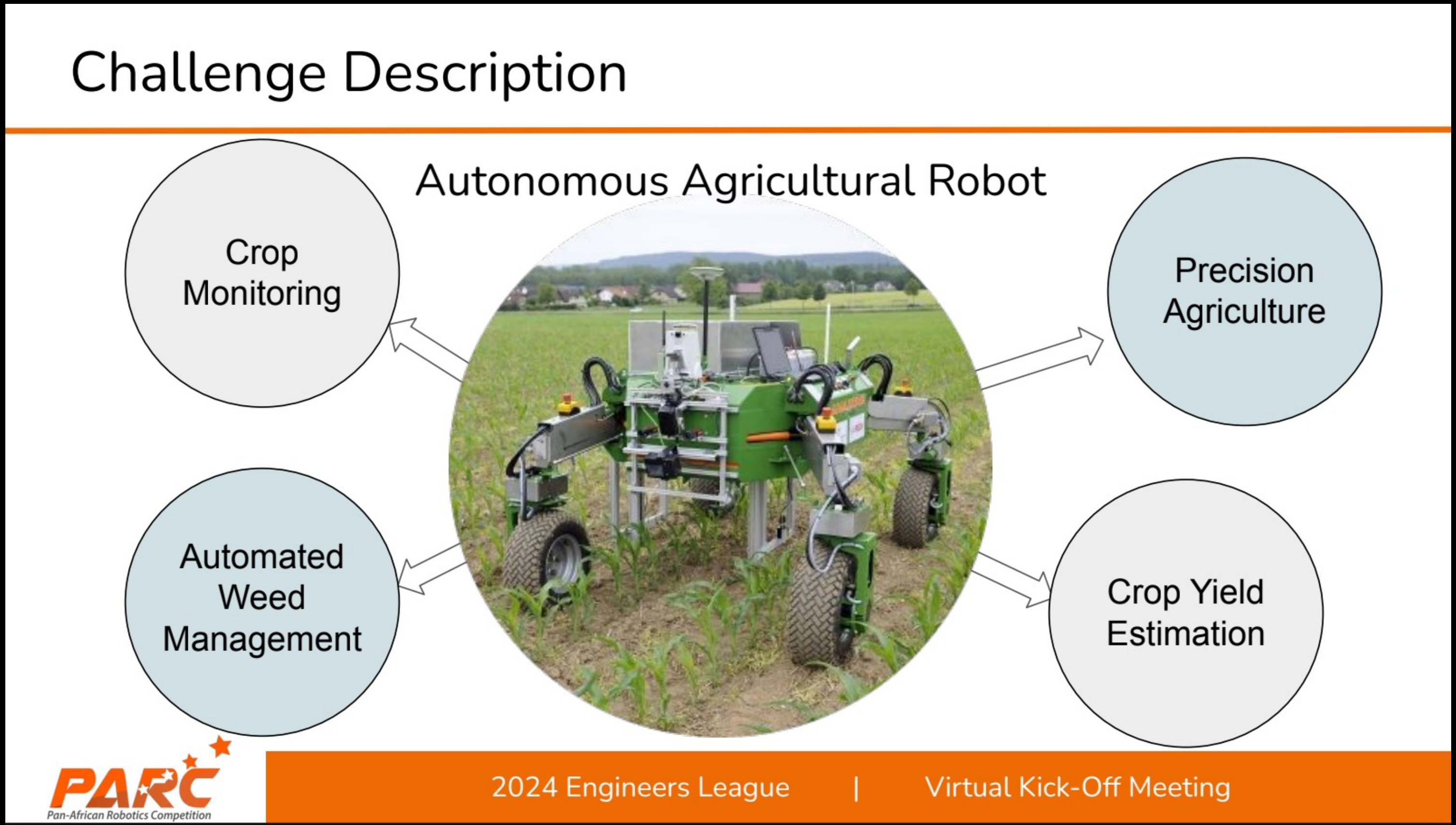
www.parcrobotics.org/

It's more than a Robotics Competition
IT'S LIFE CHANGING

Dear Mr. Sidy, it is my pleasure to meet you again a few years after participating in the Robotics Camp. Three years later, I am pursuing my studies in Electrical Engineering at École Polytechnique de Montréal, and I must admit that my participation in this camp is one of the factors that pushed me in the field of engineering.” – PARC Participant

Read PARC 2024 Activity Report

www.parcrobotics.org/

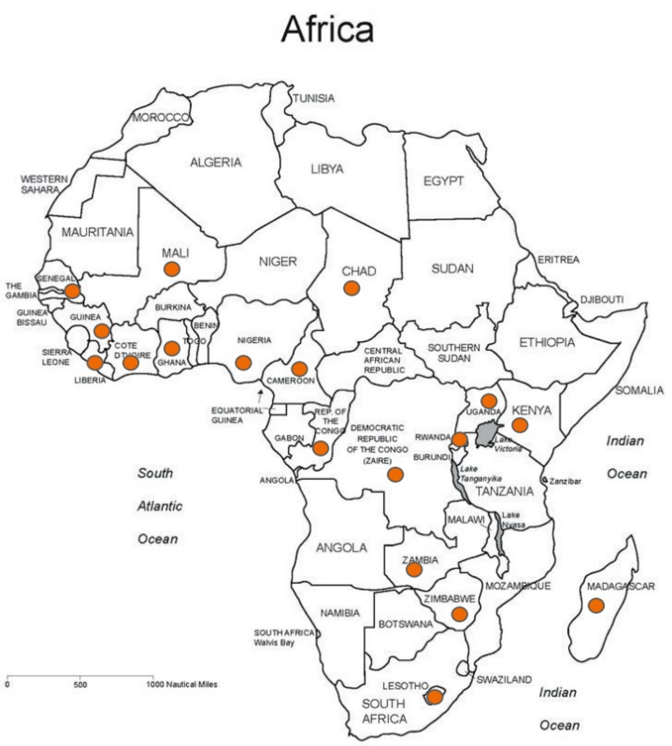


ROS
Gazebo
OpenCV
Python
Matlab

www.parcrobotics.org/

Meet the 2024 Teams!

- 38+ teams
- 18+ participating Countries



This is a royalty free image that can be used for your personal, corporate or education projects. It can not be resold or freely distributed. If you need an editable PowerPoint or Adobe Illustrator version of this map please visit www.bjdesign.com or www.mapsfordesign.com. This text can be cropped off. © Copyright Bruce Jones Design Inc. 2011

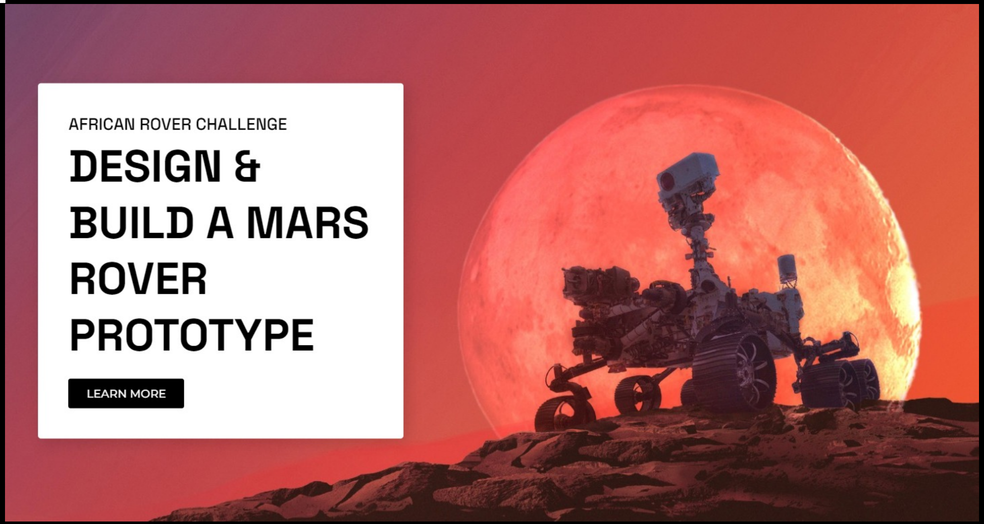
Pan-African Robotics Competition

2024 Engineers League

www.parcrobotics.org/

Cars4Mars
African Rover Challenge

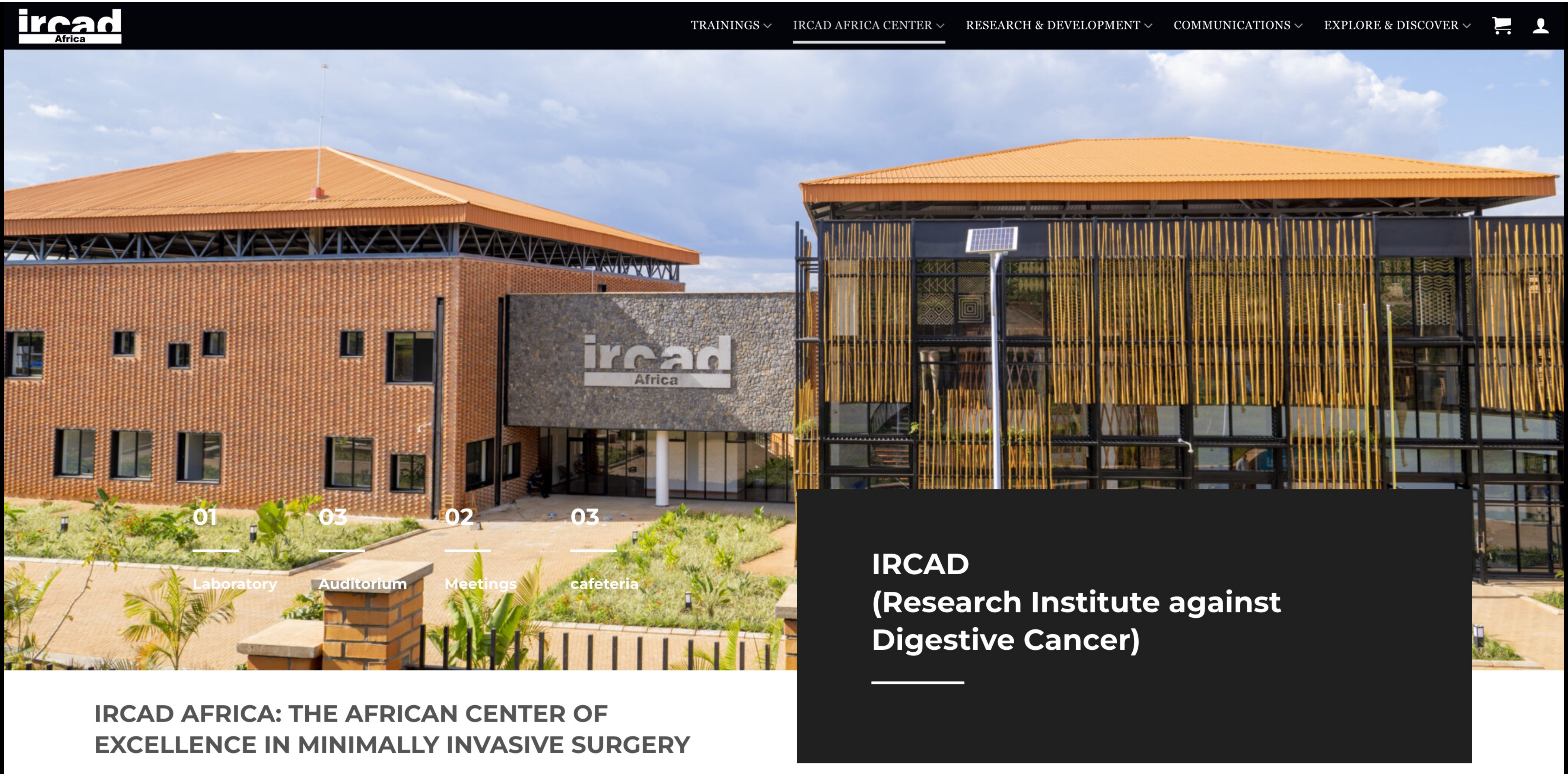
Benin
Cameroon
Egypt
Ethiopia
India
Kenya
Nigeria
Rwanda
South Africa
Tanzania
Togo
USA
Zambia
Zimbabwe



66 Registered Teams

201 Participants

https://cars4mars.co.za/



"IRCAD (Institut de Recherche contre les Cancers de l'Appareil Digestif - Research Institute against Digestive Cancer) was founded in 1994 in Strasbourg, France by **Prof. Jacques Marescaux** a surgeon fascinated by technology."

www.ircad.africa

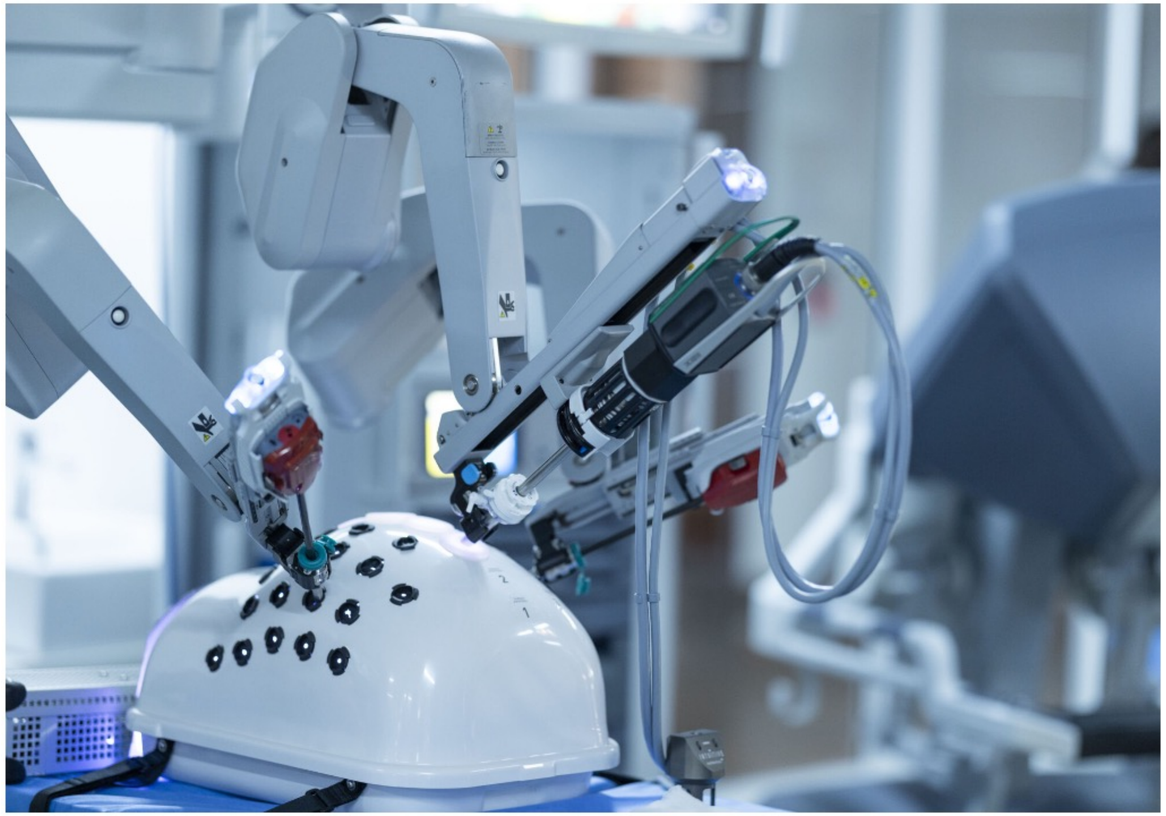
Home | IRCAD Africa Center | Training | Research And Development | Contact Us | EN

IRCAD-There is no better way to learn

Home | IRCAD Africa Center | Training | Research And Development | Contact Us | EN

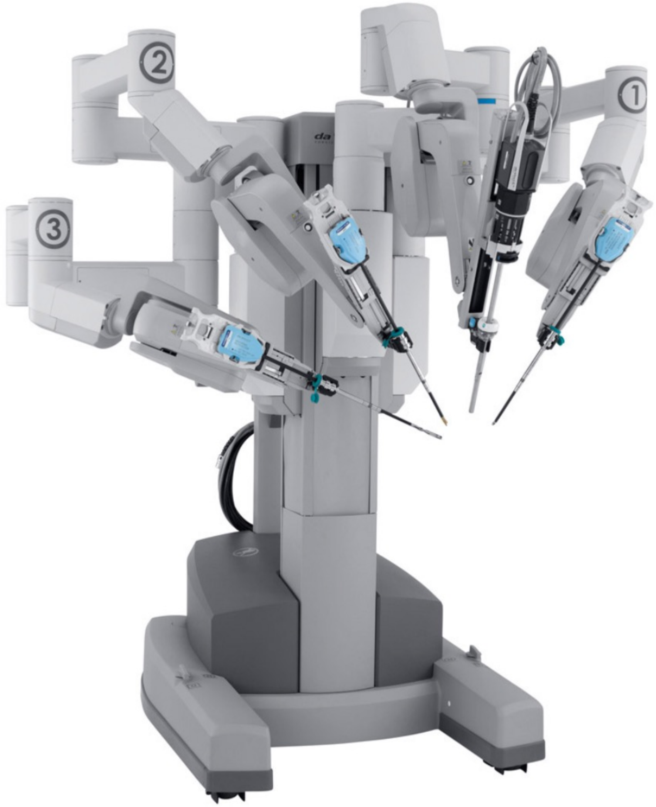
@ircad.africa

www.ircad.africa



EXPERIMENTAL OPERATING ROOMS

16 laparoscopic operating tables



Da Vinci

The da Vinci is a surgical robot designed for minimally invasive procedures. It has four arms equipped with surgical instruments and cameras that a physician controls remotely from a console.

CREATOR
Intuitive Surgical

COUNTRY
United States 🇺🇸

YEAR
1999

TYPE
Medical

Source: https://robots.ieee.org/robots/davinci/

THE DA VINCI SURGICAL SYSTEM

SURGEON SIDE

1. High Resolution Stereo Viewers (HRSVs)
2. Master Tool Manipulators (MTMs)
3. Foot pedal tray

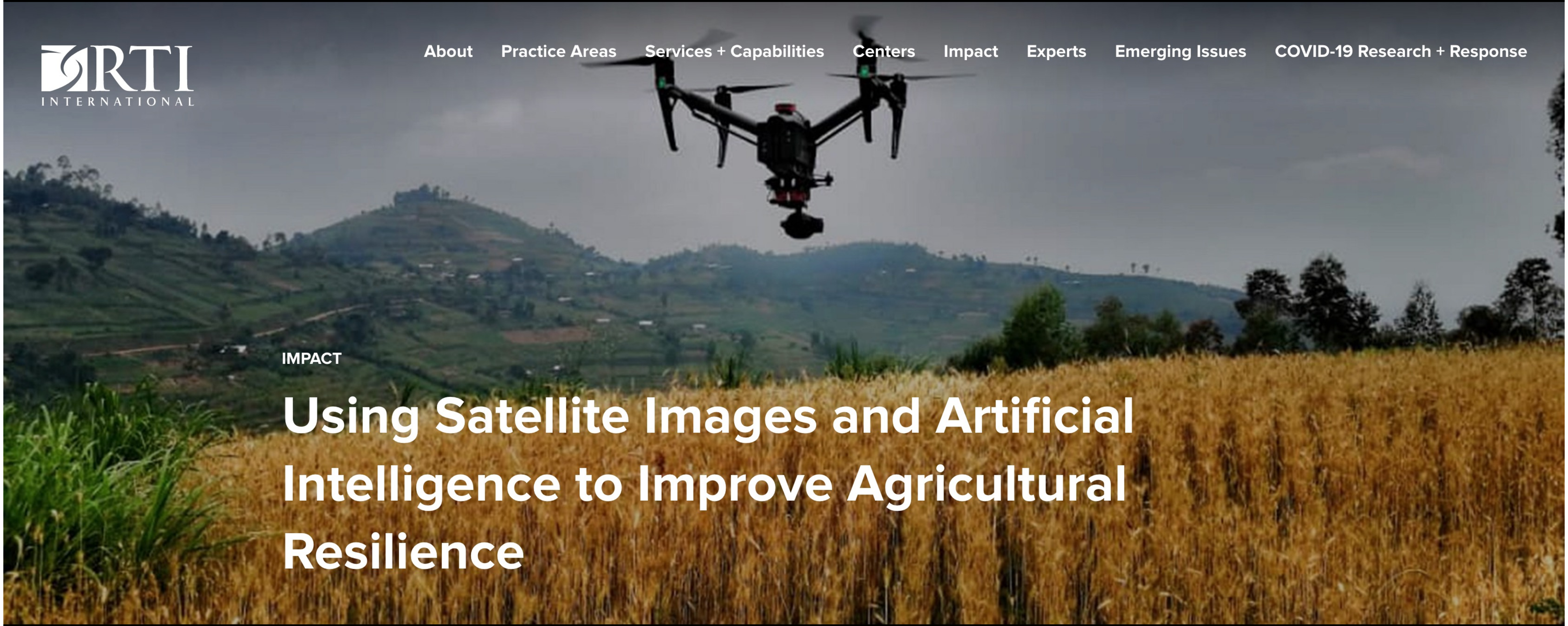
PATIENT SIDE

1. Patient Side Manipulators (PSMs)
2. Endoscopic Camera Manipulator (ECM)
3. Vision Cart

Patient Side Manipulators: robotic arms teleoperated by the Master Tool Manipulators, they mount the surgical tools.

Endoscopic Camera Manipulator: robotic arm that is also teleoperated by the Master Tool Manipulators, it holds the endoscope.

An Ubtech CRUZR service robot deployed by ZoraBots Africa Ltd. to check the temperature of travelers arriving at Kigali International Airport, Rwanda.



https://www.rti.org/impact/using-satellite-images-and-artificial-intelligence-improve-agricultural-resilience

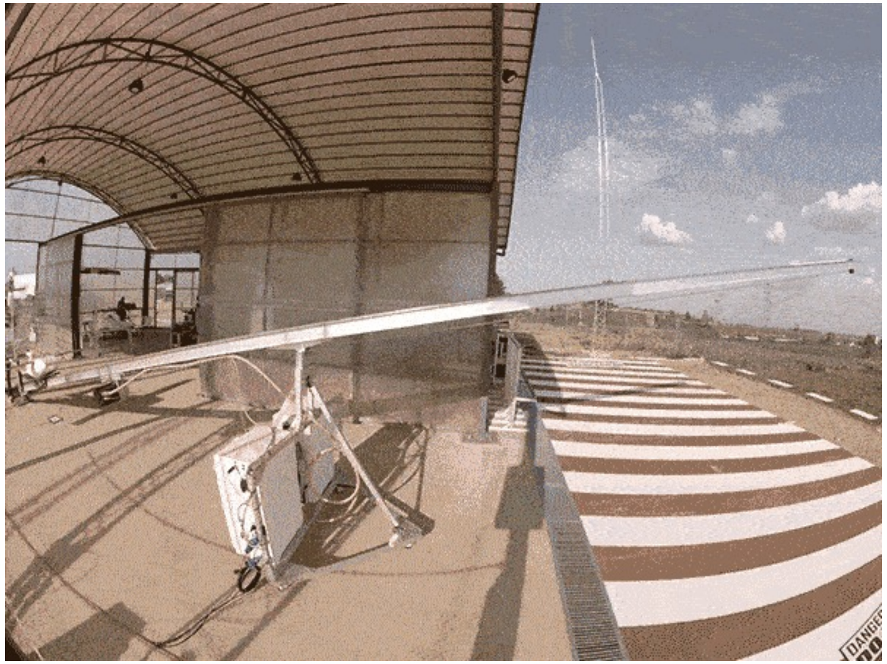
In the Air With Zipline's Medical Delivery Drones

Commercial operations in Rwanda prove the company can deliver emergency blood packs in minutes, rather than hours

By **Evan Ackerman and Michael Koziol**

TECH EXPEDITION

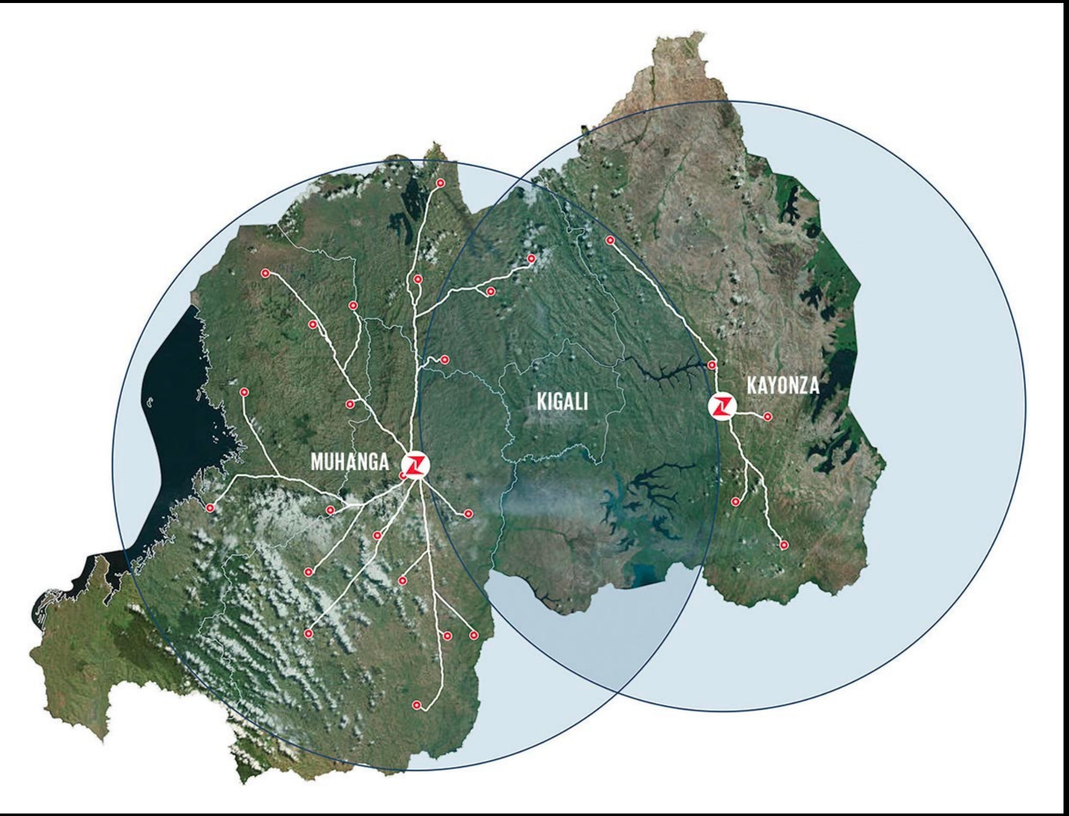
East Africa's Big Bet On Drones



Gif: IEEE Spectrum

https://spectrum.ieee.org/robotics/drones/in-the-air-with-ziplines-medical-delivery-drones

Zipline Medical Delivery Drones



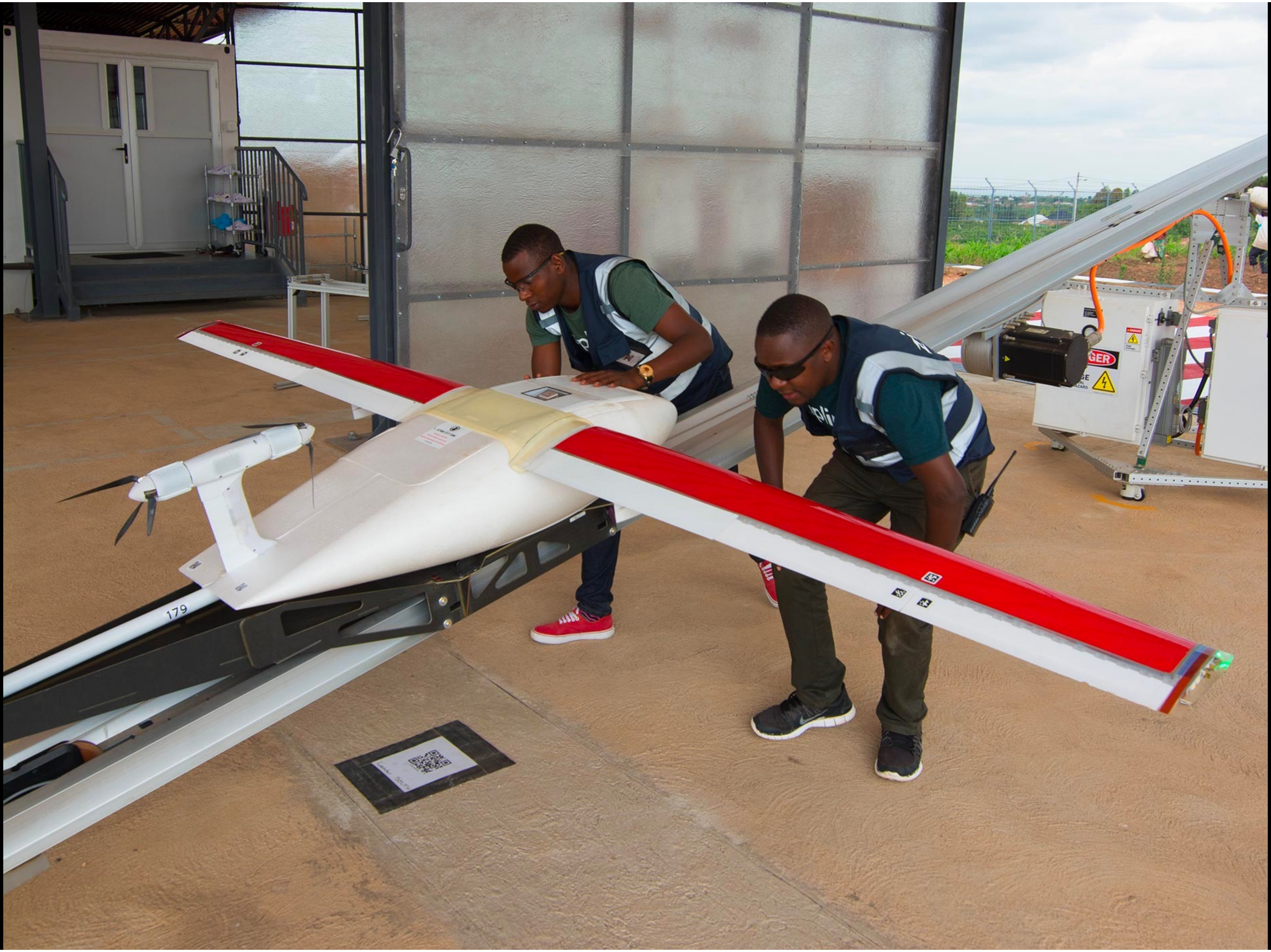
https://spectrum.ieee.org/robotics/drones/in-the-air-with-ziplines-medical-delivery-drones


O+ UNITS
TERUMO
8 366064
O+ UNITS


O+ UNITS
PEDIATRIC O+
PEDIATRIC A+
PEDIATRIC B+
PEDIATRIC O-
PEDIATRIC A-
PEDIATRIC B-


6:10
Helmer
TRANSFUSION SET
STERILE 25 SETS
JMS
TYPE:5


zipline
zipline
CAUTION
ZIP CROSSING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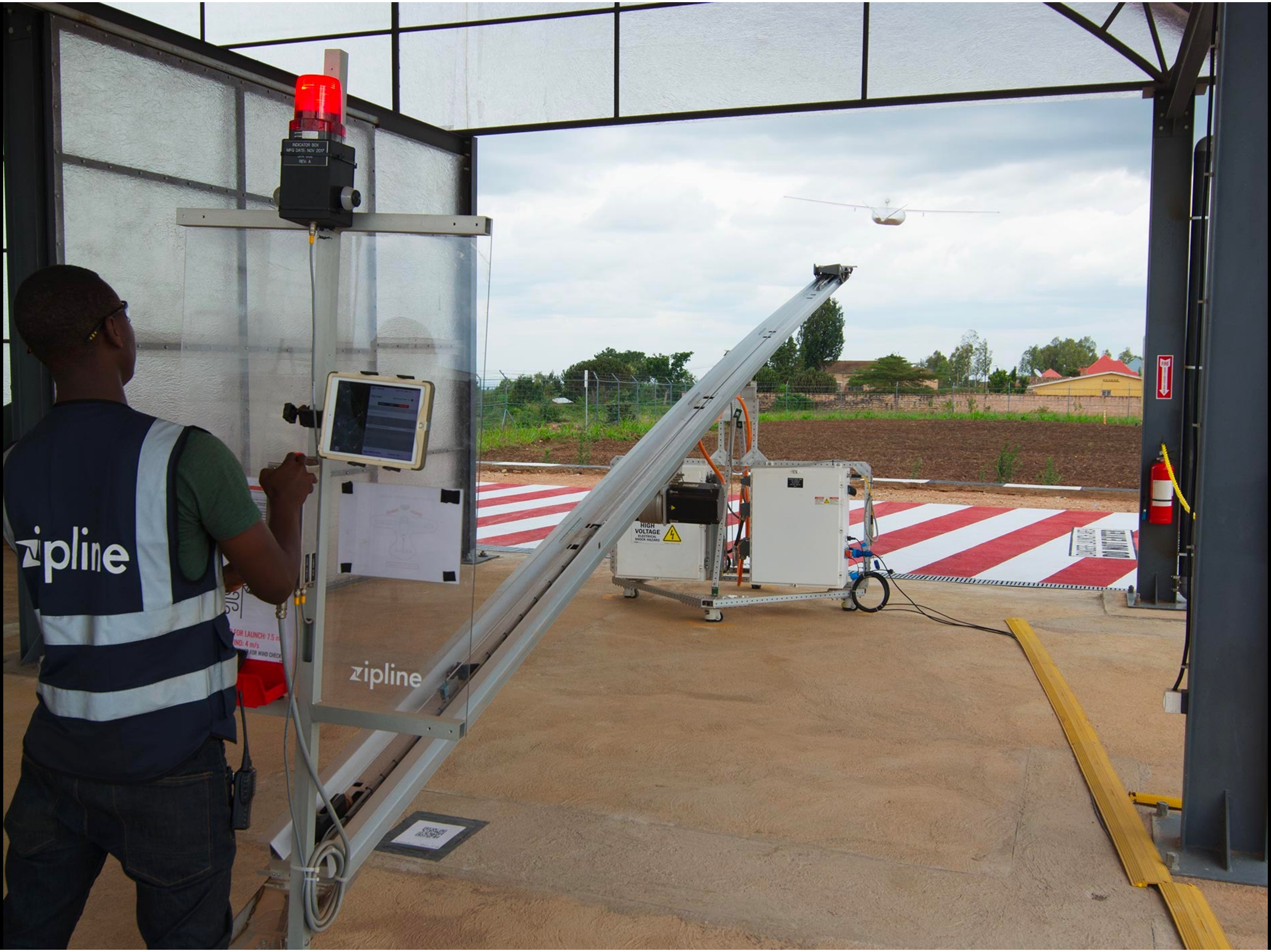
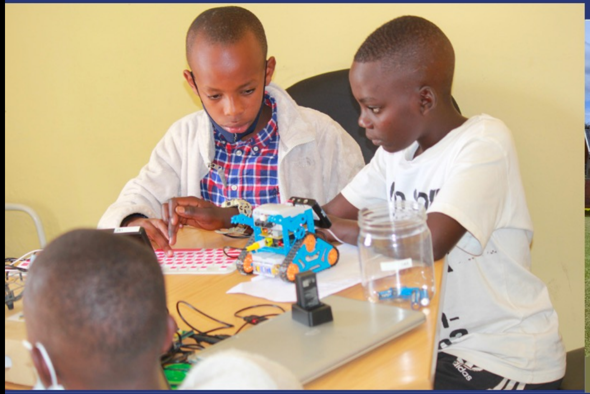

zipline
zipline
HIGH VOLTAGE

Keza Education Future Lab



Keza Education Future Lab (KEFL) is a social driven company that supports the achievement of MINEDUC and its affiliated institution REB in providing quality education by improving the use of science and technology among children. KEFL aims to build on successful foundations in the use of ICT for kids by introducing them to robotics and programming at an early age.

Get in touch

Tel: +250786701376
Email: Keza.info@gmail.com
Website: keza-education.rw
Office Adress: Bibare-Ingeri-St No 192
Kimironko, Gasabo,
Kigali City

Kids are engineers

https://keza-education.rw/

Robotics

With our Robotics programs, your child will enjoy exciting projects that use 21st century skills.

Robotics for Kids

Age group	7 - 13 Years old
Language	English
Level	Primary education

http://creativity.rw/robotics

26 pilot schools involved in the Rwanda National Robotics Program 2024

https://www.instagram.com/rwandaict/p/C_5LPBiA-OF/?img_index=1
https://en.igihe.com/news/article/robots-to-be-integrated-into-student-learning-programs

26 pilot schools involved in the Rwanda National Robotics Program 2024

Ministry of ICT and Innovation | Rwanda
@RwandaICT

This week, we celebrated a major milestone in the National Robotics Program! 🎉 We handed over 452 robotics kits to 26 piloting schools as part of the sandbox experiment. 33 trained teachers are ready to kick off this trimester, transforming how students learn. Big thanks to @Rwanda_Edu,@giz_rwanda, and our solution providers for their continued support in making this a success! 🤖📚 #STEM #Innovation #Education #Rwandan

11:35 AM · Sep 14, 2024 · **5,428** Views

https://x.com/RwandaICT/status/1834888620534104561

To find out more

Robotics and Artificial Intelligence in Africa

By David Vernon

Artificial intelligence (AI) provides many opportunities for social and economic empowerment in developing countries. However, when one thinks of Africa, robotics does not spring immediately to mind as the most relevant application of AI, considering that the continent typically has high unemployment and fast-growing populations. Nevertheless, some countries in Africa have embraced robotics on the basis that it has an important role to play in their economic development. In this article, we explore this role and the ways in which Africa can best exploit the opportunities afforded by intelligent automation and robotics. It also highlights strategies to offset the threats posed by global factors, such as premature deindustrialization.

The Growing Impact of AI in Africa

There is an increasing awareness of the positive impact that AI will have on developing countries, including sub-Saharan Africa, in sectors such as agriculture, health care, and public and financial services [1]. AI has the potential to drive economic growth, development, and democratization, thereby reducing poverty, increasing education, supporting health-care delivery, increasing food production, expanding the capacity of the existing road infrastructure by increasing traffic flows, improving public services, and bettering the quality of life for people with disabilities [2]. AI can empower workers at all skill levels to be more competitive [3], [4]. Specifically, it can be used to augment and enhance human skills—not to replace or displace humans—and to do so at all levels, enabling average and low-skill workers to fit better in high-performance environments and take on more complex responsibilities.

Africa's biggest economic challenge is to equip large sections of its economy with average workers who are primed to perform tasks far better than most employees are currently managing to do. In South Africa, approximately 31% of employers cannot fill their vacancies [4]. AI will make technology easier to adopt and harness [1], [4]. In the health-care sector, AI helps address the shortage of doctors through telemedicine and access to medical supplies through drone deliveries [5]. In agriculture, AI (including machine learning, remote sensing, and data analytics) has the potential to improve productivity and efficiency at all stages of the value chain, enabling small-holder farmers to increase their income through higher crop yields and greater price control, detect and precisely treat pests and diseases, monitor soil conditions and target fertilizer applications, create virtual cooperatives to aggregate crop yields, broker better prices, and exploit economies of scale. Internet of Things (IoT) platforms may offer cost-effective ways to achieve those benefits [6]. For example, Microsoft is applying its Farmbeats platform [7] in developing countries by lowering the cost associated with densely deploying sensors, exploiting sparsely distributed sensors and aerial imagery to generate precision maps, and replacing expensive drones with smartphones attached to hand-carried, low-cost, tethered helium balloons [8].

Premature Deindustrialization

On the downside, factory and call-center work will slow as tasks are replaced by AI-enabled automation, including robots, which will add pressure to unemployment rates that are already high in developing countries, including those in Africa [5]. This will be exacerbated by growing populations, reducing opportunities still further. Africa's population is large and expanding fast: most of its people are young and urban with a median age of 19.5 years, compared to Germany (47.1), the United States (38.1), and China (37.7), and the youth population is set to reach 225 million by 2055 [5]. Kenya, Nigeria, and South Africa, for example, are projected to have approximately 5.5%, 8.5%, and 12.5%, respectively, of their workforce displaced by automation [9]. A report by the Oxford Martin School at the University of Oxford, United Kingdom, and Citigroup, New York, summarizes the situation in Africa in stark terms [10]:

> In most of sub-Saharan Africa, the manufacturing share of output has persistently declined over the past 25 years. The share of jobs in manufacturing is even smaller: just over 6% of all jobs. This figure barely changed over the course of the three decades

Digital Object Identifier 10.1109/MRA.2019.2946107
Date of current version: 11 December 2019

IEEE Robotics and Automation Magazine December 2019

https://ieeexplore.ieee.org/document/8931075

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AI and Robotics in Africa

(Redirected from Artificial Intelligence, Robotics, and Machine Learning in Africa)

signifies a recently added item

Robotics in Africa [edit]

African Robotics Network (AFRON)
All-girls robotics team from Ghana wins World Robofest Championship in the U.S.
Award-winning professor ignites passion for STEM learning in Africa
Awarri "Our mission is to enable the development and adoption of advanced AI & Robotics technology on the African continent"
Culturally competent social robots target inclusion in Africa
Fundi Bots robotics for kids classes, motivating STEM education generally
Humanoid robot Sophia addresses Africa technology summit in Rwanda
IRCAD in the press
MIT-Africa Robotics Boot Camp
Pan-African Robotics Competition General Overview
Pan-African Robotics Competition 2023 AgTech Challenge uses more advanced tools, e.g., ROS, Gazebo, and OpenCV, and Scout robot from AgileX.
Reflect Robotics
Research Institute against Digestive Cancer (IRCAD)
Robofest 2019
Robotics and Artificial Intelligence in Africa, IEEE Robotics & Automation Magazine, Vol. 26, No. 4, pp. 131-135, December 2019.
Robotics for Kids
Robotics in Education in Africa Ayorkor Korsah, Ashesi University, Ghana, Plenary speaker at the 2015 IEEE International Conference on Robotics and Automation
Robots at reception: South African hotel turns to machines to beat pandemic.
Robots in Africa. What does this mean for the continent?
Ryonic Robotics
Ubtech CRUZR service robot deployed by ZoraBots Africa Ltd. to check the temperature of travellers arriving at Kigali International Airport, Rwanda.
Working with Robots as Colleagues: Kenyan Perspectives of Ethical Concerns on Possible Integration of Co-bots in Workplaces
ZoraBots Africa Ltd.

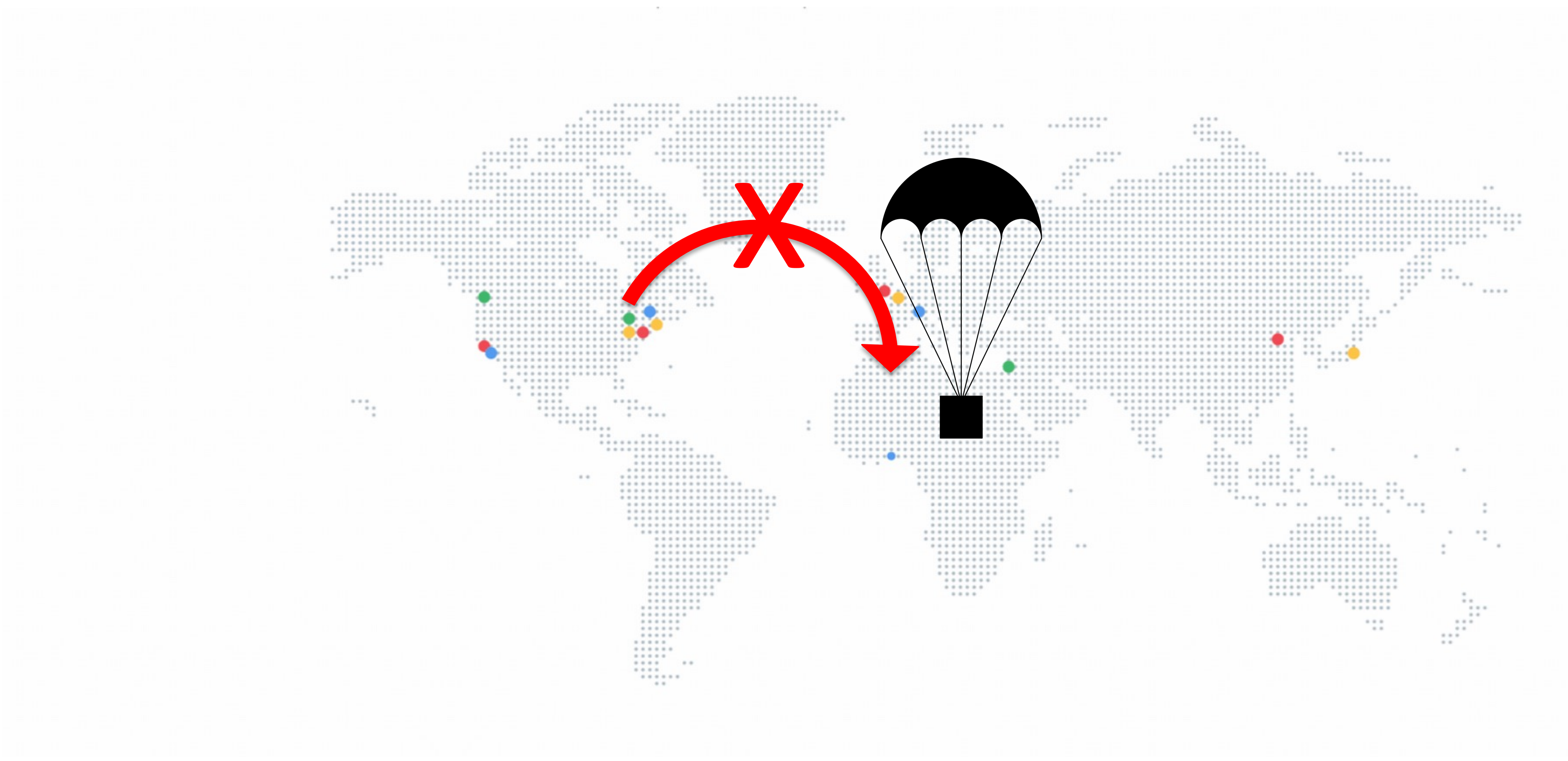
Robotics Education in Africa [edit]

Carnegie Mellon University Africa website and video
ICRA 2015 - Robotics in Education in Africa
Keza Education Future Lab for kids aged 3 to 14
Leapr Labs
Mtoto Robotics (part for Leapr Labs)

Artificial Intelligence, Robotics, and Machine Learning in Africa

www.vernon.eu/wiki/Artificial_Intelligence,_Robotics,_and_Machine_Learning_in_Africa

One more thought ...



https://www.blog.google/around-the-globe/google-africa/google-ai-ghana/
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"We need African solutions to African problems"

Michel Bézy

The difference between Invention and Innovation is Adoption

Jeremy Rose

Adoption depends on Trust

Trust

The expectation that
a service will be provided
or a commitment
will be fulfilled
(Hofman et al., 2006)

Individual Context

Trust

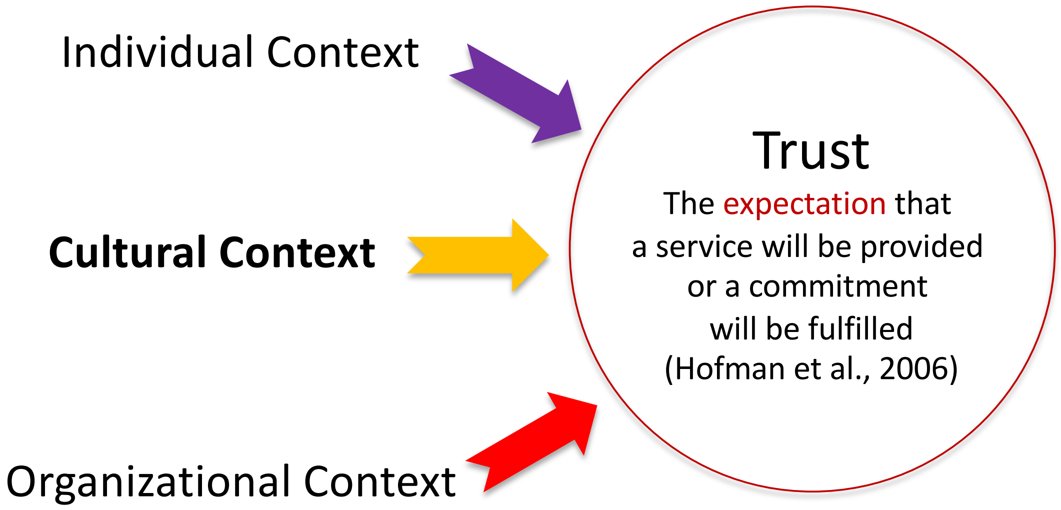
The expectation that
a service will be provided
or a commitment
will be fulfilled
(Hofman et al., 2006)

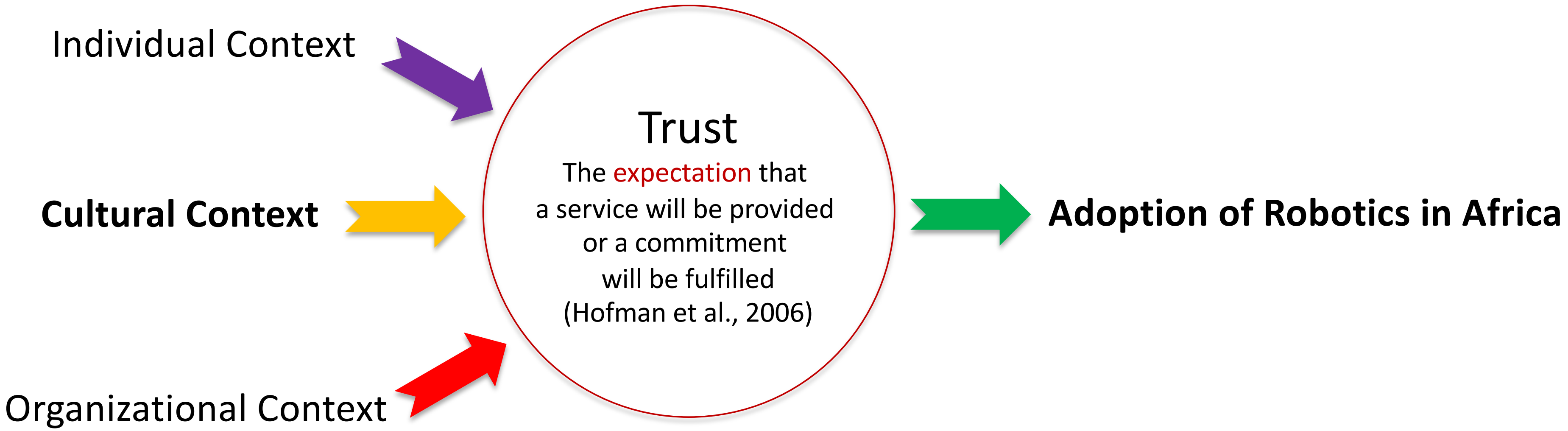
Individual Context

Organizational Context

Trust

The expectation that
a service will be provided
or a commitment
will be fulfilled
(Hofman et al., 2006)


Individual Context
Cultural Context
Organizational Context
Trust
The expectation that
a service will be provided
or a commitment
will be fulfilled
(Hofman et al., 2006)



Individual Context
Cultural Context
Organizational Context
Trust
The expectation that
a service will be provided
or a commitment
will be fulfilled
(Hofman et al., 2006)
Adoption of Robotics in Africa

Adoption hinges on cultural competence

CSSR for Africa

Culturally Sensitive Social Robotics for Africa

www.cssr4africa.org

Started in July 2023

CSSR for Africa
Culturally Sensitive Social Robotics for Africa

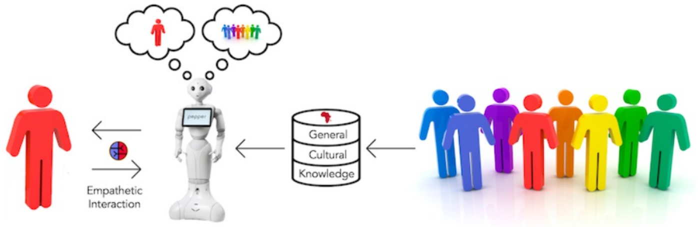
Overview | Consortium | Contact
Work Plan | Deliverables | Software
News | Wiki | Publications

This project is funded by the African Engineering and Technology Network (Afretec) Inclusive Digital Transformation Research Grant Programme.

The CSSR4Africa Project

While technological invention creates new ways of doing things, it is *innovation* that produces social and economic benefits through widespread *adoption* and the consequent change in the people's practices. Adoption depends on physical infrastructure, but it also depends on social infrastructure: the conventions that govern people's behaviour, the practices they find acceptable and unacceptable, and their sense of what is trustworthy. Cultural competence, i.e., an awareness of social norms and cultural expectations, is a key element in fostering this acceptance.

The need for technology to be culturally competent is perhaps best exemplified by the field of social robotics, a field that is growing quickly.[1] Social robots will serve people in a variety of ways: operating in everyday environments, often in open spaces such as hospitals, exhibition centres, and airports, providing assistance to people, typically in the form of advice, guidance, or information.

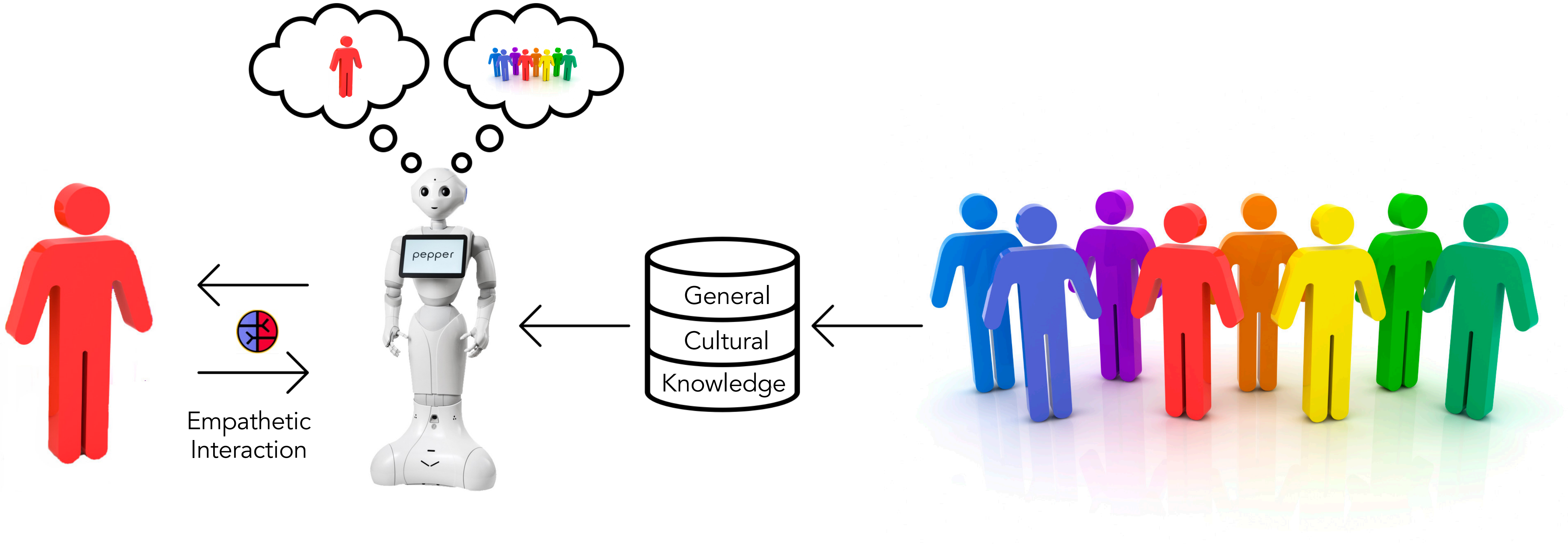


Loosely based on ethnographic research to acquire cultural knowledge about acceptable modes of communication, the CSSR4Africa project will equip robots with the ability to interact sensitively and politely with people in Africa using spatial, non-verbal, and verbal modes of communication.

[1]The global social robotics market was valued at $1.98 billion in 2020 and is expected to reach $11.24 billion by 2026 (Global Social Robots Market 2022 – 2027).

Figure based on (Bruno et al., 2017); see Overview.

www.cssr4africa.org



Graphic based based on work by Bruno et al. (2017)

Culturally Competent Social Robot

{Bruno et al, 2017}

1

Cultural knowledge representation

Culturally Competent Social Robot

{Bruno et al, 2017}

1. **Cultural knowledge representation**
2. **Culturally sensitive planning and action execution**

Culturally Competent Social Robot

{Bruno et al, 2017}

1. Cultural knowledge representation
2. Culturally sensitive planning and action execution
3. Culturally aware multimodal human-robot interaction

Culturally Competent Social Robot

{Bruno et al, 2017}

1 Cultural knowledge representation

2 Culturally sensitive planning and action execution

3 Culturally aware multimodal human-robot interaction

4 Culture-aware human emotion recognition

Culturally Competent Social Robot

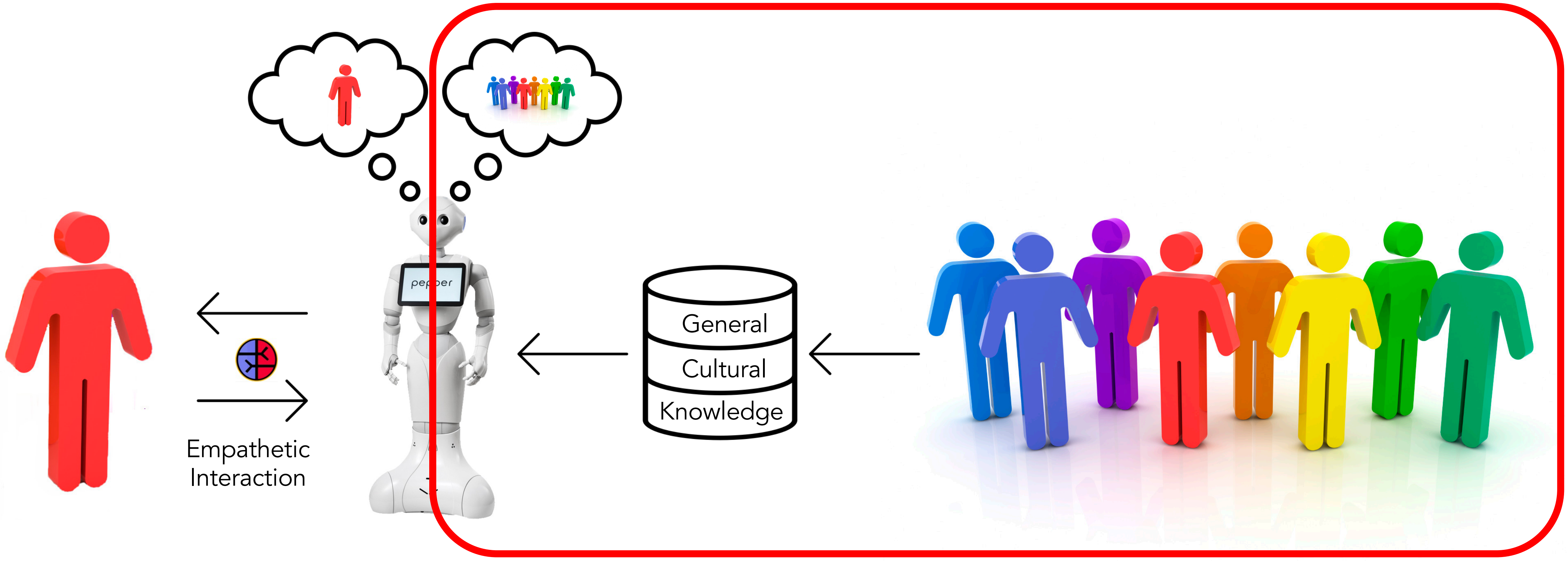
{Bruno et al, 2017}

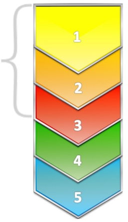
1. Cultural knowledge representation
2. Culturally sensitive planning and action execution
3. Culturally aware multimodal human-robot interaction
4. Culture-aware human emotion recognition
5. Culture identity assessment, habits, and preferences

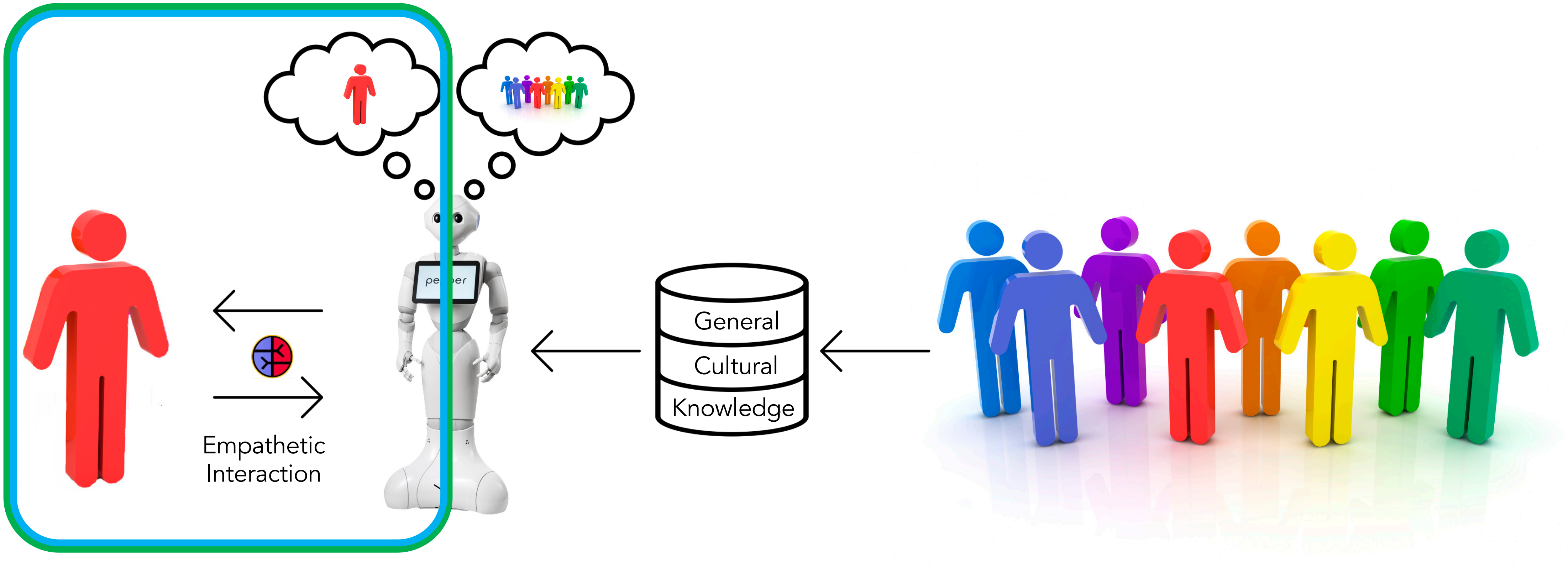
Culturally Sensitive Social Robot

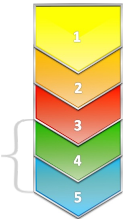
1. Cultural knowledge representation
2. Culturally sensitive planning and action execution
3. Culturally aware multimodal human-robot interaction
4. Culture-aware human emotion recognition
5. Culture identity assessment, habits, and preferences

CSSR for
Culturally Sensitive Social Robotics for Africa






Empathetic
Interaction
General
Cultural
Knowledge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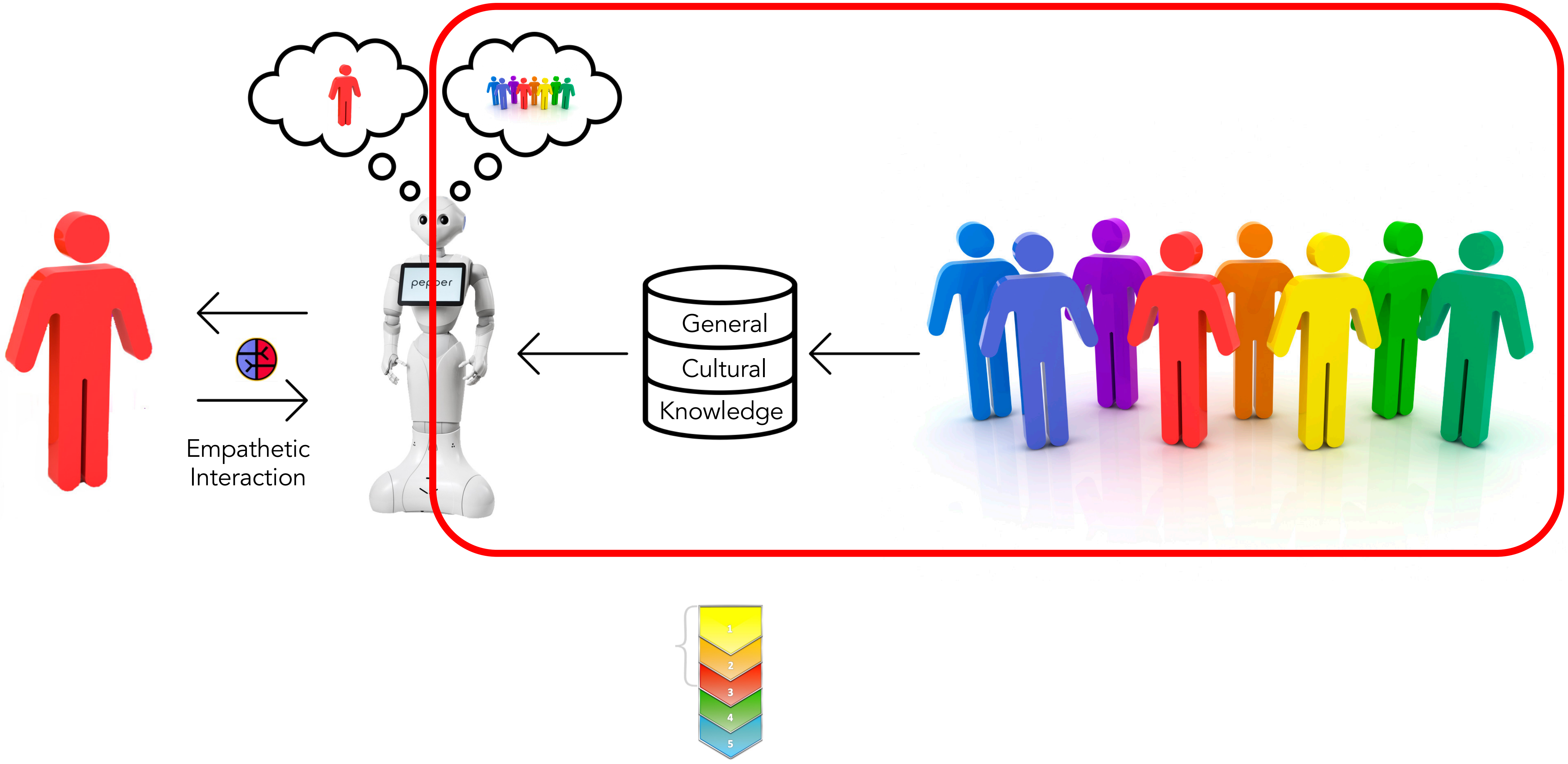
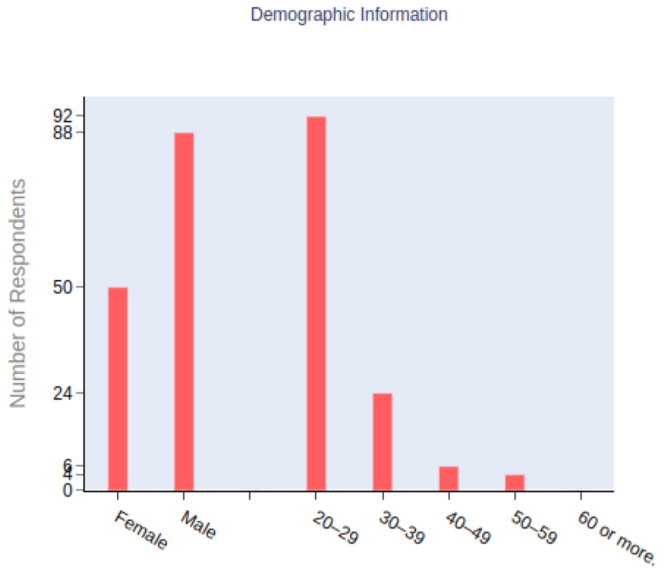
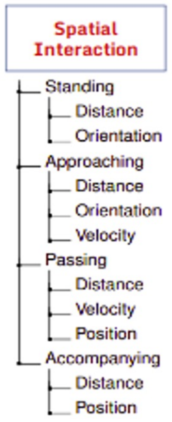
CSSR for
Culturally Sensitive Social Robotics for Africa

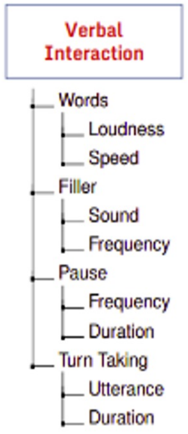


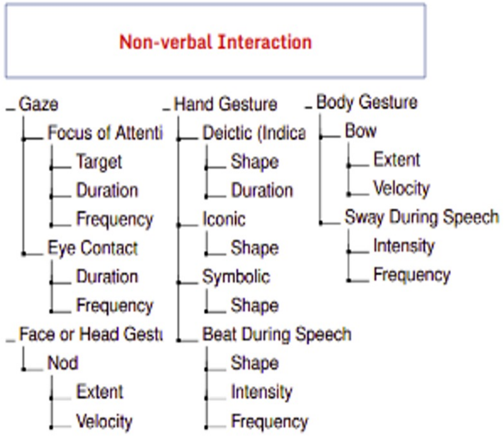
Pilot Survey of Rwandan Cultural Knowledge

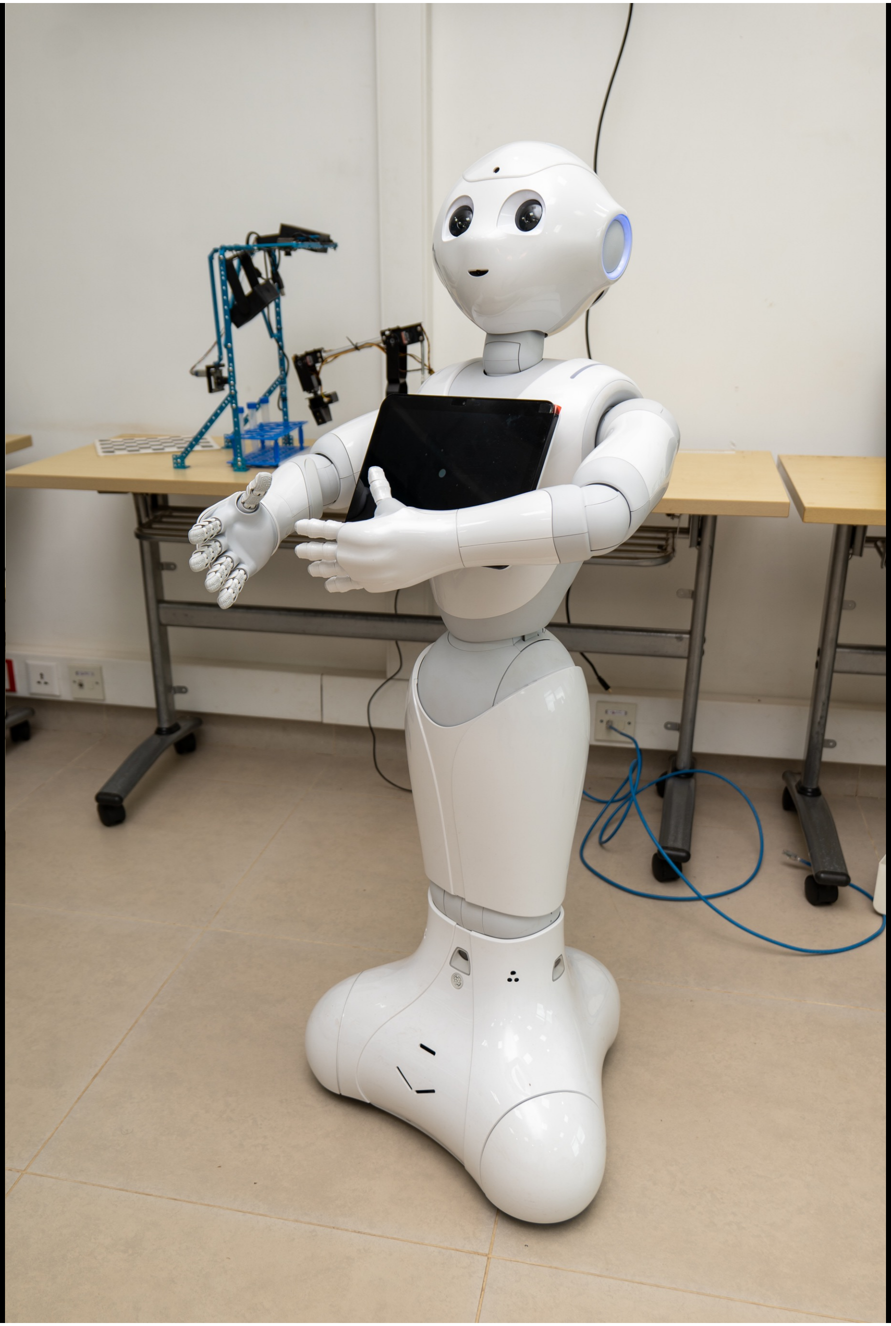
- Online survey with 59 questions (English and Kinyarwanda)
- Conducted at Carnegie Mellon University Africa
- 143 responses (108 in English, 35 in Kinyarwanda)

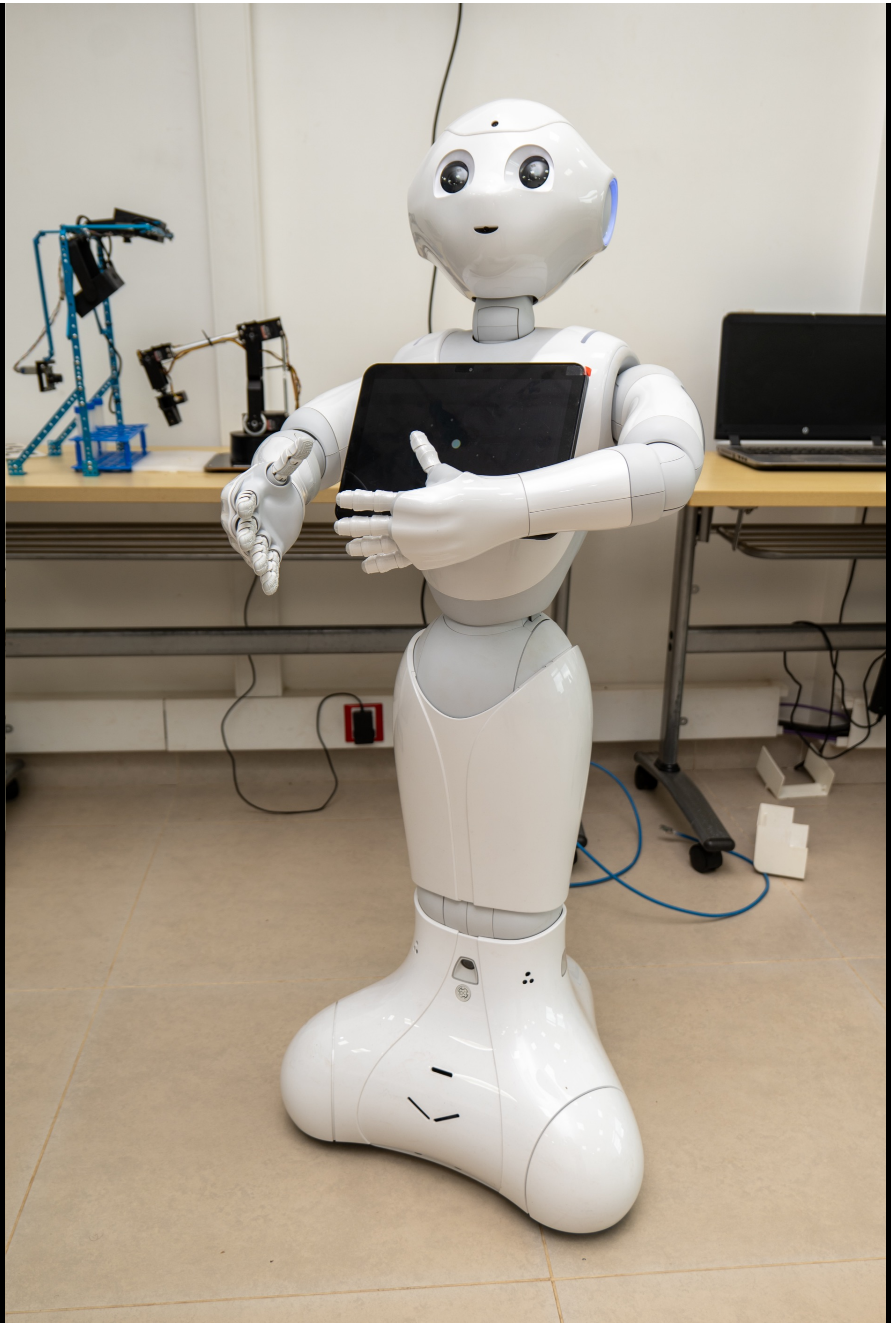


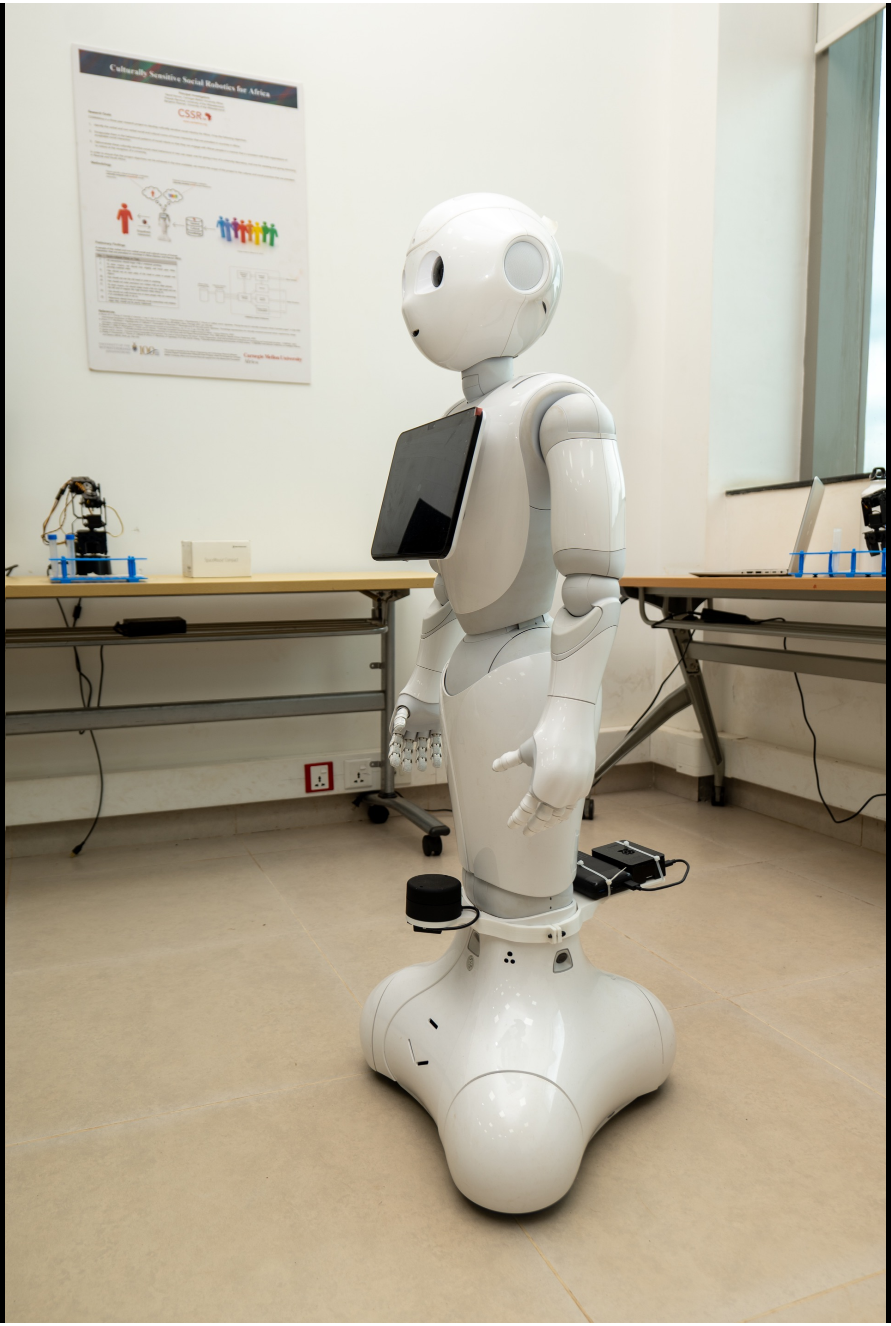


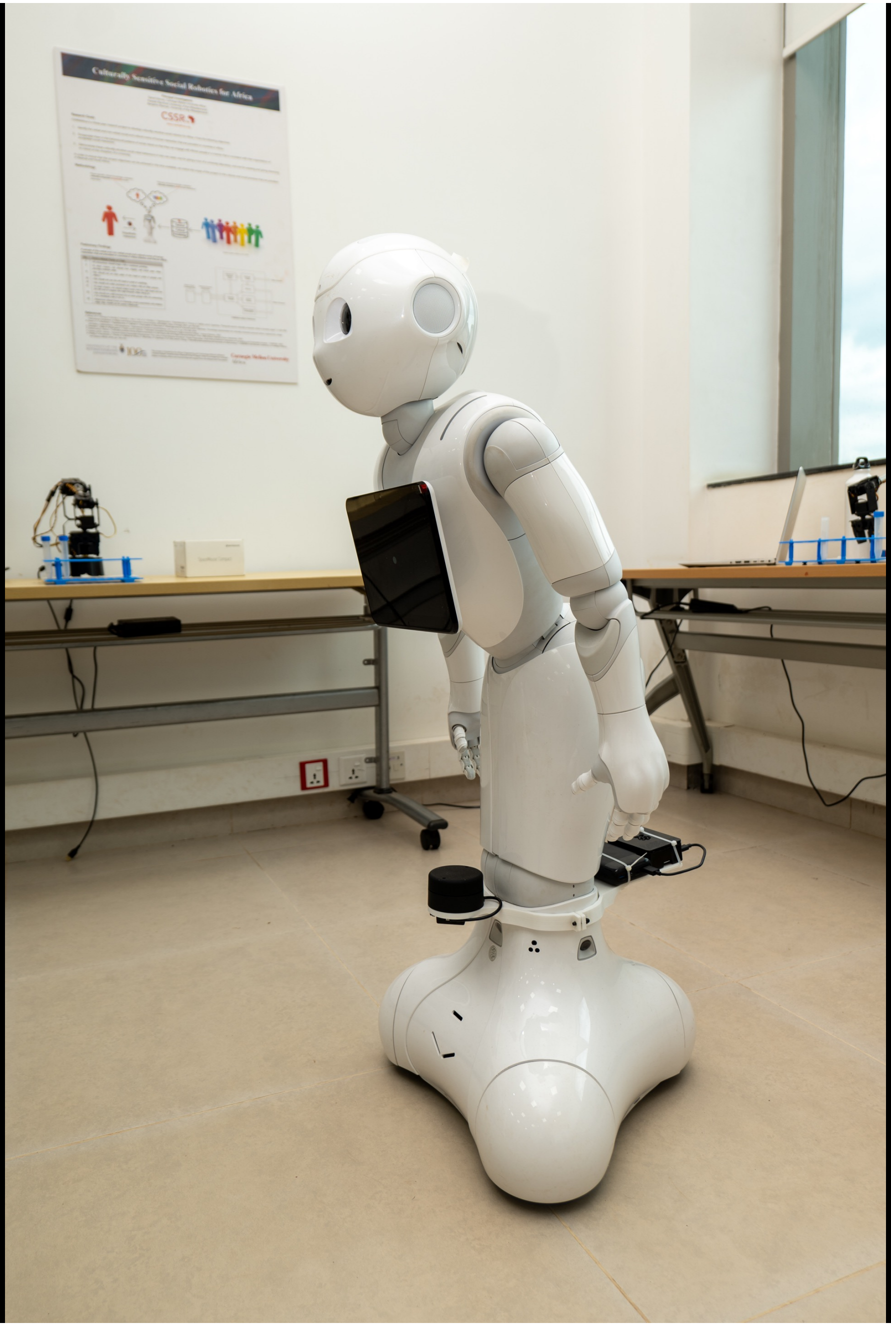


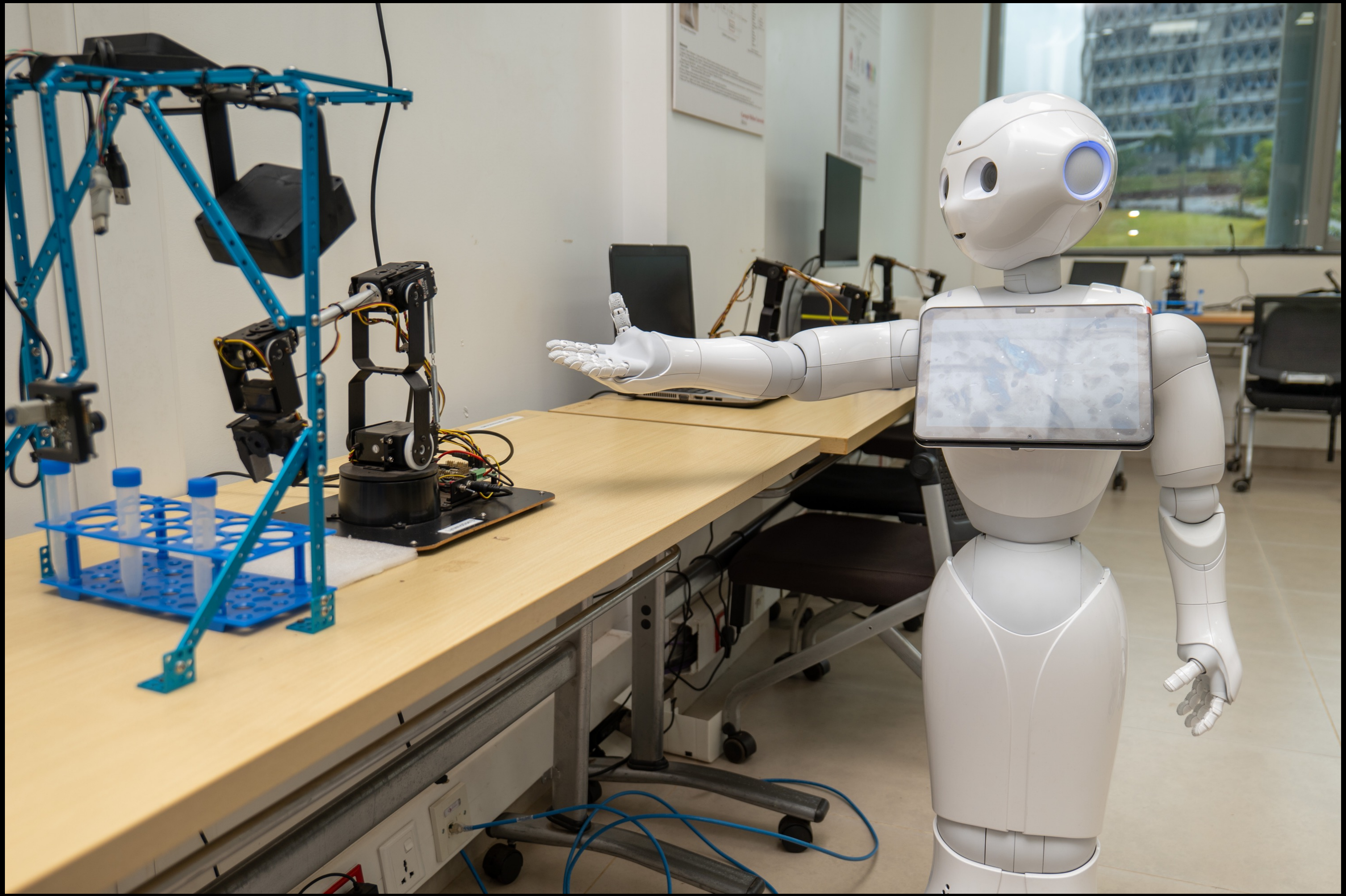







Culturally Sensitive Social Robotics for Africa
CSSR

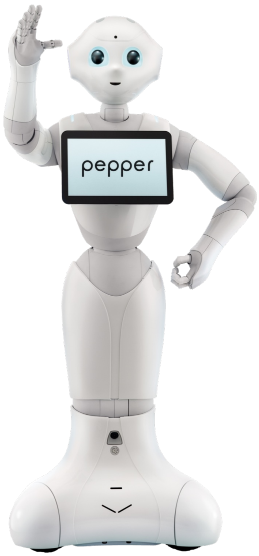

Culturally Sensitive Social Robotics for Africa
CSSR



A Sample of African Culture-specific Knowledge

No.	Socio-cultural Norm or Trait
1	All interactions should begin with a courteous greeting.
2	The younger interaction partner should enable a greeting to be initiated by an older person.
3	The younger interaction partner should bow when greeting an older person or when rendering a service.
4	One should not wave at someone from a distance; one should move towards them to greet them.
5	To show respect, one should bow slightly and lower gaze when greeting someone older.
6	To show respect, one should raise both hands and lower gaze a little when greeting.
7	One should suspend work or movements and pay attention when addressed.
8	One should use an open palm of the hand to point to people and objects.
9	One should not point an upward facing palm of the hand at someone.
10	One should not use the left hand to point to anything.
11	One should not use the left hand to hand something to someone.
12	To show respect, one should hand over and accept gifts with two hands and do so from the front, facing the recipient.
13	It is respectful to use local languages and they should be used for verbal interaction when possible.
14	One should use formal titles when addressing someone.
15	One should engage in a preamble before getting to the point, as being too forward may be regarded as disrespectful.
16	One should not interrupt or talk over someone when they are speaking.
17	One should not interrupt or talk over someone when they are speaking.
18	One should keep intermittent eye contact; lack of eye contact depicts disrespect as it shows divided attention during the interaction.
19	One should not make persistent eye contact with an older person.
20	One should not make eye contact when being corrected.
21	To show respect, one should shake hands with the right hand and use the left arm to support the right forearm when doing so.
22	One should not walk far ahead of an older person, unless leading the person (in which case, one should walk slightly to the side).
23	One should not walk between two or more people who are conversing; it is considered rude to do so.
24	An appreciation of rhythmic sound and movement is valued.
25	Behaviours should focus on fostering social connections and relationships; they should not be purely functional.

After (Bruno et al, 2019)



Spatial,
Non-verbal,
Verbal
Interaction

Design Pattern	Culturally Competent Behavior
Initial Introduction	The robot should acknowledge the presence of the person. The robot should initiate an interaction with a slight bow. The robot should greet first and should use a formal greeting. The robot should respect personal and intimate distances during interaction.
Reciprocal Turn Taking	The robot should respectfully give the initial turn to the human interaction partner. The robot should give priority to older people; it should not interrupt and it should let the other person finish their turn.
Didactic Communication	Pointing a hand directly at someone is disrespectful. For deictic gestures, the robot should use its left hand. The robot should gesture with an open palm rather than pointing a finger.
Personal Interests and History	The robot should avoid trying to share personal history since it will be perceived to be inauthentic. The robot should focus on and highlight its functional usefulness.
In Motion Together	The robot should explicitly say "Please come along" to remove any ambiguity of intention. The robot should not walk too far ahead when showing the way.
Recovering from Mistakes	The robot should apologize profusely. The robot should slightly bow when introducing itself and after it makes a mistake.
Physical Intimacy	Personal space should be entered only with prior consent. The robot should not pass in between two people that are interacting.
Claiming Unfair Treatment or Wrongful Harm	To enhance the perception that the robot is being respectful, the robot should not be aggressive by claiming unfair treatment.

A Sample of Africa-centric Design Patterns for Social Robots

After (Kahn et al, 2008)

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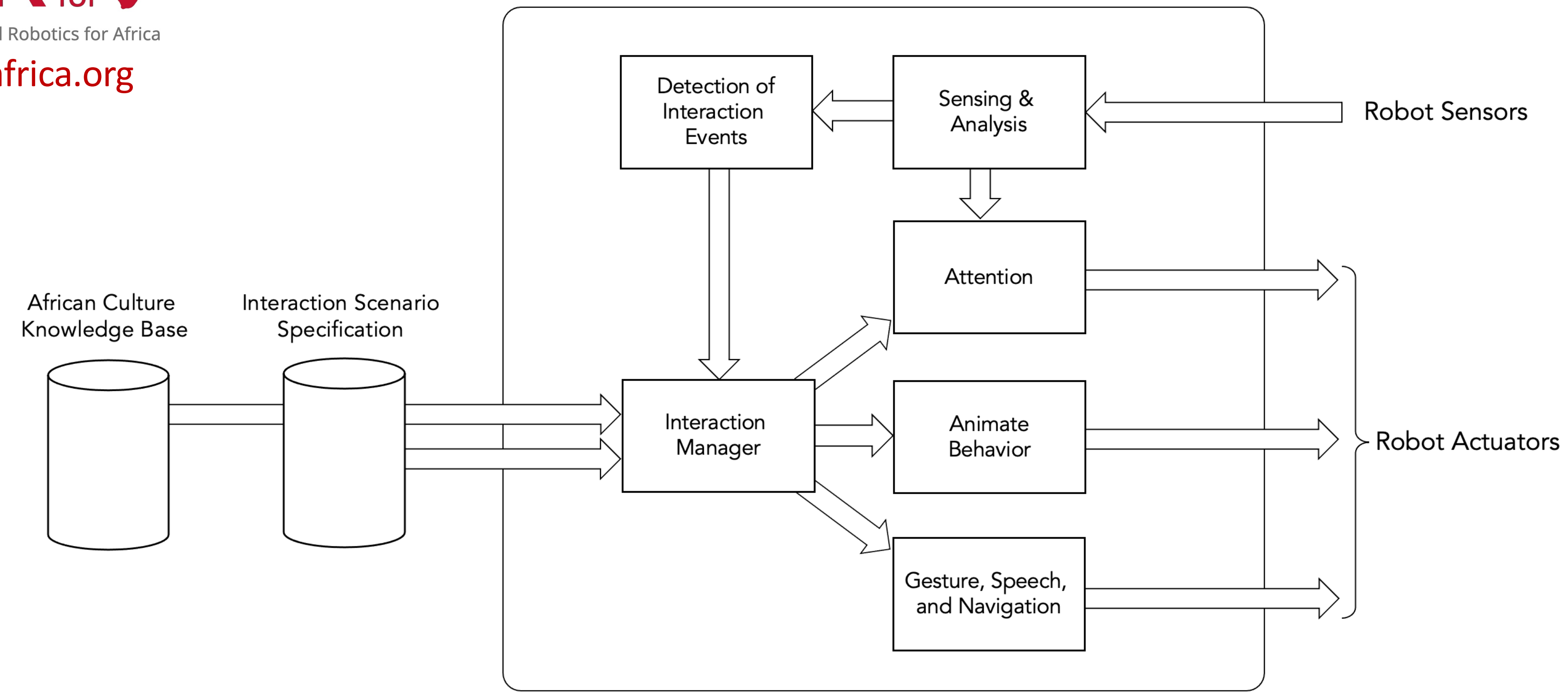
Culturally Sensitive Social Robotics for Africa

www.cssr4africa.org



Abstract system architecture for a culturally sensitive social robot

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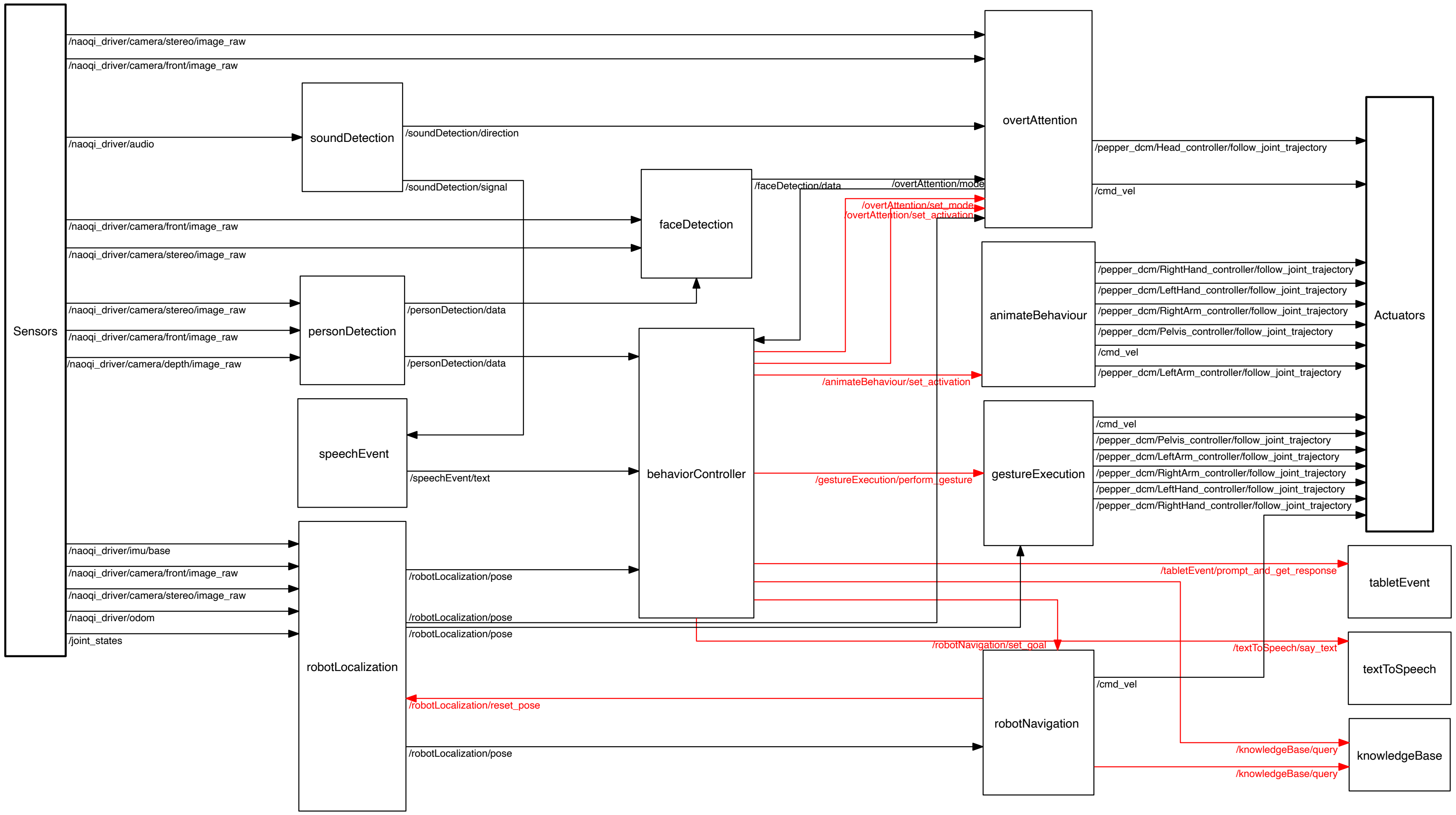


ROS system architecture for a culturally sensitive social robot

(all software will be on GitHub at https://github.com/cssr4africa/cssr4africa)

Minimum Jerk Model

$$CF = \frac{1}{2}\underbrace{\int_{t_1}^{t_2} \left[\left(\frac{d^3x}{dt^3} \right)^2 + \left(\frac{d^3y}{dt^3} \right)^2 \right]}_{\text{Cost function being minimized}} dt$$

Joint position $$\theta(t) = p_s + k\left[10(t/d)^3 - 15(t/d)^4 + 6(t/d)^5\right]$$

Joint velocity $$\dot{\theta}(t) = \frac{k}{d}\left[30(t/d)^2 - 60(t/d)^3 + 30(t/d)^4\right]$$

Joint acceleration $$\ddot{\theta}(t) = \frac{k}{d^2}\left[60(t/d) - 180(t/d)^2 + 120(t/d)^3\right]$$

$$0 \leq t \leq d$$

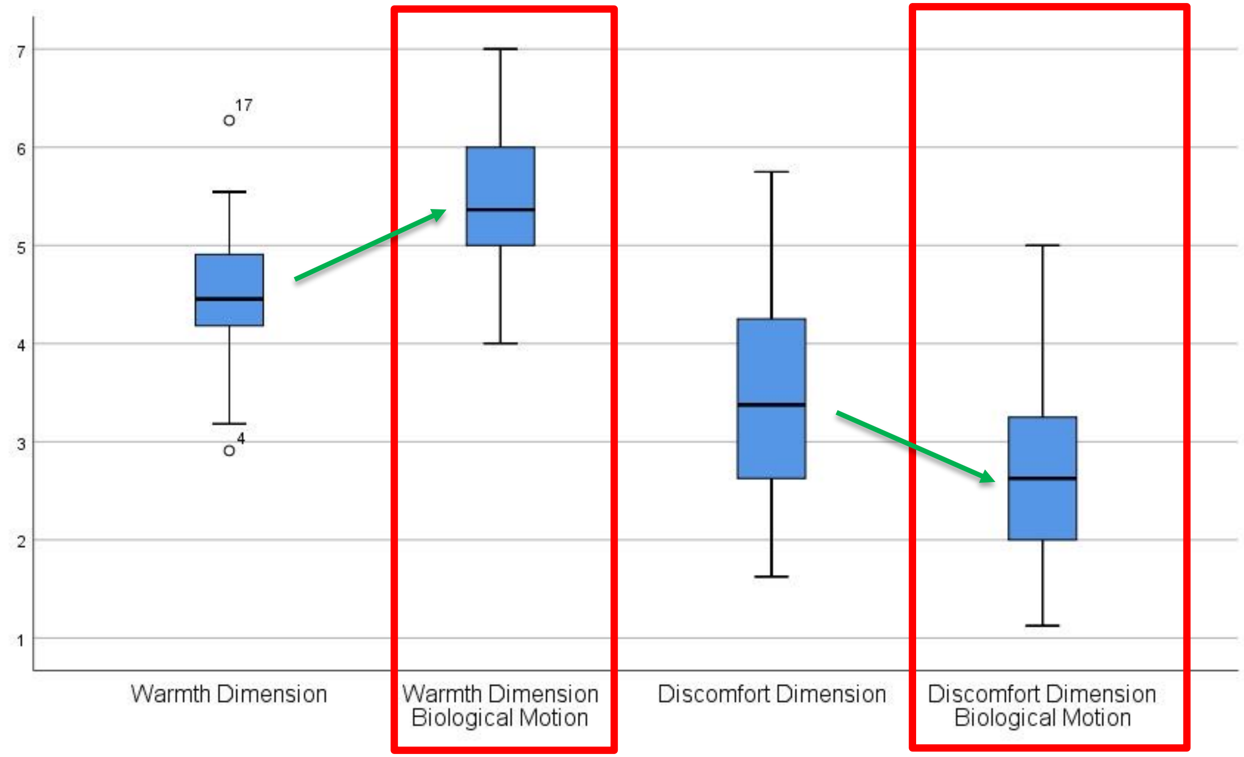
Biological Motion for Engaging Gestural Communication in Social Robots

Biological motion during human-robot interactions

Warmth increased on average by 14%

Discomfort reduced by 13%

(assessed using a variation of the RoSAS metric)



Biological Motion for Engaging Gestural Communication in Social Robots

CSSR for Africa

Culturally Sensitive Social Robotics for Africa

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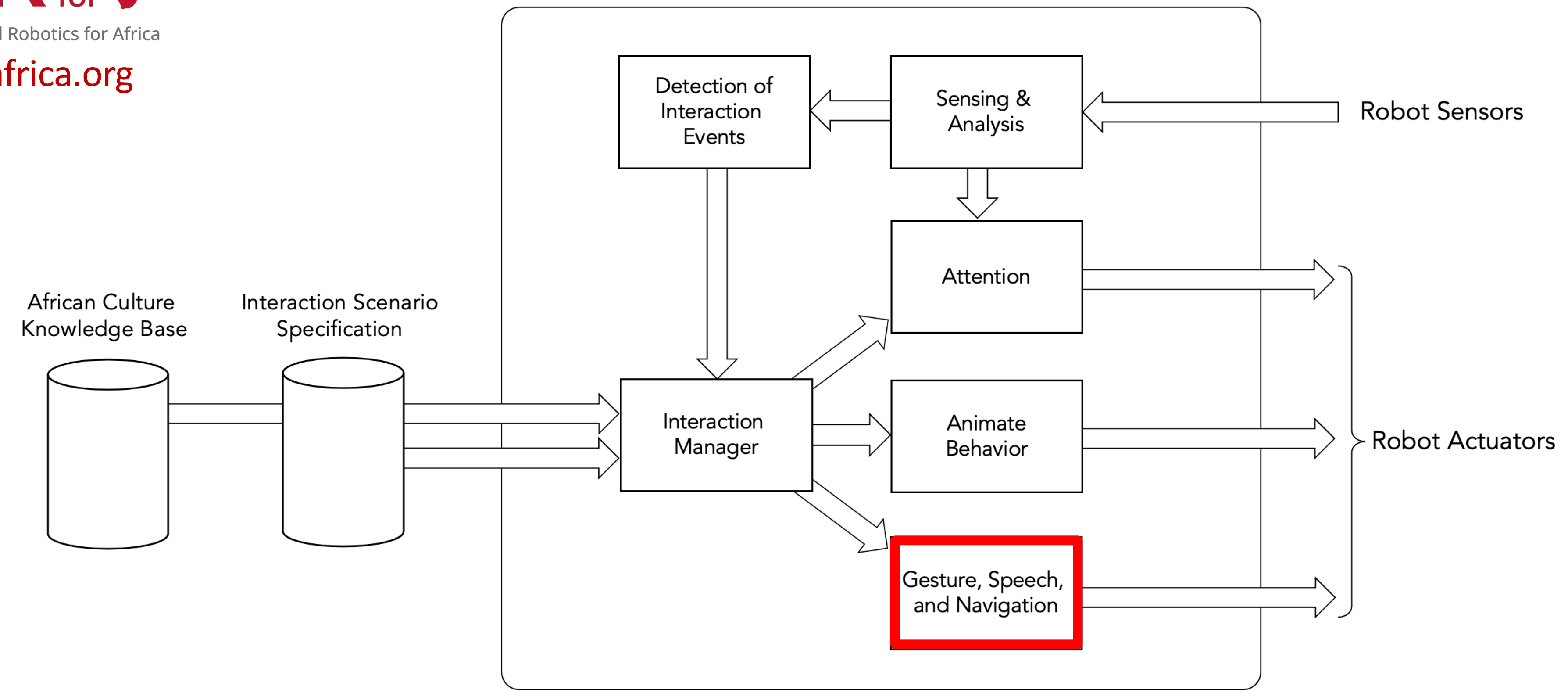

Gesture subsystem in the abstract system architecture

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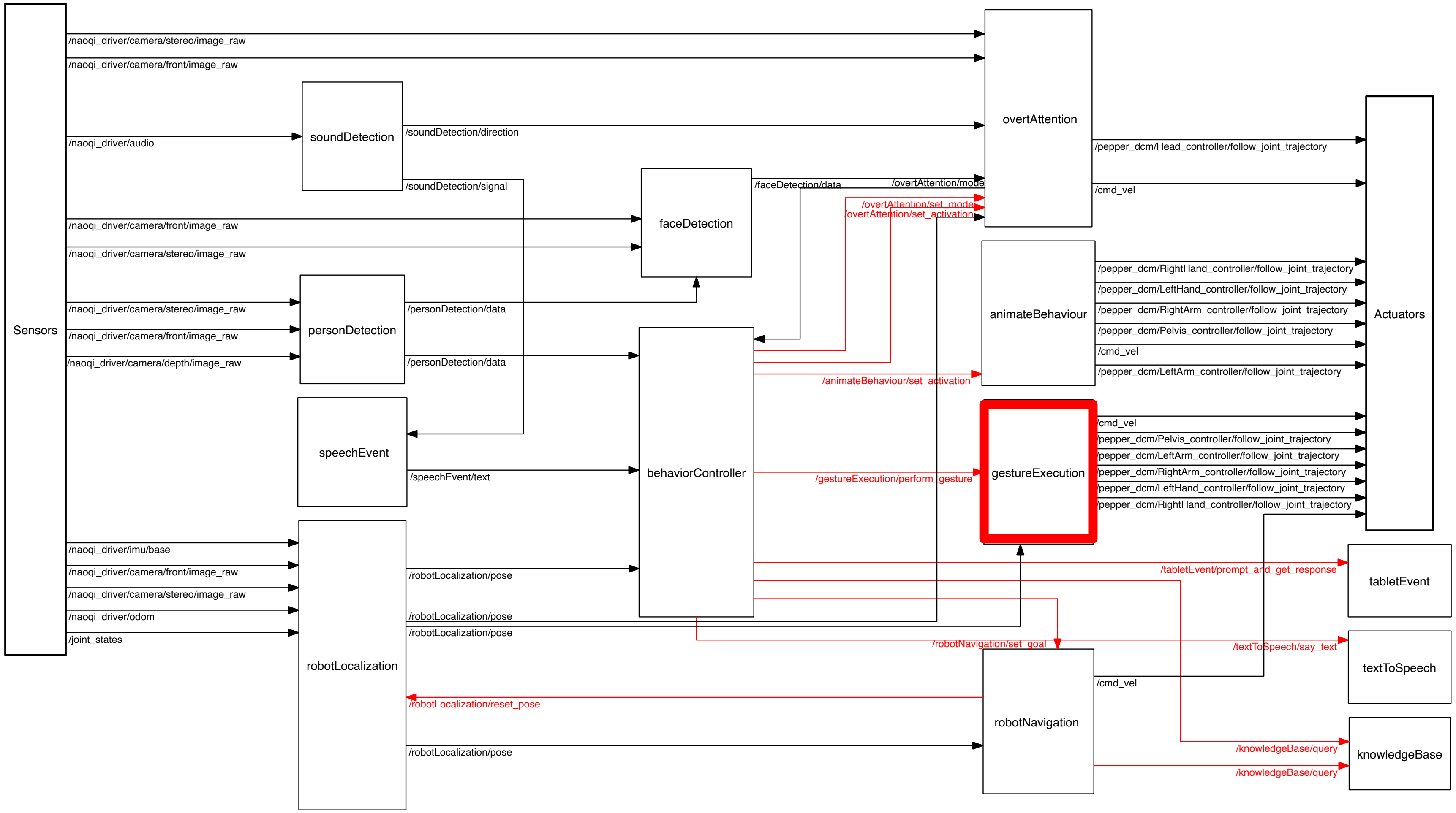


Gesture subsystem ROS system architecture

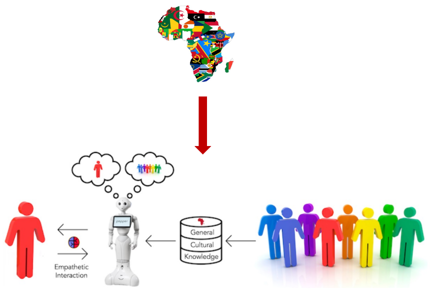
Carnegie Mellon University Africa

Rwandan Culture Survey for Culturally-Sensitive Social Robotics for Africa

Eyerusalem Birhan and David Vernon
Carnegie Mellon University Africa, Kigali, Rwanda

Research Goals

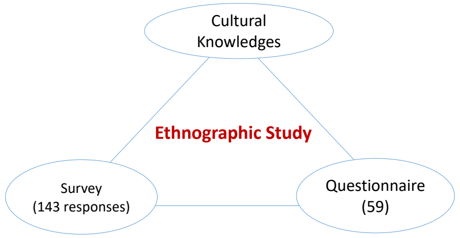
Identify the verbal and non-verbal social and cultural norms of human interaction that are prevalent in African countries, specifically Rwanda.



Cultural knowledge Ontology

- Cultural Knowledge
  - Spatial Interaction
  - Verbal Interaction
  - Non-verbal Interaction
- Spatial Interaction
  - Standing
    - Distance
    - Orientation
  - Approaching
    - Distance
    - Orientation
    - Velocity
  - Passing
    - Distance
    - Velocity
    - Position
  - Accompanying
    - Distance
    - Position
- Verbal Interaction
  - Words
    - Loudness
    - Speed
  - Filler
    - Sound
    - Frequency
  - Pause
    - Frequency
    - Duration
  - Turn Taking
    - Utterance
    - Duration
- Non-verbal Interaction
  - Gaze
    - Focus of Attention
      - Target
      - Duration
      - Frequency
    - Eye Contact
      - Duration
      - Frequency
  - Face or Head Gesture
    - Nod
      - Extent
      - Velocity
  - Hand Gesture
    - Deictic (Indicating)
      - Shape
      - Duration
    - Iconic
      - Shape
    - Symbolic
      - Shape
    - Beat During Speech
      - Shape
      - Intensity
      - Frequency
  - Body Gesture
    - Bow
      - Extent
      - Velocity
    - Sway During Speech
      - Intensity
      - Frequency

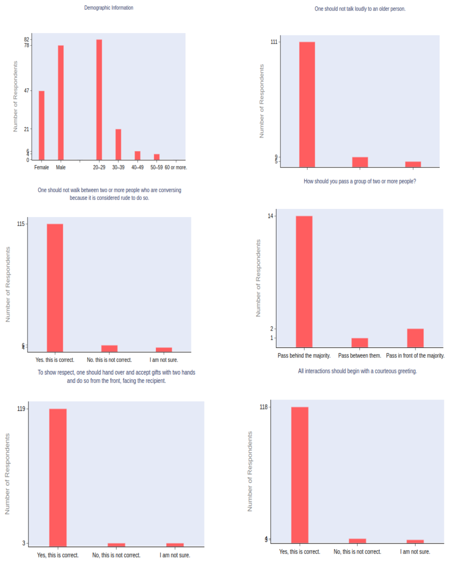
Method



Sample Questions

No.	Question
2-1	To show respect, one should lower gaze when greeting someone older.
2-3	One should keep intermittent eye contact; lack of eye contact depicts disrespect as it shows divided attention during the interaction.
2-4	One should not make persistent eye contact with an older person.
2-6	One should use an open palm of the hand to point to people and objects.
2-7	One should not point an upward-facing palm of the hand at someone.
2-8	One should not use the left hand to point to anything.
2-9	To show respect, one should bow slightly when greeting someone older.
2-12	One should not use the left hand to hand something to someone.
2-14	To show respect, one should shake hands with the right hand and use the left arm to support the right forearm when doing so.
2-15	An appreciation of rhythmic sound and movement is valued.
2-16	To show respect, one should bow slightly and lower gaze when greeting someone older.
2-17	The younger interaction partner should bow when greeting an older person or when rendering a service.
3-1	What distance should you keep when passing someone?
3-2	How should you acknowledge someone when passing them?
3-3	How should you pass a group of two or more people?
3-6	When showing someone younger than you the way, where should you position yourself?
3-7	How should you address someone who is older than you and who you haven't met before?
3-21	Would you use a face, head, hand, or body gesture to express gratitude?
3-22	Would you use a face, head, hand, or body gesture to express agreement?
3-23	Would you use a face, head, hand, or body gesture to express respect?
3-28	Is there a face, head, hand, or body gesture you should not use?
3-29	Would you use a hand or body gesture while speaking to someone?
3-30	Would you use a hand or body gesture while listening to someone?

Results



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http://www.vernon.eu/downloads/CMU-Africa_Poster_Culture_Survey.pdf

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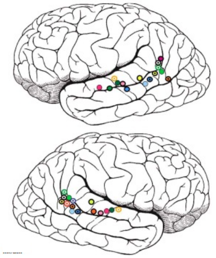
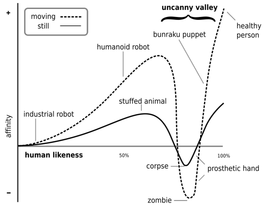
Biological Motion for Gestural Communication by Social Robots

Adedayo Akinade and David Vernon
Carnegie Mellon University Africa, Kigali, Rwanda

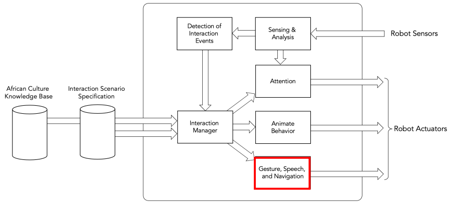
Significance of Biological Motion



Superior Temporal Sulcus activation
(Puce and Perret, 2003)



Uncanny Valley
(Bartneck et al., 2019)



CSSR4Africa System Architecture

Method

Models of Biological Motion

Minimum Jerk
(Chan et al., 2021)

$$\underbrace{CF = \frac{1}{2}\int_{t_1}^{t_2}\left[\left(\frac{d^3x}{dt^3}\right)^2 + \left(\frac{d^3y}{dt^3}\right)^2\right]}_{\text{Cost function being minimized}} dt$$

Two-thirds Power Law
(Viviani and Flash, 1995)

$$V(t) = K(t)\left(\frac{R(t)}{1+\alpha R(t)}\right)^{\beta}$$

Empirical value $\frac{2}{3}$

Tangential Velocity

Velocity Gain Factor (> 0)

Radius of Curvature

Decoupled Minimum-Jerk
(Huber et al., 2009)

$$r_z(t) = \sum_{k=0}^{5} a_{kz} t^k$$

Trajectory in z-direction

$$r_{xy}(t) = \sum_{k=0}^{5} a_{kxy} t^k$$

Trajectory in xy-direction

Trajectory Generation

Form of trajectory that minimizes jerk

$$\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5$$

Boundary conditions

$$\theta(0) = p_s; \quad \dot{\theta}(0); \quad \ddot{\theta}(0) = 0$$

$$\theta(d) = p_f; \quad \dot{\theta}(d); \quad \ddot{\theta}(d) = 0$$

Joint positions $\theta(t) = p_s + k\left[10(t/d)^3 - 15(t/d)^4 + 6(t/d)^5\right]$

Joint velocities $\dot{\theta}(t) = \frac{k}{d}\left[30(t/d)^2 - 60(t/d)^3 + 30(t/d)^4\right]$

Joint accelerations $\ddot{\theta}(t) = \frac{k}{d^2}\left[60(t/d) - 180(t/d)^2 + 120(t/d)^3\right]$

$$0 \le t \le d$$

Results

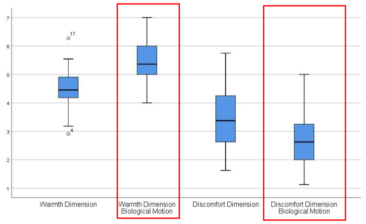
Impact Assessment

Non-biological (Control) gestures — Condition 1

Biological motion profile — Condition 2

Warmth	Discomfort
Organic	Awkward
Sociable	Scary
Emotional	Strange
Compassionate	Awful
Happy	Dangerous
Feeling	Aggressive

RoSAS Assessment Variables
Carpinella et al., 2017



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http://www.vernon.eu/downloads/CMU-Africa_Poster_Biological_Motion.pdf

Carnegie Mellon University Africa

Behavior Trees for Culturally Sensitive Social Robots: African Culture Case Study

Ibrahim Jimoh, Heran Equbay, Clifford Osano, Tsegazeab Tefferi, and David Vernon
Carnegie Mellon University Africa, Kigali, Rwanda

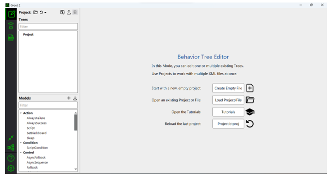
Overview

The goal of this project is to explore the use Behavior Trees to implement robot missions for a culturally sensitive social robot in Africa.

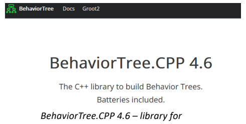
Cultural sensitivity in social robots' interaction is essential for fostering trust, ensuring respectful interactions, and enhancing user experiences. However, developing robots that can dynamically adapt to different cultural norms presents significant challenges.

Behavior Trees (BTs) were invented as a tool to enable modular AI in computer games but have received an increasing amount of attention in the robotics community in the last decade. Compared to other approaches, such as hierarchical finite state machines, they have clear advantages in terms of modularity, reusability or expandability. By developing a comprehensive and up-to-date cultural knowledge database and integrating these cultural norms into behavior trees and enabling dynamic adaptation, robots can achieve a higher level of cultural competence.

Frameworks and Tools

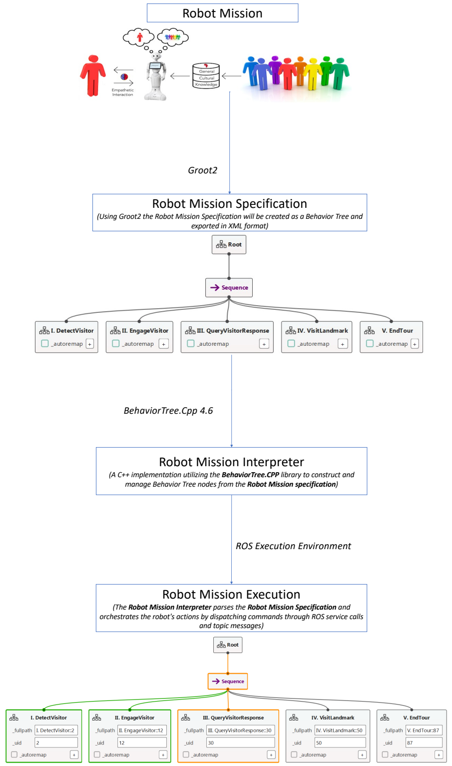


Groot2 – IDE for designing Behavior Trees

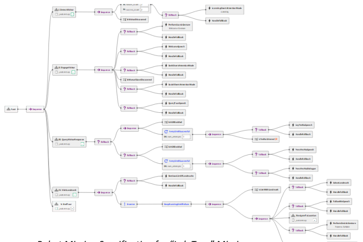


BehaviorTree.CPP 4.6 – library for implementing Robot Mission Interpreter

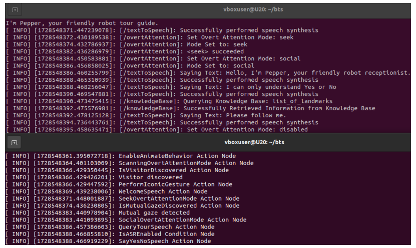
Methodology



Preliminary Results



Robot Mission Specification for "Lab Tour" Mission



Robot Mission Execution simulation, using stubs and drivers, and without including Cultural Knowledge

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http://www.vernon.eu/downloads/CMU-Africa_Poster_Behaviour_Trees.pdf

Carnegie Mellon University Africa

Semantically Modulated joint Episodic-Procedural Associative Memory

Muhammed Danso & David Vernon
Carnegie Mellon University Africa, Kigali, Rwanda

Overview

The goal of this research is to give the CRAM Robot Cognitive Architecture the ability to automatically perform new everyday pick-and-place tasks (Vernon et al., 2021). This is achieved by integrating three schools of thought in cognitive science.

1. The situation model framework: composable behavioural episodes, dual process theory (System 1 & 2), working memory, and cognitive maps (Schneider et al., 2020).
2. Ideo-motor theory: goal-directed, prospectively-guided action and joint episodic-procedural memory (Stock and Stock, 2004)
3. Semantically-primed episodic future thinking: episodic memory is used to imagine future states (Atance and O'Neill, 2001, Schacter et al. 2012)).

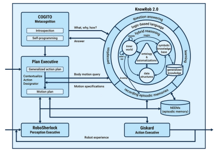
The is achieved using a deep multi-modal neural network. This memory produces composable behavioural episodes in the form of the parameters of a CRAM generalized action plan. This allows CRAM to automatically perform new pick-and-place tasks on the basis of an image of the current scene (as perceived by the robot) and a quasi-natural language action description.

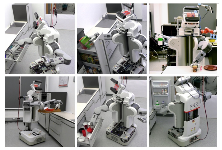
Methodology

Generalized Action Plan → Motion Plan

Design Pattern for Manipulation Actions

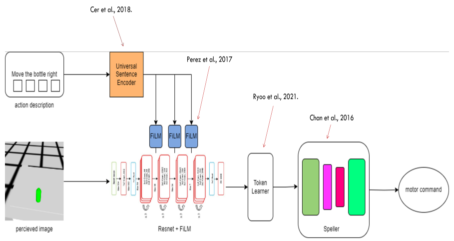
The motion parameter values are provided in CRAM by reasoning





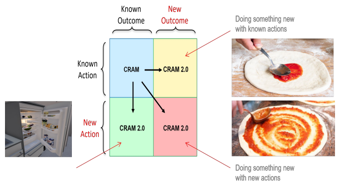
Method

Model

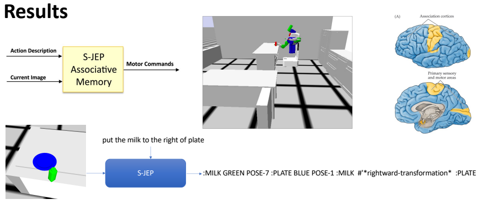


Technique

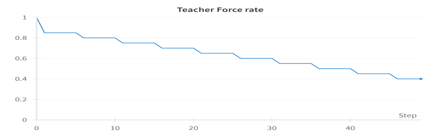
High-Level Action Description → Generalized Action Plan → Motion Plan



Results



Results



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Carnegie Mellon University Africa

Robotics in Africa at IROS 2024 Posters

http://www.vernon.eu/downloads/CMU-Africa_Poster_S-JEP.pdf

OPINION

An African Perspective on Culturally Competent Social Robotics

Why Diversity, Equity, and Inclusion Matters in Human-Robot Interaction

By David Vernon

Artificial intelligence (AI) and robotics are playing a central role in driving the Fourth Industrial Revolution in Africa, powering the digital transformation of African economies through technological innovation. However, successful innovation requires trust, acceptance, and widespread adoption. In turn, these depend on sociocultural factors. This is particularly true in the case of social robotics, where cultural competence is pivotal for adoption. We provide examples of culture-specific knowledge derived from diverse social and cultural norms in African countries and explain how this impacts social robots if their behavior is to be acceptable. We conclude by unwrapping the concepts of diversity, equity, and inclusion, and we explain how culturally competent social robotics can impact each of these three issues.

SOCIOCULTURAL FACTORS UNDERPIN THE FOURTH INDUSTRIAL REVOLUTION IN AFRICA

AI is having an increasingly positive impact in Africa in many sectors, such as energy, health care, agriculture, public services, and financial services. It has the potential to drive economic growth, development, and democratization, reducing poverty, improving education, supporting health-care delivery, increasing food production, improving the capacity of existing road infrastructure by increasing traffic flow, improving public services, and improving the quality of life of people with disabilities. AI can empower workers at all skill levels to make them more competitive.

AI forms the foundation of the Fourth Industrial Revolution, Industry 4.0. Countries around the world have prepared AI strategies to ensure they are in the vanguard, leading the revolution. The scope of these strategies is extensive, embracing the research and development necessary to advance AI science and engineering, the strategies for promoting innovation, and the standards required for the ethical use of AI. While most of the effort to develop and exploit AI happens in developed countries, there is increasing awareness of its relevance to developing countries, with some countries, such as Rwanda, creating national AI strategies and hosting a World Economic Forum Center for the Fourth Industrial Revolution (C4IR). (South Africa also hosts a World Economic Forum C4IR.) Africa, a continent comprising 54 countries, launched a 10-year plan in 2022 for the digital transformation of its economies (the Digital Transformation Strategy for Africa, 2020–2030; see [11]).

The Fourth Industrial Revolution and digital transformation require innovation, something that is not as straightforward as it might seem. Rose [1] distinguishes among creativity, invention, and innovation. Creativity can lead to the invention of a novel idea or artifact, but innovation carries the creativity and inventions into wider use: the diffusion of that invention and its widespread adoption, leading to substantial social change in the practices of a community of people. He captures this in an equation: "innovation = invention + exploitation + diffusion," where the invention is commercially developed; exploited; and, significantly, adopted in a wider community of users.

Successful innovation depends on infrastructure. Rose [1] notes that "infrastructure is the unnoticed precondition for technology innovation." There are two forms of infrastructure, the physical and the social. The physical infrastructure includes the availability of electrical power, communications networks, or Internet connectivity, something that is taken for granted in developed countries but that cannot always be assumed in developing countries. Of equal importance is social infrastructure, which includes the social conventions that govern people's behavior and the practices they find acceptable and unacceptable. Social infrastructure heavily impacts whether or not an invention is adopted and becomes an innovation that can yield benefits for the local community. Social infrastructure includes trust and people's sense of what is trustworthy.

Hoffman et al. [2] define trust as "the expectation that a service will be provided or a commitment will be fulfilled," emphasizing the importance of expectation in their definition. Expectations are grounded in the sociocultural experience of those whose trust is required. The importance of the cultural context in building trust is emphasized by Lee and See [3]. They define culture as "a set of social norms and expectations that

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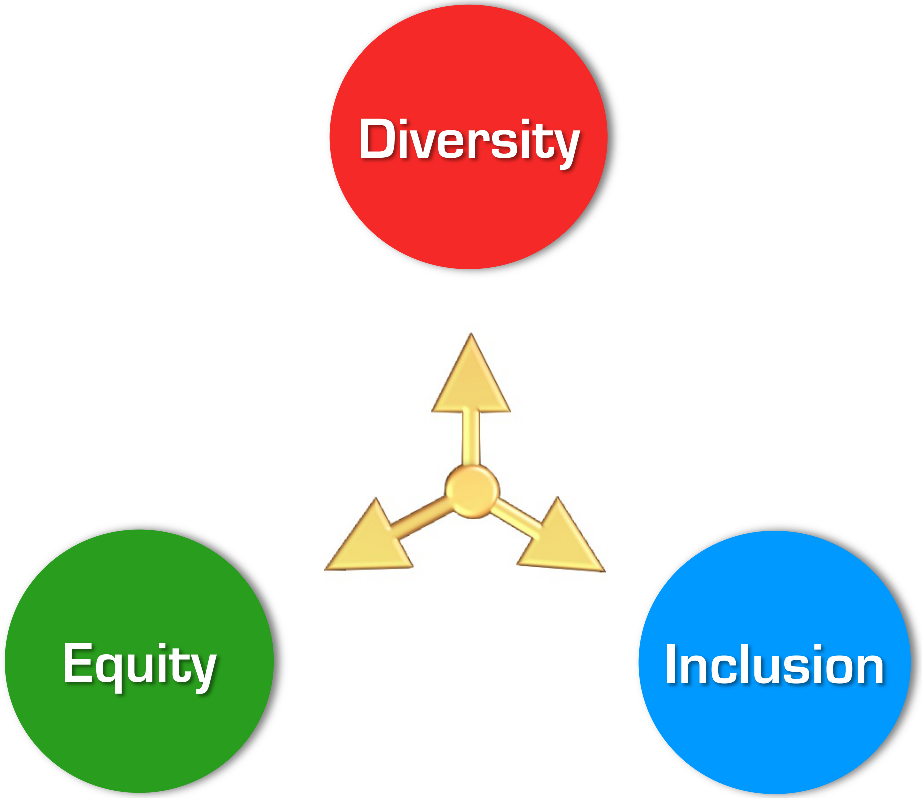
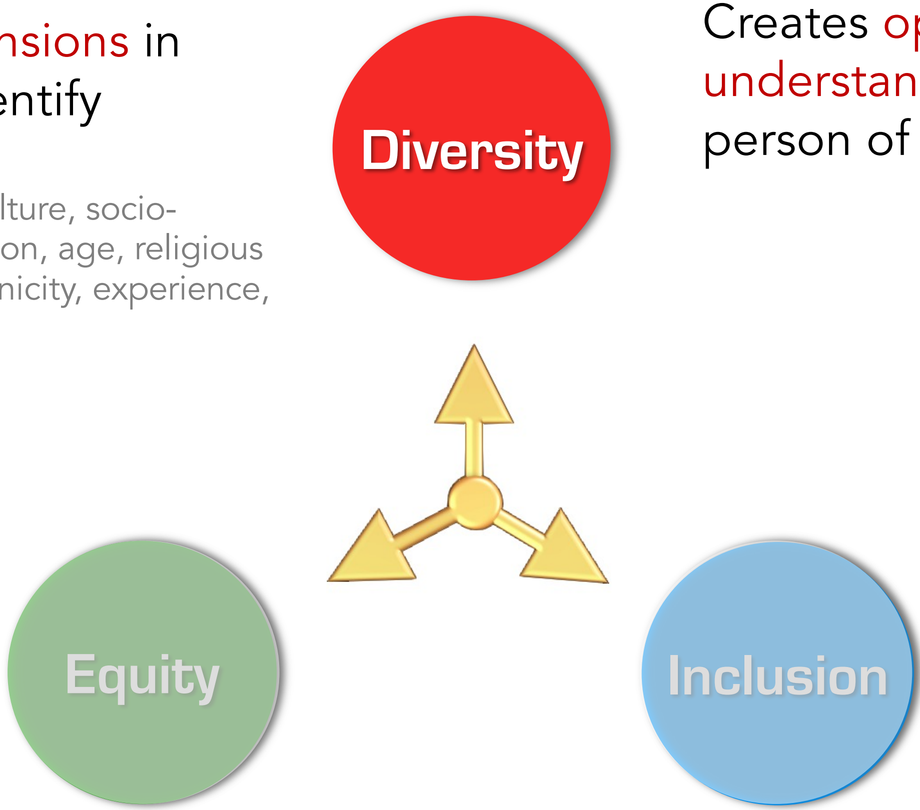
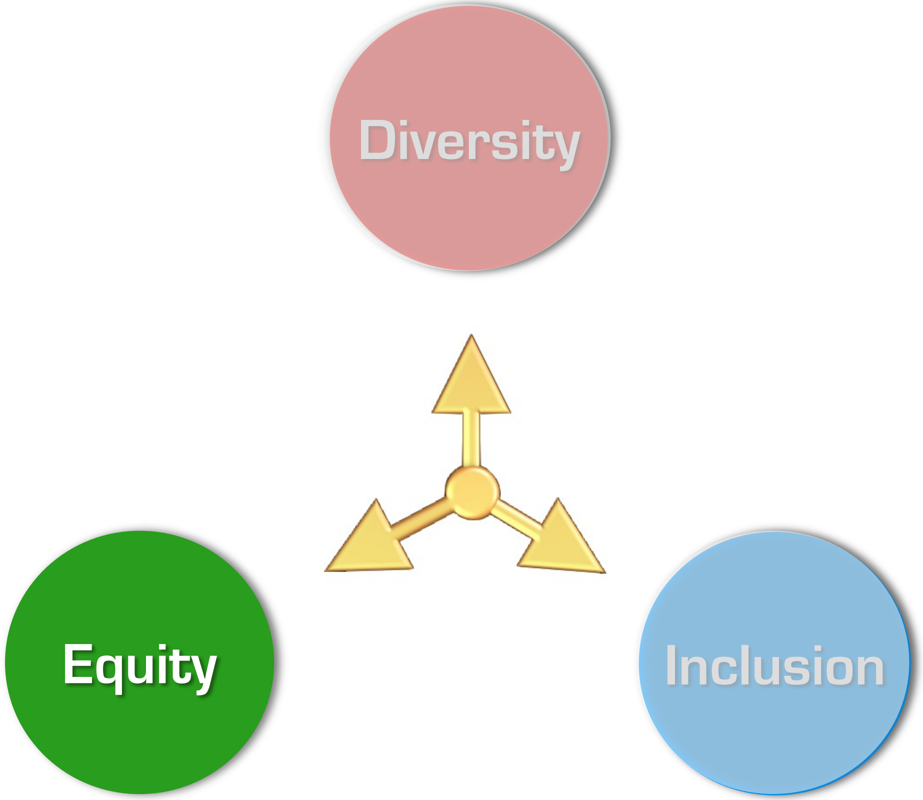

Diversity
Equity
Inclusion

The many different dimensions in which people differ & identify

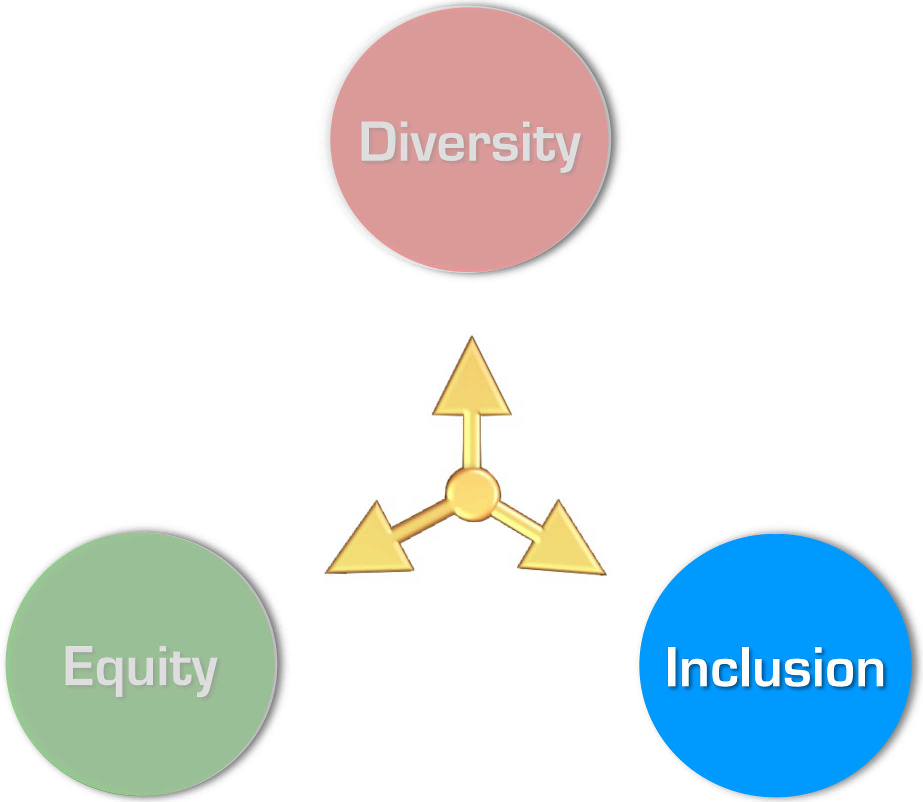
Gender, sexual orientation, race, culture, socio-economic status, traditions, education, age, religious and spiritual beliefs, nationality, ethnicity, experience, physical ability



Creates opportunities for greater mutual understanding of the contribution that a person of each background can make



It is the act of empowering, the process that leverages the potential latent in diversity



Means that each person feels they belong in that environment and that their place is valued

This is the achieved by empathy

"The highest form of knowledge is empathy,
for it requires us to suspend our ego and live in another's world"

George Eliot
Pen name of Mary Ann Evans

"The highest form of knowledge is empathy,
for it requires us to suspend our ego and live in another's world"

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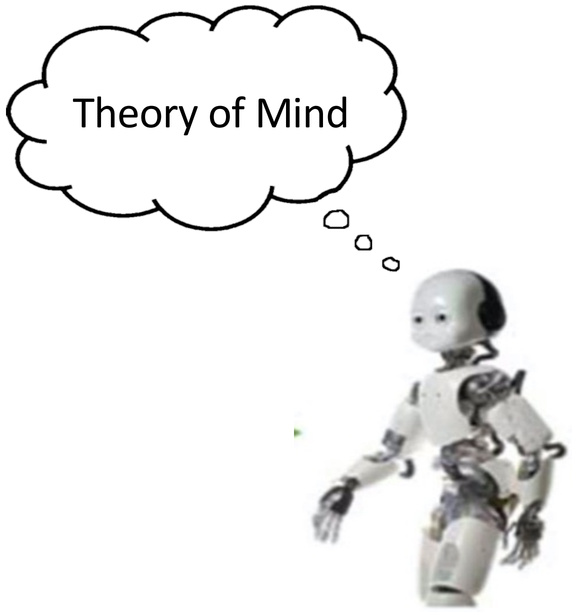
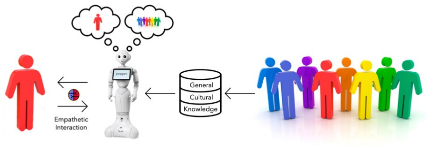
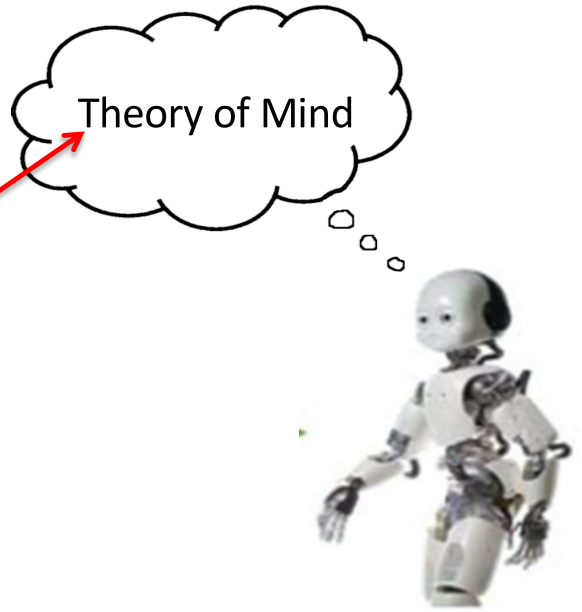


"The highest form of knowledge is empathy,
for it requires us to suspend our ego and live in another's world"

George Eliot
Pen name of Mary Ann Evans

Culturally Competent





Culturally Competent Social Robotics

Culturally Competent Social Robotics

Motivated by
Polite Interaction

Cultural Sensitivity

Culturally Competent
Social Robotics

Motivated by
Polite Interaction

Cultural Sensitivity

Diversity

Culturally Competent Social Robotics

Motivated by
Polite Interaction

Cultural Sensitivity

↓

Diversity

↓

Weak DEI in HRI

Culturally Competent Social Robotics

Motivated by
Polite Interaction

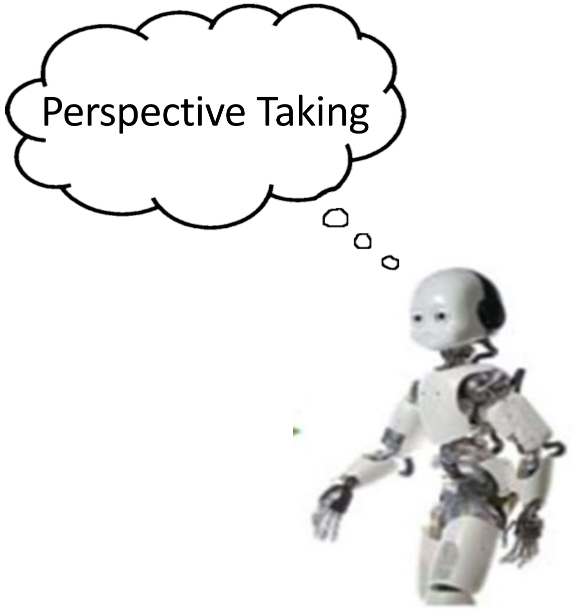
Cultural Sensitivity

Diversity

Weak DEI in HRI

Motivated by
Respectful Interaction

Empathy



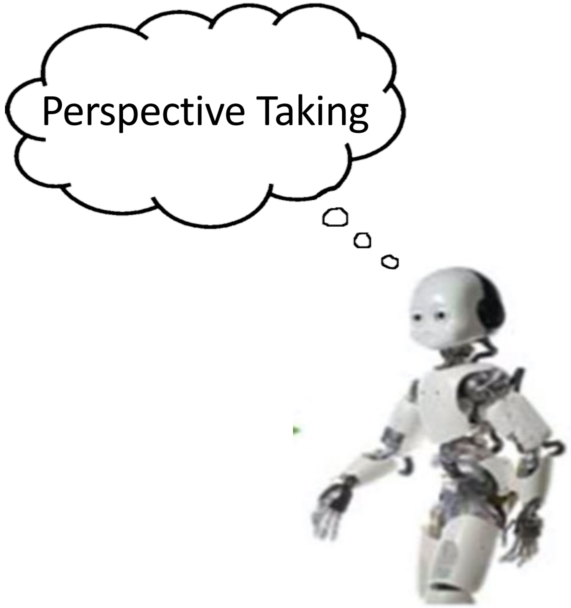
Culturally Competent Social Robotics

Motivated by
Polite Interaction

Motivated by
Respectful Interaction

Cultural Sensitivity → Diversity → Weak DEI in HRI

Empathy → Inclusion



Culturally Competent Social Robotics

Motivated by Polite Interaction

Cultural Sensitivity

Diversity

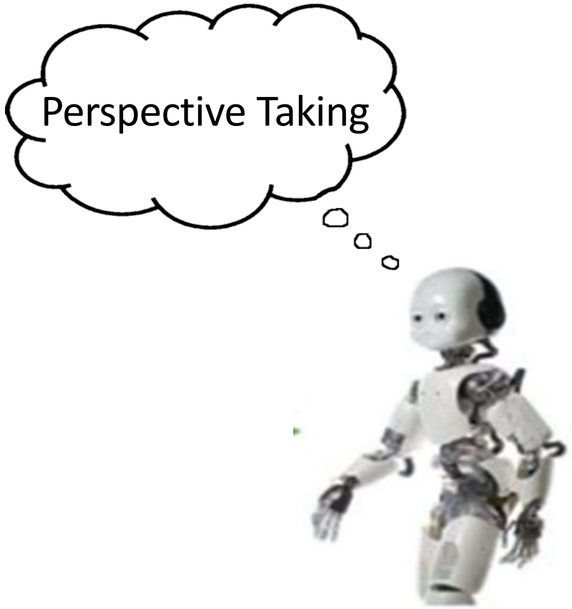
Weak DEI in HRI

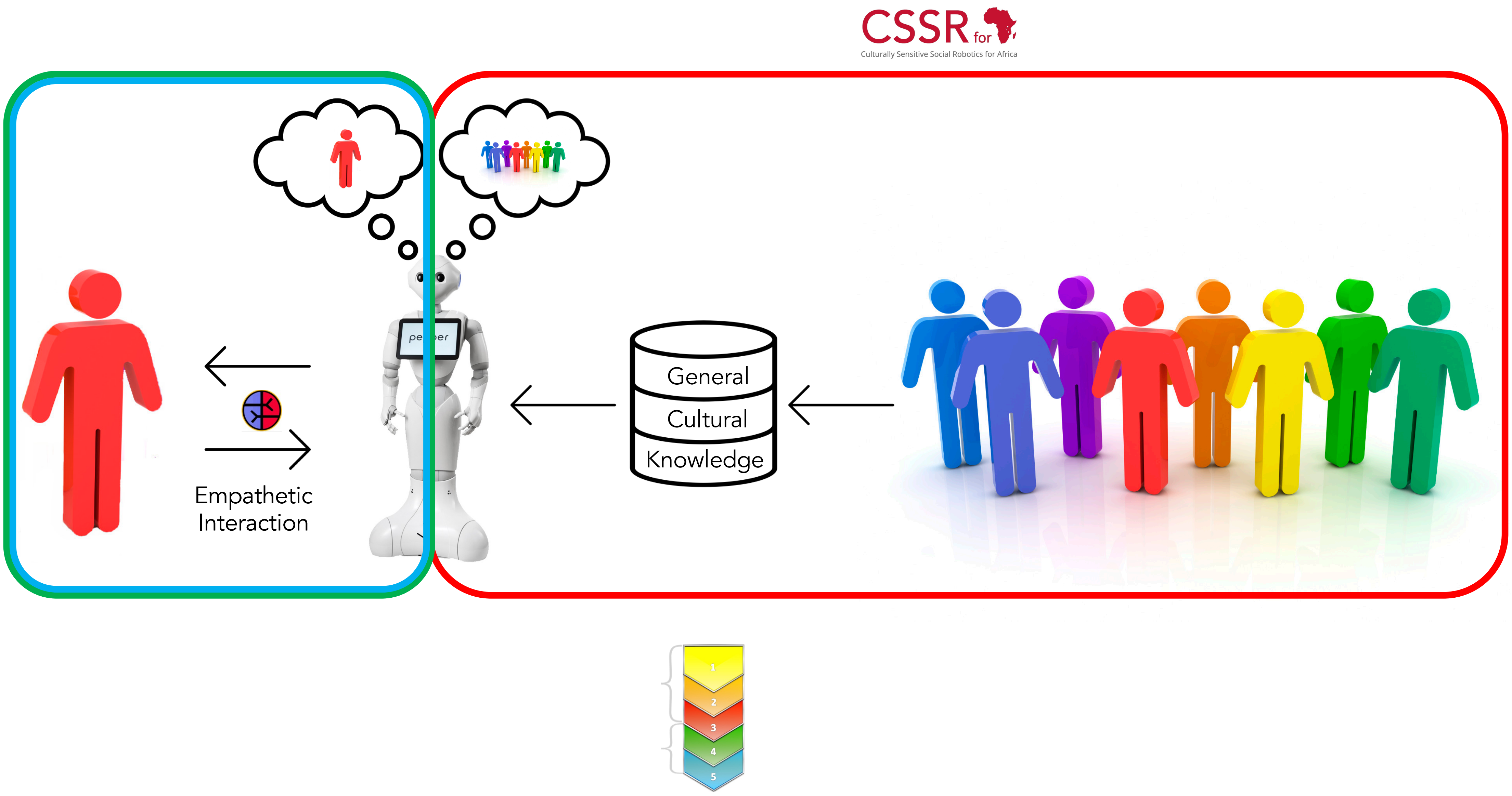
Motivated by Respectful Interaction

Empathy

Inclusion

Strong DEI in HRI




CSSR for
Culturally Sensitive Social Robotics for Africa
Empathetic
Interaction
General
Cultural
Knowledge
1
2
3
4
5

DEI is an ethical imperative

DEI in HRI empowers the individuals with whom the robots interact

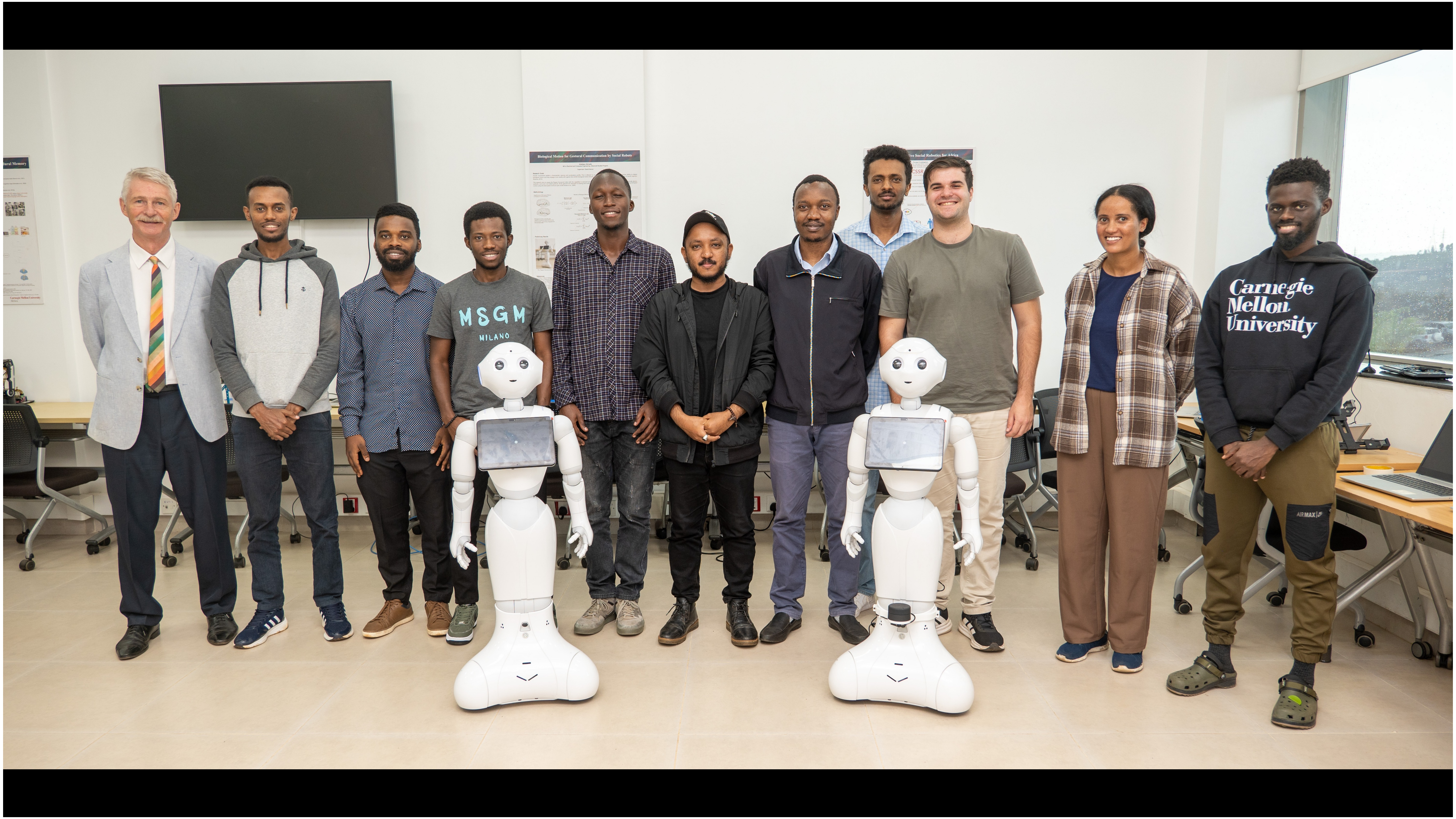
by actively valuing the cultural heritage of those individuals

cf. the message conveyed in the Opening Ceremony:
The importance of preserving cultural heritage while pursuing technological innovation

CSSR for

Culturally Sensitive Social Robotics for Africa

www.cssr4africa.org


Biological Motion for Gestural Communication by Social Robots
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AI & Robotic Lab
Interns, Research Assistants, and Research Associates
2020 - 2024

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Mihiretab Taye Hordofa
Muhammed Danso
Muhirwa Richard
Natasha Mutangana
Pamely Zantou
Timothy Odonga
Tsegazaeb Taye Tefferi
Yohannes HaileArisema

Selected Publications

D. Vernon, "An African Perspective on Culturally Competent Social Robotics: Why DEI Matters in HRI", IEEE Robotics and Automation Magazine, in press.

D. Vernon and G. Sandini, "The Importance of Being Humanoid", International Journal of Humanoid Robotics, 20th anniversary issue, February, Vol. 21, No. 1, 2024.

A. Akinade and D. Vernon, Biological Motion for Gestural Communication in Social Robots, accepted for presentation at Robotics in Africa Forum, IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Abu Dhabi, UAE, October 17th, 2024.

E. Birhan and D. Vernon, Surveying Rwandan Cultural Knowledge for Respectful Human-Robot Interaction in Africa, accepted for presentation at Robotics in Africa Forum, IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Abu Dhabi, UAE, October 17th, 2024.

I. O. Jimoh, H. S. Equbay, C. Onyonka, T. Tefferi, and D. Vernon, Behavior Trees for Culturally Sensitive Social Robots: African Culture Case Study, accepted for presentation at Robotics in Africa Forum, IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Abu Dhabi, UAE, October 17th, 2024.

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P. Zantou and D. Vernon, "Inclusion Drives Sustainable Development: The Case of Social Robotics for Africa", Poster Presentation, ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies - COMPASS, August 2023.

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AFRETEC NETWORK
BY CARNEGIE MELLON-AFRICA

This work was carried out as part of the
African Engineering and Technology Network (Afretec)

Afretec is managed by Carnegie Mellon University Africa
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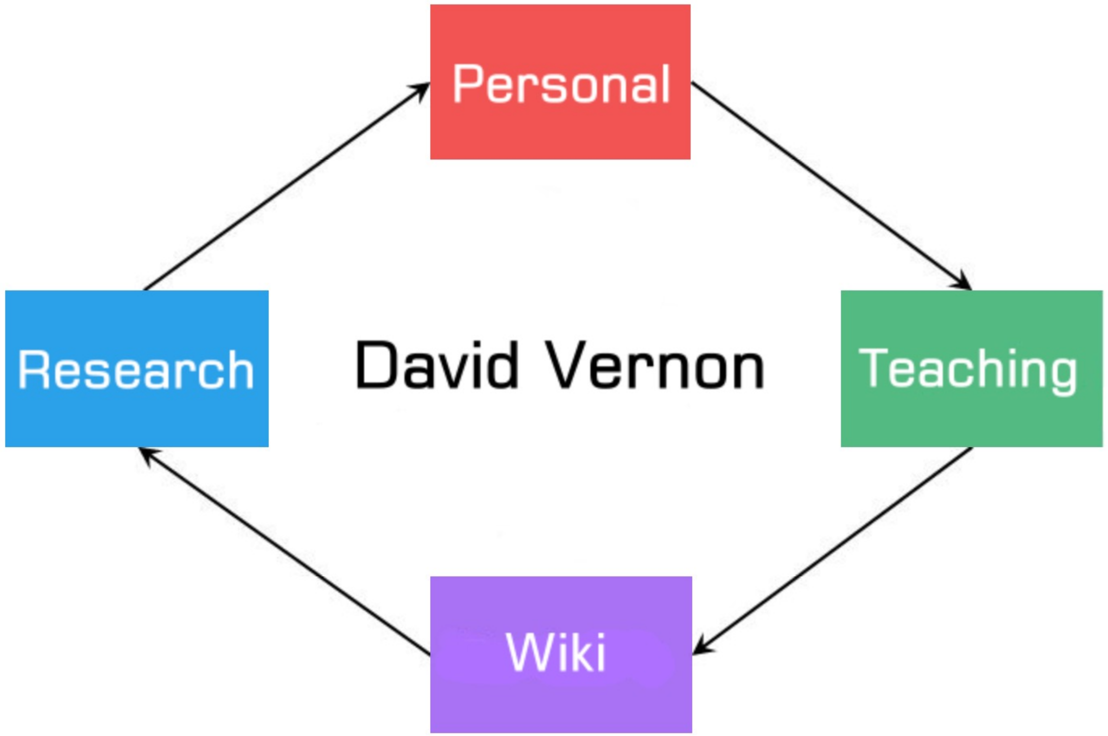

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Robotics in Africa Forum at IROS 2024

16th October 2024

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