# Towards Enactive Systems: Affective Cane

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**Abstract**

The TechnoScience territory for artistic experimentation at LART propitiates collaborative networked practices of Brazilian high-level researches in the context of New Leonardos collective intelligence and practices. The focus on radical digital domain applied towards enactive affective systems, related to human experience facing technologies, expand art manifestations to fields of embodied cognition and body apparatus living in. The sense of presence and actions in daily life for transformations allowed trough technologies are the main secret topics that must be analyzed when envisioning the creative technologies and innovation for the expanded sensorium and aesthetic responsive changes of the sensorial apparatus. Knowledge, methodologies and practices mixed to ethnographic issues and objectives look for the integration of body sensors, computer vision, GPS and networked connections, environmental laws, and mutual and reciprocal responses in data visualization. We developed an affective cane prototype, which has been designed to enable the active participation of people with disability or reduced mobility supporting their autonomy, independence, improved quality of life, and social integration, using the idea of affective enactive systems together with mobile technology. Enactive affective systems mapping affective narratives collaborate for the end of “nature itself” and the emergence of a “future healthier engineered reality".

## I. Introduction

Collaborative practices in Art and TechnoScience are problem-centered and strive to meet societal challenges with uncommon insights, diverse techniques and methods for innovation envisioning the planet life´s challenges: education, biodiversity and health. Researchers integrate labs and groups, creating a context where professors, technicians and students collaborate with the objective of trigger innovative solutions. Creative technologies deal with cross knowledge inside radical fields for covering disruptive innovation, beside the industries and market, for bringing solutions to the contemporary the ways of living. Our central focus are the health challenges: biological, environmental and social behaviors. The New Leonardos Program, term proposed by the Leonardo Organizations, International Society for Science, Art and Technology (ISAST) chaired by astro-physicist Roger Malina, cover our expectation in terms of methodologies and institutional structure for application within the culture. The transit of disciplines in trans or antidisciplinar methodologies brings together researchers with a diverse range of interests and expertise. Society’s scientific development with consequent anthropological issues and artistic and scientific discoveries require New Leonardos actions, and a team in collective intelligence. Trying to synthesize the genius, the Group acts in a bottom-up atmosphere, putting together people who cannot stand in rigid environments, and seeking the more challenging and fertile integration between areas. Among the variety of study objects, everyone produces knowledge, without hierarchical working relations. These collaborations also serve as an ongoing cross-education within the working group broadening the participating researchers experience while retaining full disciplinary depth and expertise.

The LART − the Laboratory of Art and TechnoScience, at the University of Brasilia at Gama (UnB/FGA) founded in 2010 by Dr. Domingues and implemented in the CNPq - National Research Board the respective Research Group composed by artists, engineers and scientists from several areas is one of the followers of the New Leonardos philosophy. LART's general proposal expands pioneer investigations in Brazil in Interactive Art [1], [2], [3], [4] toward the profound levels of Art and TechnoScience and disruptive innovations in bioart and mhealth [5], [6] e [7]. The condition for such research is to combine the repertory of scientific topics for shared plans with other Unb and Brazilian Labs. The rich curriculum of scientists and artists and their repertory with recognized background, in collaboration with Dr. Domingues, pioneer researcher in art, science and technology, allied to the state-of-the-art in scientific developments by Rocha [8], Miosso [9], Fleury [10, 11], and the energy of young academic graduate students are the main fertile seeds for the humanistic and social perspectives in creative skills for innovative medicine in biomedical engineering. Advanced levels of research establish intertwined collaboration between practices and theoretical approaches. In the Sensor Lab as well in the Science, Tecnology and Health Program, Ceilândia Campus, Prof. Silvana Funghetto at Physiological Lab at University of Brasilia (UNB) has collaboration with LART for discussing several issues involving m-health, physiological signals in daily life and mobility. Prof. Gilda Assis from University of Ouro Preto (UFOP) has started collaboration with LART researchers in augmented reality and computer graphics areas. In addition, LART have high level Brazilian collaborative researchers, such as Prof. Dr. Ricardo Torres from the RECOD Lab, founded at the Institute of Computing (IC), Unicamp, in 2009 and started to host and foster projects on complex data in straight. Computer Vision, Information Retrieval, Machine Learning and Digital Forensics. Other collaboration is with Dr. Cecila Baranauska, reference on Human-Computer Interface and Cordinator of the Project: Socio- Enactive Systems, Unicamp/Fapesp.

The transit of disciplines as software engineering, energy engineering, electronic engineering, automotive engineering and aerospace engineering, specially the advanced researches in biomedical engineering confirms the urgency for eliminating the barriers between types of knowledge and immediately integrate common issues of several areas. To respond the complex questions of life we must integrate our investigations in Bioart and M Health [12], [6], [13], [14], in the territory of freedom of experimental art which puts experts in an area of dissipation and create cognitive frameworks, working procedures, communities of interest and methods of dissemination by mixing rationality, intuition, and emotion.

In the border area of disciplines shared objects go for extremes, and the excess where art and science contaminate each other. Image science in data visualization of biological and cosmic life, besides, the humanities' ethnographic method is necessary to understand human acts by the effects of seamless, nomadic, mobile [15] and ubiquitous condition [16].

The design of enactive affective systems[1], from invisible computers, calm technologies, transparent interfaces {16} increasingly mixed to life thanks to mobile technologies and locative interface are topics to understand how life is and how calm and intuitive connections are mixed in daily life. Artistic intervention in scientific environment and scientific laws in art arouse another reality of problems and possibilities. Aesthetic theories of modernity become obsolete under the more complex factors of properties of the immaterial culture and art based on processes and scientific laws. Changes in the human scenario based on networks, mobile technologies, and pervasive-sentient interfaces require the forming of professionals for scientific and social interventions and collective contributions.

## The Reengineering of Life and innovative technologies: enactive affective systems

LART and the collaborative researches responsibility and urgent attention to life reengineered in ontological levels of creative technologies consider three axes: (i) sensorium and affective enactive systems reengineering by microsensors and physiological synaesthetic signals in daily life; (ii) nature and biodiversity challenges reengineering to face the infirmity of landscapes in the sense of affective geographies in Brazil's huge territory, facing dengue, and also the preservation of species in Amazon rainforest biomes; (iii) culture reengineering by envisioning the infirmity of landscapes, and the role of social platforms, associated to the ubiquitous condition provided by sentient technologies [18] and enhancing awareness of human presence amplified by mobile technologies, providing a socially and healthy reengineered nature in extreme, hostile environments.

In this proposal, we explore the axe 1, the condition of life enhanced by biofeedback devices and mobile technologies, which transform our notion of body. Wireless devices and the possibilities of affective mobile computing modify the traditional concept of ecosystem, by allowing informational flows, biofeedback and affectiveness in an ecolocated world[2].

The beginning of the project is based on the entitled 'Reengineering Life: Creative Technologies for the Expanded Sensorium', international collaboration between LART/FGA/CNPq and the Camera Culture Media Lab at the Massachusetts Institute of Technology (MIT). Through this project, members of the LART research group have the opportunity to work in the environment of Camera Culture Media Lab at MIT, an institution synonymous with transdisciplinary work, and where creativity and innovation

[1] We amplify the concept of enactive systems by Tikka [21], dedicated to the movies and images; this amplification leads to the affective enactive systems, dedicated to the daily life and sensorial data.

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are main premises for any starting idea. An important benefit of our enactive affective system is the fact that it integrates Bioart and Health and includes the study of Brazilian rituals in Arts, Humanities and Sciences. The prototype of an affective insole for diabetics was produced as an embedded system to analyze human actions and includes variables that allow us to infer not only movement, kinesiology (proprioception), but also physiology and synesthesia. In transphysiological dimension it is explored aspects of motion, electricity, graphic design~~,~~ in data visualization and data sonification. Body movements, gestures, postures, fragmentation, reinstatements, dynamics, internal-external connections and motor schemes, dealing with gestures, rhythms, not only at each stage of the movement, but also considering what affects you, the environment and the coupled interior and affection in the flows of life with affective enactive sensors. Biofeedback with outside environment in enactive affective conditions can help understanding the internal excitation of nerves or the immediate impression of the senses, or by a complicated chain of senses' impressions, previously experienced, stored in the memory of sensations, emotions and thoughts. Attempts are being made for the system to read the rhythmic patterns of movement. The daily life and affective narratives of diabetics are the contribution for mhealth.

In the main senses, anthropological issues of mobile condition amplify the phenomenology of "being here" [19], altered by the use of cell phone mob cameras [20], and locative and geographic interfaces enhanced by sensorial data and physiological enactions to the environment. The newest development of LART is an enhanced cane, called affective cane which use the principles of the theory showed above.

## The affective Cane: enactive system for cognition, mobility and freedom.

The purpose of this work is to collaborate in the field of cognitive computing, related to ethnographic methodologies and strategies for practices with the objective of promoting mhealth and well-being. The prototype to be commercialized will integrate the list of technologies of Internet of Things by representing an enactive affective system.

Such enactive affective system is an embedded system composed of a regular cane and sensors that supports the locomotion and aids to recover the possibility for helping people with mobility difficulties. It also allows mobile communication using technologies of location and ubiquity. One of the goals is to avoid unbalance in gait and falls, by monitoring walking and providing tactile or auditory feedback to alert the individual when there is a potential risk of falling. In this case, the cane would "talk" to the user, performing a check-up implemented through a protocol of questions, filming the face or eyes, measurement the temperature variation in the hand, measuring blood Oxygen Saturation levels - the heart and breathing rates or in the pattern of the patient's footprint, gait rates.

Furthermore, in the case of a fall, the cane is able to identify the event by the accelerometer and a gyroscope data. It initiates a check-up protocol concerning spatial orientation (angulation), velocity, with previously recorded information to determine if a serious injury occurred. Also, it notifies useful information if the person is potentially risk, for a stroke, heart attack or convulsion. The system as a mobile device is also able to inform the individual's location to the family or caregivers through GPS and to communicate the incident via portable devices.

The biggest qualities to frame the cane as an affective system are its capacities coming from the physiological sensors for capturing and reveal the body actions in its mutual and reciprocal effects to the environment. How the environment affects the body and how the body itself is affected by the environment? (Figure 1).

Figure 1: The Affective Cane enactions with the environnent . Photo of the Brasilia's Cathedral.

The physiological data and the environmental data in dialogue with signal processing generated during the living narratives, transmitted, become an affective system that records the exchanges or the enactions (body in action) with the environment and the results of the cane data visualization. The system registers the exchanges of body–environment narratives and creates living maps that can be 'returned'.

The prototype innovates as a prosthetic enactive affective system in the sense that Massumi takes the Spinoza's [22] affectus as an ability to affect and be affected when connected to the environment. It is not in an emotional way, but in a biological manner, having as a basis the sense of 'biograms' [23] as topological lived situation, where individuals are challenged by obstacles, situations, and episodes that trigger behaviors in a 'whole organic' way.

Our prototype of sensors expands the body locative interfaces with signal processing and decision-making, allowing methods to reveal synaesthetic maps in data visualization and spatial navigation of the walking intensity as variables of affective exchanges experienced in relation to the topologies. The "ecological perception" [24] combining different nature of sensors and the different displacements of organisms in this application is dedicated to mHealth and the stories of elder people embodied actions lived in constant negotiation between body and the environment. We record the responses of structural coupling between body–environment [25] and the body act on space in a synaesthetic way. We obtain living maps of the walking scenes and the variations of topologies that provoke several biograms recorded in a body's topographical memory [26]. That displacement within the space makes us remember that biograms are topological lived events [27].

The cane episodes measure the experience of aging and inform about the conditions to deal with biological transformations, and physiological changes regarding human organism in levels and in manners of evolutive needs, in the case of their displacements and the environmental conditions. We emphasize the physiological modifications in the corporeal composition from reduction of the muscles' strength, range of motion, velocity of contraction to postural alterations [28] [29]. In view of the aforementioned alterations, it is observed that there is a reduction in the ability of performing of daily activities and functional capacity often triggered by a decrease in muscle mass called sarcopenia [30], which can increase the susceptibility of falls and fractures.

These technically augmented devices have been developed with the help of potential users who have been contributing with valuable information about the product in order to highlight their needs and the needs of their caregivers.

In addition, the use of the device in its real context provides a richer source of data: to extract spatial and temporal patterns of use and behaviors associated physiological status, environmental conditions, to the interrelationships between them. At the same time, by increasing the use of augmented systems by elderly users, it will produce data streams specific to this demographic group, generating a great resource of information that can be used to better provide data for them.

## II. Development of the Affective Cane

From a perspective of design and creative technologies, it is important to contextualize the use of the walking cane in the health area. The cane is classified as a Locomotion Assistance Device or as an Auxiliary Walking Device (AWD). In clinical practice, the choice of the AWD model to be prescribed differs according to the need of each patient and their financial condition. All these devices can help solve problems of balance, pain, fatigue, weakness, joint instability, excessive skeletal load, and esthetics. Professionals experienced in clinical practice, among them, physical therapists, should be the ones to guide users in the use of each device for each specific user, for avoiding the risk of injury or falls, and worsening of their physical condition [37].

The participants themselves performed tests with force and motion detection and prepared mathematical and physical analyses, as well as visualization schemes [41], which facilitate data interpretation.

An integrated hardware and software solution incorporating multiple locational, physiological, environmental, and mobile communication sensors were embedded in the cane so that specific algorithms can be developed to capture signals that can assess the possible imminence of stroke, infarction, and seizure, issuing an automated alert to caregivers about possible falls [33] [39] (Figure 2).

This intelligent cane prototype CPU is an Arduino Uno, and all its peripherals were built in a single shield board, thus facilitating portability (Figure 3 and 4).

The current prototype (V4.0) have features distributed in three main blocks, regarding the main functions of a typical cane. Each one is described as follow:

- Module 1 (Environmental): This module is responsible for gathering the environmental context of the user. The system can gather basic information about weather and temperature and use this data to better recognize its surroundings. The features of this module are:

- Ambient Temperature (in Celsius) and Relative Humidity (in percentage). The responsible sensor is the DHT11 (AOSONG Electronics Co., Guangzhou, China). This is an integrated microcontrolled device capable of exporting temperature and humidity data through a serial connection at the sampling rate of 0.5 Hz. [34] [36].

- Ambient Light (in percentage). The responsible sensor is an LDR (Light Detecting Resistor). This sensor voltage is obtained by a simple voltage divider, and then compared to a bias. Low luminosity corresponds to a small sensor output, and vice versa. [36]

- Module 2 (Locativity): Aligned with Module 1, this second module completes the environmental data with spatial facts of the user and the cane itself. Data regarding the inclination and distance from the floor are constantly being sampled by the cane. The features of this module are:

- Angular rotation in three dimensions (also known as Yaw, Roll and Pitch) in Degrees. The responsible sensor is the MPU6050 Accelerometer and Gyroscope. (INVENSENSE, San Jose, USA). By using a complimentary filter implemented in software, both data given by the sensor are fused, resulting in the given angles. Data is then filtered to eliminate the associated noise [40].

- Distance from the floor in centimeters. The responsible sensor is an Ultrasonic Distance Sensor (HC-SR04). This device emits a sound and measures the delay of its echo, then calculating the distance from any object (in this case, the floor). [35].

- Cane ground touch sensor. The responsible sensor is a FSR (Force Sensing Resistor). From a simple voltage divider, we identify the resistance of the component, which varies according to the pressure exerted on it. A low resistance indicates a high pressure and vice versa. The pressure value is then compared to a threshold, and if this value is below, it is considered as non-pressed. And if it is above, it is considered as pressed.

- Global Positioning System (GPS). The responsible sensor is a NEO-6M module and a GPS Antenna.

• Module 3 (M-Health): This module interacts directly with the cane's holder by continuously monitoring its physiological signals in a non-invasive fashion. This way, the cane can be aware of its user, without disturbing its walk. This is the most challenging module to develop, due to the nature of the signals it deals with (small amplitude, and very susceptible to noise), and therefore is still a work in progress. The feature of this module in the current cane version is:

o User's hand temperature [38], in Celsius. The responsible sensor is a thermistor. The thermistor is a component whose resistance varies with temperature. A signal conditioning circuit generates an output voltage which is related to the measured temperature. This signal is useful as an indicator of many maladies, such as stress, anxiety, and as second effect of inflammations.

Besides the three modules, the developed prototype also has some user-oriented features. These facilitate the interaction between the user and the system. The features are the following:

- OLED Monitor for system viewing (Model: SSD1306). Functionality: Small 0.6 " flexible monitor for human-computer interface of the cane.

- Real Time Clock (Model: DS1307). Functionality: A real-time clock that allows the system to provide the user of the Affective Cane with a permanent sense of time.

Finally, the embedded software was developed with time accuracy and continuous operation in mind. That said, the system has low energy consumption (can survive days with only a E-type 9V battery), Bluetooth communication capabilities and fast responses to events. The next prototype (V5.0) (Figure 2) will focus on the M-Health modules, gathering more biomedical information from user, such as its galvanic skin resistance, Hearth rate, blood oxygen saturation rate (also known as SPO² rate)

Figure 2: Affective Device attached in a regular cane (SolidWorks).

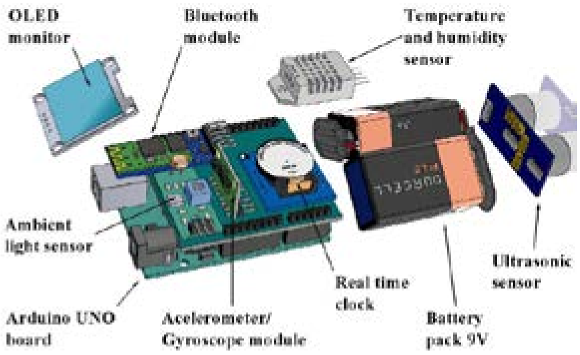


Figure 3: Hardware package embedded in the Affective Cane.

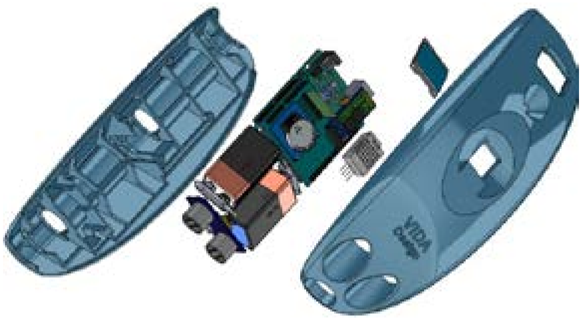

Figure 4: Assembly of the case of sensors for Affective Cane.

**Data Visualization**

The validation process was done in conjunction with the visualization of the data issued by the cane. The methodology used was a video analysis of common situations and potential hazards, such as: the person walking on a smooth floor with obstacles, a sloping ramp and a small ladder.

A data viewer was developed using Processing software. The programming of this viewer includes:

- Touch analysis on the floor when the color of the floor changes color by FSR sensor;
- Ambient temperature' evaluation, when the color of the screen changes according to the temperature gradient from hot (red) to cold (blue) by DHT11 sensor and
- Spatial position of the cane is also measured along the three axis of rotation (X, Y and Z) with data from the gyroscope/accelerometer, see Figure 5 to 7.

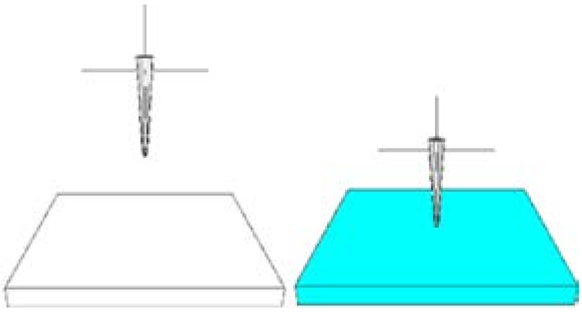


Figure 5: Data visualization of the Affective Cane – Touch analysis

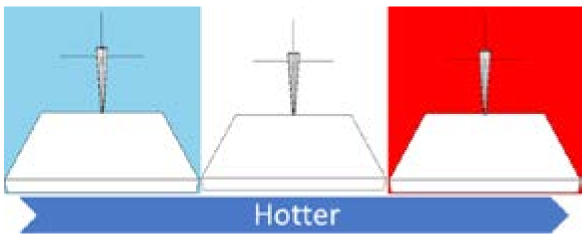


Figure 6: Data visualization of the Affective Cane – Temperature variation

Besides, another data visualization, based on proof of concept, was proposed in the software Blender.

A sensor: FSR (Force Sensing Resistor) generates continuously pressure values. Each pressure value is then compared to a threshold, and if this value is below, it is considered as non-pressed. And if it is above, it is considered as pressed.

Data classified as pressed were used as input for the animation to use as outreach material. The sensor data were used as a scale factor to determine the translation on the y axis (height) to be applied on some faces of the plane (ground), producing an effect of "stepped" in a deformable plane.

Solid Works 3D model of the affective cane was exported to STL format, then the STL file was converted to 3DS and finally imported into Blender.

When the cane collides with the plane (ground), a "deformation" occurs on the patch of collision cane-plane and on nearby patches within a radius of action, randomly selected at each step, see Figure 7.

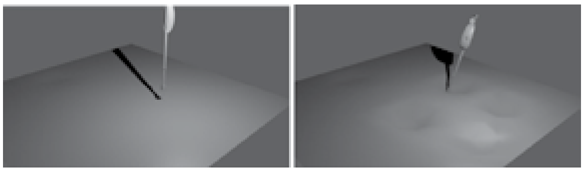

Figure 7 – Frames extracted from Blender animation showing the "morphing of the ground.

A more technical version of this work was presented in the conference VSMM 2017 - International Society of Virtual Systems and MultiMedia, however with a focus on the area of Computer Science. In the article for the VSMM was presented the prototype of 2017 of the affective cane and its previous results for its development.

The next step in test target users such as seniors and people with locomotion difficulties to adjust the system to have a greater precision and to amplify the application for smartphone integrated to the affective cane.

## III. Conclusion: Relevance and Impact Claims

### *A. Social Impact: Empowering Impaired People*

According to the World Health Organization, in 2011, over 1 billion people globally experienced disability. Furthermore, 1 of 2 of impaired people cannot afford health care. In this scenario, the development of cognitive computing systems that can be used to construct assistive devices and technologies that can enable people with disabilities to be independent is of paramount importance.

The investigation proposed in the context of this project addresses these issues, by allowing the identification of novel cross-modal-sensor-based enabling technologies that can be made commercially available in the future. The foreseen technologies are expected to take advantage of cutting-edge solutions and approaches available in the area of machine learning, computer vision, and information visualization. We will develop cognitive computing system prototypes, ethnographic methodologies, and strategies for practices in the domain of technologies for health and wellbeing. These prototypes support the active participation of people with temporary or permanent reduced mobility or disability, promoting autonomy, independence, improved quality of life, and social integration.

In order to be successful in this endeavor, we need to re-imagine life within this hybrid condition, or better, biocybrid condition, (bio +ciber data) and hybrid - the word qualities) to invent the ways in which it can support an individual's life history/life narratives, increasing the quality of life, prolonging independence, promoting dignity, social contact and integration within communities. Affective exchanges [42] configure biological components to “ecological perception” [24], says Diana Domingues, or the reciprocal influence body/environment and the feedback flux that are shaped by the vital signals and the dialogues with the locations. In terms of the seminal urban life, E-topia and mobile connectedness confirm William J. Mitchell’s premise: wear/where and aware [43].

But normal canes are only helping devices: although they have can prevent some events, they cannot do much more. In this sense, the developed cane is an improvement over a normal cane in the sense that it cannot only foresee many other health problems related to their physiological sensors, but also sense the environmental context in which someone using the cane is inserted.

The results obtained this far in the ongoing research project were the development of a walking Stick and differs of the other single embedded electronic system. It provides a complex embedded sensorial perceptive expansion and supplementation, aiming to increase the quality of life, functionality and independence of people in their daily activities. Fortunately, we have many new tools available to collect, manage, analyze, and disseminate data. The development of low-cost low-power sensors increasingly deployed objects of common use and linked to mobile processing and communications, an ‘internet of things’, enables the monitoring of environments and interactions at unprecedented levels. These sensors allow the collection of physiological data in real-time from active human and non-human agents while simultaneously monitoring environmental conditions. These can be concatenated into databases and merged with others that can give new understandings, histories, and epidemiology. Thus, new questions can be posed and new understandings developed.

### *B. Social Impact: Trans-disciplinary Research*

There are challenges in understanding the complexity of the problems we face and in formulating approaches that lie beyond traditional disciplinary bounds. There is the task of developing methods to correlate incompatible data sets, process large and complex databases, and to extract and communicate comprehensible regularities from them. To do so the capacities of any single discipline are insufficient, instead a new approach is required, combining researchers from many fields of knowledge.

While research at the intersection of technoscience, the arts, health, and environment, has been of the essence researchers and groups in this proposal, the network must be strengthened, broadened, and deepened if it is to have a greater impact. A new generation of researchers must be trained capable of understanding socio-environmental problems in depth, not limited by disciplinary perspectives, and capable of dialogue across a wide range of stakeholders. There are two scientific hubs in this proposal: Computer Science, whose research activities will be led by the RECOD Lab, Institute of Computing, University of Campinas; and Health, Arts, Humanities, and Sciences, led by the LART Lab, University of Brasília.

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