Ecosystem Based on Extended and Responsible Ethics for Mobile Robots and Artificial Intelligence in Cuba

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ABSTRACT

Our main hypothesis is that an extended moral agent cannot fulfill their expectation of "extendedness" without a dynamic and evolutionary ecosystem where the agent develops and behave properly. It is important to establish a bridge between extended moral agents and ecosystems for two reasons: first, there is not enough direct theoretical reflection about this link. The scholar's focus has been independently on improving the "extended agent theory", the concepts of "ecosystem" or "ecosystem of innovation". Second, if we want to understand the wide scope of the decentered ethics in the design of mobile robots and AI these two theoretical frames cannot be seen separately but in joined interdependency. As a survey case, we will argue how a form of responsibility as a "swarm" operate and ensembles the ecosystem and the extended agency of Cuban mobile robot called Palmiche. The conception and application of this project have shown that public policy is in need to design instruments to ride the new wave of innovation, adapt the workforce to the challenges imposed by technological change to improve the possibilities of technological adoption, minimize the costs of this transition and ensure that society benefits from this change.

1. Introduction

The presence in our daily lives of technological artifacts brings about some challenges to our contemporary societies. The huge impacts in economics, politics, entertainment, communication, education, and health, just to mention some, implies that human beings have changed drastically their relations with technology in a few decades.

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International organizations and governments have seriously taken the priority to regulate the production and design of technological artifacts. Ethics in the design of mobile robots and Artificial Intelligence (AI) and how to achieve its best possible implementation and results for humankind have been the center of discussions in the academic area.

However, do classical ethics have the tools to improve the design of these new technologies? We think they do not for two main reasons: first, mobile robots and AI are settled over the presupposition that the best model for their implementation is interwoven between the agent and the environment, where their components are dynamically connected with the "outside world". On the other hand, classical ethics (influenced by the metaphysics and ontology from Modernity) claims a limited centered-subject basis where there is a cognitive division between subject and object.

Secondly, the ethics we are looking for design mobile robots and AI is extended and ecosystemic where the ethical decisions, responsibility, and actions are not centered in a subject´s point of view (subjectless) but mediated by the environment, technological artifacts, and active participation of society as a whole.

Our main hypothesis is that an extended moral agent cannot fulfill their expectation of "extendedness" without a dynamic and evolutionary ecosystem where the agent develops and behave properly. It is important to establish a bridge between extended moral agents and ecosystems for two reasons: first, there is not a direct theoretical connection between these two subjects. Scholars have focused on improving the "extended agent theory" and the concepts of "ecosystem" or "ecosystem of innovation" independently. Second, if we want to understand the wide scope of the decentered ethics in the design of mobile robots and AI these two theoretical frames cannot be seen separately but in coupled interdependency.

This hypothesis will have a theoretical and empirical impact on the design of a Cuban mobile robot: Palmiche UGV. A Cuban engineer created this technology taking into consideration the control environment with an ethical and responsible performance. However, due to the deep problems of the Cuban ecosystem of innovation in refining several complex processes such as finance resources, openness and interdependence of the components, and mutual learning between subsystems, the "extendedness" of Palmiche as a moral agent has been affected dramatically in technological and development scenarios.

These negative results in the Palmiche "extendedness" and ecosystem environment have convinced us that these theoretical approaches must be ensemble if we want positive scenarios of research and development, and the implementation of a non-classic ethics in mobile robots and AI in Cuba.

Accordingly, this article will present the limits of the application of classical ethics in technological artifacts. Besides, we will discuss and establish an extended moral agent vision that includes the technological artifacts and environments in moral decisions. We will also engage in an argumentation in favor of an ecosystem of innovation coupled with an ethical vision. Moreover, we will present the Cuban mobile robot Palmiche UGV and its problematic current ecosystem of innovation. Finally, we will propose an ecosystem based on extended and responsible ethics for mobile robots and AI in Cuba.

2. Is classical ethics good enough for the design of mobile robots and AI?

When the engineer Rodney Brooks (1997) is questioning why we should build a mobile robot over a centered-subject basis, he was criticizing a well-established position in ontology and philosophy: the anthropocentric point of view.

According to Latour (1993), Heidegger (1977) and Verbeek (2005) (2011), anthropocentrism traced back to Modernity and supports a moral modern subject. For example, the well-known Cartesianism point of view claimed by a *res cogitans* versus *res extensa,* namely humans, as the subject of knowledge, have a content of the experience of themselves separated from an outside and objective world.

From the anthropocentric point of view, this moral modern subject is preoccupied with the right action to do in the outside world and he can manipulate the object to achieve his goals. Of course, this position, on one hand, embodies values such as self-determination, autonomy, dignity, and responsibility, and on the other hand; human beings develop a capacity for scientific rationalism to discover the process of Nature.

However, Heidegger (1977) appoints that this separation between subject and object implies a new reality. When a human being represents the reality and the objects outside of him, he cannot realize the relation between how the environment has active participation in the configuration of the knowledge of himself and the world. As Verbeek (2009, p. 246) claims:

> To understand oneself as a subject facing objects, an explicit act of separation is

> needed. Humans are not self-evidently "in" their world anymore here, but have a relation to it while being also distanced from it.

Likewise, Latour (1993) emphasizes that also the metaphysics and ontology of Modernity established this division of subject-object as two different domains: the social sciences and the natural sciences. These two domains implied that non-human objects (also artifacts) should be separated from concepts such as responsibility, freedom, and democracy. The centered subject of knowledge has a strong influence on centered-subject ethics. The question in this line of thought is "how do we act in this situation?" and the moral values we choose reflect a kind of intervention in the outside world. The core point is the moral value that we select has nothing to do with the participation of the outside world in our moral decision. As a matter of fact, we can judge and calculate rationally our actions in the real world without considering the consequence for the environment.

Following Valdés Menocal y Fernández Valdés (2011) and López Bombino (2002), Modern ethics has two principal approaches: deontological and consequentialist. Here, we do not discuss deeply the complex of their argumentations or a historical view but we can emphasize that the two approaches defend one of the poles of the subject-object dichotomy.

Immanuel Kant is the well-known champion of deontological ethics and the moral modern subject. His main preoccupation is how the human will can be subordinated to universal mechanical law. For Kant, contingent circumstances cannot pervade the *a priori* in reason, so any intervention in the real world will interfere with moral decisions. That is why the subject must make his judgment in a *pure* form of the thought where the real world cannot affect him:

> Pure general logic stands to it in the same relation as pure ethics, which contains only the necessary moral laws of a free will in general, stands to the doctrine of the virtues strictly so called –doctrine which considers these laws under the limitations of the feelings, inclinations, and passions to which men are more or less subject. (Kant, 1933, pp. 83-84)

Despite the rule guiding (proscribing, recommending, limiting) human action, that action is based on an inner process of thought isolated from the real world. In AI this is problematic because if in Kantian prescription the rule-maker is similar to the action-agent -the human subject-, the designer of AI is not who is acting in the real word under certain humanity statement as "the categorical imperative".

In the case of Consequentialist ethics, as Verbeek notes (2009, p. 249): *on the other hand, does not seek to find grip in the pure will of the subject but in determining and assessing as objectively as possible the consequences of human actions.* The maximization of utility (utilitarianism) or pleasure (hedonism) is adjusted to the right actions. S*everal variants of consequentialist ethics have developed which all attempt to assess the value of consequences of actions in specific ways (...) All these variants share the ambition to determine which acts in the world 'out there' has the most desirable consequences for the people 'out there'. They put effort into determining and assessing these consequences, in order to make a substantiated decision.*

In sum, deontological ethics and consequentialist ethics are working along with subjective judgments or with objective consequences of the actions. They are focused on a centered-subject basis where the "objective world" is outside of them. This anthropocentric point of view (the modern subject of knowledge plus modern moral subject) limits the scope of the impact of the technology and environment over the beliefs, behavior, and actions of the human beings.

It is clear that Rodney Brooks is not the only one who reacts against the Modernity subject, but he definitely broke how the robot mobiles were built based on the centered-subject model. As a consequence, this new perspective needs a new ethics adjusted to the new technological requirement. Brooks (1997) realized that the building of robots under the so-called *good old-fashioned artificial intelligence* (Fodor, 1987) characteristics failed when the environment dramatically changes. We will not go further in this discussion here. We want to highlight that this new perspective opens wide possibilities to analyze the implementation and performance of non-human artifacts inside the human cognition, ethics, and society.

3. A decentered point of view about ethics

Brooks' (1997) critics of the centered-subject model have a core assumption. If in the construction of a "creature" the best model is the real world; if the creature should be morphologically dynamically adjusted to the changes of the environment; if the creature should not collapse with the changes of the environment but *can adapt to surroundings and capitalize on fortuitous circumstances* (1997, p.402); then the moral considerability should be decided to take into account others variables as sensorimotor capabilities, the real world and not just the capability of the creature to judge semantically an action.

The assumption is directed against the privilege of the modern moral subject and considers strongly a decentered and distributed conception of moral subjectivity. There is no more moral subject but a moral agent who acts in correlation with other external factors that undermine the behavior and performance of the agent. There are some fair objections (Clark, 1997) (Clark, 2008) (Clark & Toribio, 2001) (Kirchhoff, 2015) (Fernández Valdés, 2018) to Brooks' proposal which we do not consider here. For us, the argument about the emergence of a decentered point of view of the agent and the necessity of a new moral considerability is good enough.

We will see another sophisticated alternative in Hanson (2008), (2009) and Verbeek (2009), (2014). Hanson's "extended agency theory" begins with a radical question: *Where does the moral responsibility for the priorities generated by the computerized system lie: with the human programmers and users alone, or also with the databases and computer hardware and software?* (2009, p. 91).

Hanson assumes the Extended Mind Hypothesis by Clark and Chalmers (1998) that all kinds of technology as lap-tops, phones; tools such as hammer, and pencils; and animals and non-human entities are not distant objects that people manipulate in pursuit of their goals. If they constitute and substitute biological cognitive process as if they take place in the brain, then they are part of the cognitive process (Clark, 1997), (Clark, 2008), (Wilson, 2004). For example, if instead of recording the number address of your colleague in your brain you store it in the database of your Android phone, Hanson, Clark, and Chalmers say to you that the Android has substituted your biological cognitive process (your memory) and it has constituted together with the environment, sensorimotor and brain factors the cognitive process of the remember a number address.

This perspective has a profound impact on the significance of the technological factors in the life of human beings. It becomes impossible not to consider the active mediation of technology in a moral human world. Verbeek (2009), for instance, argues the importance of ultrasound and amniocentesis to determine if the unborn *suffers from* spina bifida *or Down´s syndrome* (2009 p. 250). The results of the technology are decisive for a moral abortion decision in an early option in pregnancy. If ultrasound was not there, there was no moral issue at this point of the pregnancy, the technology constitutes and mediates actively an ethical point of view of the phenomenon.

Hanson claims that thinking about an extended agency theory is to consider that computers should be considered as moral agents too. This could be problematic because pencils, hammers, and ultrasounds cannot take moral autonomous decisions, neither the mobile robots nor AI… at least not yet. Hanson resolves this apparent contradiction with the term "joint responsibility" where the *moral agency is distributed over both human and technological artifacts* (2009. p. 94)

The main point is the presentation of the network of relations beyond the human individuality and takes other parts of the system such as AI and cultural factors inside any ethical valuation:

> When human individuals realize that they do not act alone but together with other people and things in extended agencies, they are more likely to appreciate the mutual dependency of all the participants for their common well-being. The notion of joint responsibility associated with this frame of mind is more conducive than moral individualism to constructive engagement with other people, with technology, and with the environment in general (Hanson 2009, p. 98).

Verbeek (2009) goes beyond Handson about the characteristics of the designers as materializer of morality: *It becomes impossible not to consider a responsible design of the material environment a central task of ethics* (p. 254). In the vein of the extended agency theory, the designers can not be human individuals, the ethics must consider the *material infrastructure for morality* (Verbeer, 2009, p. 252). That is why Verbeek proposes two lines of thought that he defines as posthumanist ethics:

- *Designing mediating technology (designing the human into the non-human)*
- *Reflecting on the moral role of things (making visible the human in the non-human* (p. 253)

Verbeek argues that it is not possible to continue the separation between three kinds of agents: the designers, the user of the technology, and the artifact. There is much emergent mediation that cannot be reduced to the decision of one pole of this triad. However, Verbeek and Hanson say little about these "emergent mediations". The main reason is that these two principles above are too narrow. We propose the addition of two lines of thought:

- Responsibility for the Nature (the human design cannot be possible without the resources and characteristics of our Earth Planet)
- Creation of a dynamic Ecosystem of Innovation (the human design is developed in a variety of ecosystems as economic, political, and technological factors)

In sum, we have established the necessity to rethink the classical ethics point of view and redirected until a decentered vision of it. The extended agency theory is a good point to start. However, in this line of the argument, we precise another wide vision where this new ethics takes place: the ecosystem.

4. Ecosystem of Innovation

There are well-known traditional research in Biology about the interactions between the organisms and the environment (Baedke, Fábregas Tejeda, & Prieto, 2021), (Laland K, 2018), (Uller & Laland, 2019) (Laland & Brown, 2002). Richard Lewontin´s seminal essay (1983) and his book with Levins (Levins & Lewontin, 1985) argued a strong criticism about considering individual organism (the part) and ecosystem (the whole) as two different things: *What constitutes the parts is defined by the whole that is being considered. Moreover, parts acquire properties by virtue of being parts of a particular whole, properties they do not have in isolation or as parts of another whole* (1985, p.18).

Within the ecosystem ecology (Jones & Lawton, 1995), arouse the idea to treat it as a web of food *dominated by trophic and competitive interactions* (Laland, 2019, p.128). Furthermore, this web is the understanding of the structures of that ecosystem. However, Nancy Grimm (in Jones & Lawton 1995) is thinking of wide considerations and applications of the ecosystem notion: what the ecosystem does *in a landscape or biosphere context* (1995, p.6) This last notion is coupled with the extended agency theory because the ecosystem cannot be localized in a single spot, but the interdependence and coevolution of components conform to what the ecosystem *does.* In this sense, Stahl (2021) embraces the idea that an ecosystem can be applied to define the dynamical environment of innovation for robot mobile and IA. Actually, it is a term recognized by international organizations. The White Paper of the Europe Commission (Commission, 2015) highlights AI as an *ecosystem of excel-*

lence and the European Committee (Europea, 2020) as an *ecosystem of trust.* Likewise, OECD (OECD, 2019) ensures to policymakers develop an ecosystem for IA and Arteaga y Ortega (2019) proposes a specific AI ecosystem for Spain.

Stahl (2020) identifies some characteristics of the ecosystems of innovation to AI: openness, co-evolution, and mutual learning of their members, *and the interdependence and complex relationship between those members.* (p. 81). It is not too difficult to realize how these characteristics work. The system has to be open to dynamic change, and every component has to be attuned to this change, evolve and cooperate at the same time. The innovation ecosystem is not a closed system and every actor who emerges in the process is dynamically inserted and has to act accordingly.

The co-evolution of the actors implies the mutual learning of each other inside the ecosystem. Notice that Nylund et al. (2019), Gobble (2014), Gomez et al. (2018) and Pombo-Juárez et al. (2017) ensure that this learning is produced inside of a network with a central node: a general organization or a platform of technology:

> that innovation ecosystems are generally recognized to be subject to intervention and change. These interventions can be catalyzed by members of the ecosystem, normally organizations, but also individual or non-organizational collective actors. They can also be triggered by actors who are involved in, support, or contribute to the innovation ecosystem, but do not necessarily play a part as members of the ecosystem. For instance, a regional ecosystem may be influenced by a national actor, or an ecosystem of AI may be influenced by non-AI technical developments in, say, quantum computing. Innovation ecosystems are notably different from natural ecosystems in that they have the ability to reflect on their status and think about the future with a view to changing and improving the situation (Stahl, 2021, p. 84).

Diagram 1 (Stahl, 2021) shows how these characteristics have interdependence and influence each other:

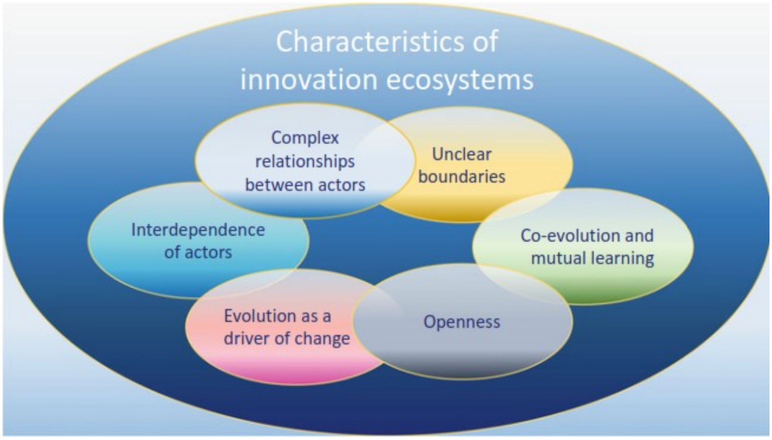

Figure 1

5. The limited Cuban Ecosystem and Palmiche mobile robot case

The Cuban government has changed its science, technology, and innovation policy (STIP) in the last 10 years. The Constitution of the Republic (Cuba C. d., 2021), the Economic and Social Guidelines (Cuba P. C., 2011), some decrees No. 363/2019 (2019), No. 2/2020 (2020), and decree-law No. 7 (2020) reflect how this STIP has improved the restricted and old model of innovations system to Research and Development (R&D) before 2011.
In the writing of Guidelines and decrees, the government gathered with prestigious Cuban scientists and the positive results were a wider STIP and flexibility in the making-decision tasks.

The UNESCO science report (2021) recognizes *Cuba's efforts to reform its model of governance have reconfigured the country´s main economic and political actors, opening spaces for private sector participation* (p. 221). Also, the International Organization distinguishes the limits of Cuba´s R&D because *[the] strong dependence on exports and its difficulties in participating in trace since the USA blockade was restored in 2017 are holding the country back* (p. 221). Of course, the negative global impact of the Covid-19 pandemic has influenced unenthusiastic economic results in this country and its scientific development.

The decree-law No. 7, for instance, in articles 1, 2, and 3 empowers the Cuban System of Science, Technology, and Innovation of certain autonomy of ministries for integrating different components such as juridical laws, economic development, the environment, society, national and international investments, the universities, industrial supports, and scientists.

According to UNESCO, the creation (through the Decree No. 363) of the Science and Technological Parks *as interface firms; and the establishment of several high-tech firms* (2021, p.222) are an instantiation of the volition of that important change in the SITP in Cuba.

In spite of the better government understanding of change, there are main problems that remain in the decisive expansion of R&D and have an impact in the progress of mobile robots and AI in Cuba:

1. Little flexibility in the interdependence of the actors who participate in the scientific and technological process (up-bottom model)
2. Low external financial resource
3. Little discussion about ethical principles in the design of mobile robots and IA implementation

These topics will be discussed below when we propose an efficient ecosystem for Cuba and ethics for the design of mobile robots and IA in an effective and affordable technological environment. In this place, we can say that the current Cuban SITP has a limited ecosystem for mobile robots and AI because the actors involved in the process are not independent between each other; they are not learning mutually, and the openness is limited by the same policy, and the subsystem are not evolving symmetrically. Furthermore, there is a limited vision of international investment and the importance of ethics in the production of technology. These elements are vital to understanding why a Cuban robotic project like the creation of the Palmiche mobile robot has evolved asymmetrically, namely Palmiche was born in a complex and contradictory context in which it has not been connected efficiently with the legal frame, national research programs, national (or abroad) funds, and the industrial production of the SITP.

5.1 Palmiche UGV robot

Robotics has become one of the fundamental pillars in the development of 21st-century society. Wherever you look, in the modern industrial process, it plays a fundamental role. One of the fields in which robotics and new technologies are leading great development is logistics, due to the importance of controlling the storage of products, their correct location in the warehouse, and efficient management of the same (Valverde-Castro, 2020). There are situations where the efficiency of the process requires an immediate solution to dissimilar problems, which is generally provided by the use of new technologies. One of the main elements used in the development of these processes is mobile robots. Known as robotic devices connected to a program in charge of transmitting work orders, simplifying the logistics management of pallets or different materials to be transported; these devices move through an environment autonomously. Generally, they are characterized by being collaborative robots, and thanks to the advances that have occurred in recent years in artificial intelligence, their possibilities have been exponentially expanded.

Cuba needs this process of automation and control in countless centers and companies in the nation. The implementation of autonomous mobile robots for the transportation of materials are one of the technologies that are imposed worldwide, due to the good results they offer with their implementation. In the context of Cuban robot making, the existence and abundance of electronic components generally used in robotic platforms are dramatically reduced concerning the global scope. Therefore, one of the main focus while designing a robot was to produce a solution which integrated actuators and sensors that were already common and relatively inexpensive within the Cuban industry. In addition, the platform should base its electronic design and software development on open-source platforms to further reduce the overall cost and make the project more easily replicable, thereby making the product even more, appealing to be deployed in multiple branches of the Cuban economy and help increase the efficiency of logistic processes.

5.2 General Description of Palmiche UGV

The Palmiche UGV robot is a low-cost and easy-to-implement unmanned ground vehicle. It has a chassis of black and stainless steel, **Figure 2**, designed to support a weight of 300 kg and obtain a maximum speed of 1.2 m/s. It uses 72 V and 28 A lithium batteries, two 72V brushless motors, and two 1000-watt controller boxes, all these elements can be found in electric motorcycles. This type of vehicle is commonly used today in Cuba, so it was decided to use its electronics to develop this autonomous vehicle prototype.

Figure 2

The vehicle has an autonomy of 4 hours of work and links 3 hardware platforms: A Teensy 3.2 microcontroller programmed in C ++ was used in the orientation and control mechanisms, for which an inertial measurement unit of 6 degrees of freedom (MPU6050), HES-25-2MD encoders of 2500 p/r and a module was attached GPS from the manufacturer Adafruit. The information obtained by these measurement units is processed by algorithms programmed in the Teensy, to govern both control boxes and reach the correct differential traction mechanism of the UGV through PID controls. The second platform consisted of an Arduino nano coupled to 10 ultrasonic sensors that allowed it to detect objects in a range of fewer than 2 meters, thus allowing it to avoid a collision. Finally, for visual and remote control, a Raspberry pi 3b was used to which a PiCam was connected and at the same time, the Teensy was governed.

Figure 3 shows the details of the electronic design of Palmiche UGV. Palmiche UGV has two navigation methods that it implements independently, depending on the workplace. For outdoor use, a navigation system based on the Extended Kalman Filter (EKF) algorithm is used for INS / GPS sensor fusion. Indoors, where a possible prolonged loss of GPS signal would render the control system inoperative, a navigation system based on the use of artificial vision techniques was implemented to identify and follow the lines that define a route or path.

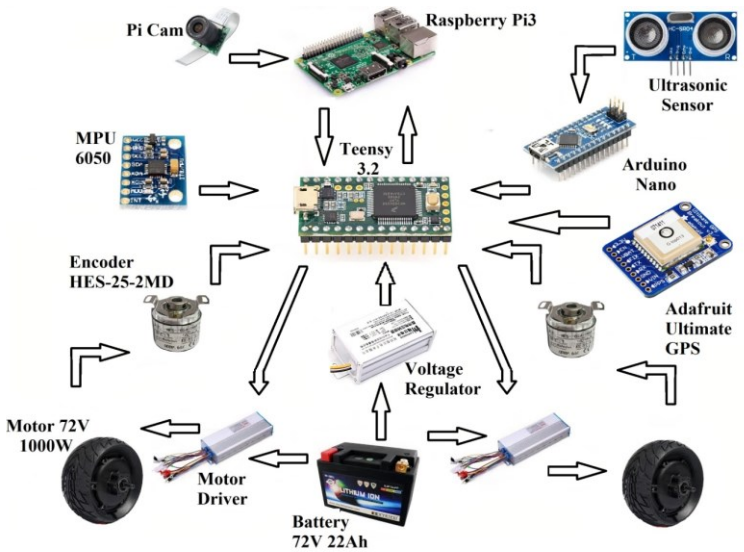

Figure 3

5.3. Navigation system based on the Kalman Extended Filter algorithm

Inertial Navigation is the technique whose objective is to calculate the position, speed, and orientation states of a vehicle by measuring acceleration and angular velocity. In general, an Inertial Navigation System (INS) is classified as a dead reckoning system, that is, it does not require external sources for its operation and has been the subject of study in applications in the commercial and military fields (MacKenzie, 1993). According to Groves (Groves, 2013), the main advantage of this type of navigation is the sampling rate, less than 30ms; however, the precision of this type of navigation degrades over time, due to cumulative errors caused by offsets, biases, scale factors and non-linearities present in inertial sensors (Grewal, Weill, & Andrews, 2007).

On the other hand, the position and speed of a vehicle can be obtained using a GPS system (Global Positioning System), which requires a constellation of satellites in orbit for its operation. This navigation technique allows measurements to be obtained approximately every 1 second and a limited error of 3 to 5 meters for civil use (Aggarwal, Syed, Noureldin, & El-Sheimy, 2010). However, for control applications their low update rate is not the most appropriate. Furthermore, a possible prolonged loss of signal, between the receiver and the satellites would render the control system inoperative.

Sensor fusion is defined as the process of combining observations from different sensors, providing robustness and a complete description of the environment or process of interest (Whyte & Henderson, 2008). In the case of navigation, sensor fusion techniques allow for correcting the cumulative errors of the INS system, using measurements provided by a GPS receiver. Furthermore, this fusion process has a sampling period equal to the INS system and in case of prolonged loss of the GPS receiver, the sensor fusion continues estimating the states according to the latest update, given by the GPS. The Palmiche autonomous vehicle implements a navigation system based on the Extended Kalman Filter (EKF) algorithm for sensor fusion, providing filtering techniques and stochastic estimation of non-linear systems.

5.3.1 EKF Sensory Fusion Algorithm

The EKF algorithm used in the vehicle's INS / GPS sensor fusion bases its operation on Bayesian inference, allowing the estimation of the states of the navigation equation defined in the previous section, by measuring the position given by a Global Positioning System (GPS). For the development of the Palmiche navigation system, the following works were taken as a reference: Kalman (Kalman, 1960) and Kirie (Bekir, 2007). For an in-depth development on Bayesian recursive estimation, the works by Bain (Bain & Crisan, 2009) and Candy (Candy, 2011) were consulted, where the EKF filter is approached from a Bayesian inference perspective, for signal processing, system identification, automatic control, and sensor integration applications.

The iterative process of the Kalman filter is broken down into two stages: (I) *Predicting* the state from the previous state and the dynamic equations and (II) *Updating the prediction* using the observation of the current state.

The essential idea of the Extended Kalman Filter, (see Dan, 2006), (Schmidt S, 1985), consists of a variation of the Kalman filter to address the nonlinear estimation problem based on the linearization of the functions that describe the dynamic system, considering only the first order terms of the Taylor series development of such functions, a linear approximation of the originally non-linear system is achieved, in which the Kalman filter is applied to obtain the estimate of the states.

5.3.2 Route Tracking Algorithm

For the robot to be able to support transportation and logistics tasks it would be necessary to reliably follow a route. One possible approach could be to set a starting point and a goal location and let the tracking the algorithm decides what route to take to fulfill the mission. However, this approach would require very sophisticated and expensive hardware for the robot to be able to have the perception to safely get from one point to another without running into static and dynamic obstacles, since the tracking algorithm might not even guide the trajectory towards using the streets as the means of transportation. Taking these considerations into account it was more fitting to the application at hand to develop a more guided route tracking algorithm, one that would incorporate information about the streets location and static obstacles in order to maximize the chance of success for the robot in performing the transportation task.

5.4 Artificial vision: lane detection for autonomous driving

Artificial vision is a field within computer science and a sub-area of Artificial Intelligence, which extracts graphic information from the the physical world, and uses its properties (Szeliski, 2010). One of the more used methodology in this context is the street lane detection (Collado Hernáiz, 2009), (Zhao, Pan, Du, & Zheng, 2015) and image segmentation and object detection (Nieto, Laborda, & Salgado, 2011).

The Palmiche UGV's street lane detection methodology can be summarized in the following steps:

1. The computer application created was developed in the Python programming language with version 2.7.9 and using the OpenCV library in version 2.4.11, we used the MOV video format, with a resolution of 640 x 480.

2. The gray scale is the way to represent an image, where each pixel represents a numerical value between 0 and 255, related to its luminance (Alfaro & Mendoza, 2006). The segmentation algorithm used is based on discontinuity, one of the basic properties of gray-level values. This property splits the image based on sudden changes in gray level, making it ideal for detecting isolated points, lines, and edges.

3. It is necessary to define the region of interest, to reduce noise in image processing. The ROI represents a set of pixels in the sequence of images, which is classified into classes, applying different segmentation techniques. In order to find the lines on the road, we use an ROI located in the lower half of the image, where we find the most useful information.

4. During edge detection, we use Canny's algorithm (Szeliski, 2010), which performs a search for edges of different thicknesses and significantly reduces noise, by implementing a Gaussian filter (He, Rong, Gong, & Huang, 2010).

5. For the detection of lines we use the Hough transform, which bases its operation on a voting system, where the lines that may exist in the image are searched as a result of the union of their pixels [20].

6. Delimiting the lines boils down to taking them to the limit of ROI. This process is important to increase detection efficiency.

5.4.1 Image filtering

During the video processing, a Gaussian filter was used, in order to eliminate the noise inherent in the resolution. Histogram equalization improves efficiency in detecting lines on the road by improving the gray distribution throughout the image. The use of masks improves the performance of the computational equipment, by facilitating that only a certain area of the image is processed (Nieto, Laborda, & Salgado, 2011).

5.4.2 Lane detection

Through the cv2.HoughLine function of the OpenCV library, which makes use of the normal Hough transform, the angle of the line and its Cartesian coordinates are obtained. It should be noted that only the straight lines of the road have been detected, in the curved lines according to (Collado Hernáiz, 2009), and (Hillel, Lerner, Levi, & Raz, 2014) more complex detection methods are used. As future work of this research, it is intended to implement new algorithms for the detection of curved lines, such as genetic algorithms, Kalman filter, etc.

These algorithms are more complex and allow objects to be detected through their color (Hillel, Lerner, Levi, & Raz, 2014). One of the most used applications in this way of working results in smart warehouses. In these work-spaces, where routes can be predefined and jobs are repetitive, it is common to use marks or lines on the surface that guide the vehicle through the different paths, safely and reliably. Generally, in these working spaces, the GPS signal may have irregularities and it is for this reason that the artificial vision mode and odometry are used to achieve the correct navigation of the vehicle.

6. Proposal of ecosystem based on extended and responsible ethics for mobile robots and AI in Cuba.

We have defined the ecosystem of innovation in Cuba as limited due to 1. little flexibility in the interdependence of the actors who participate in the scientific and technological process (up-bottom model), 2. low external financial resources, and 3. little discussion about ethical principles in the design of mobile robots and AI implementation.

It is important to discuss what kind of ecosystem we are advocating here because it will have an impact on the growth of an extended moral agent: Palmiche UGV. We want to establish that an extended moral agent cannot fulfill their expectation of "extendedness" without a dynamic and evolutionary ecosystem. Therefore, if we realize the wide scope of the decentered ethics in the design of mobile robots and AI, these two theoretical frames cannot be seen separately but in coupled interdependency.

Palmiche UGV is the instantiation of how decisive is the coupled interdependency of these two theoretical frames. On one hand, a limited ecosystem for mobile robots and AI in Cuba does not permit the dynamic interrelation of different actors in the innovation process as universities, national and international business enterprises, government, industries and engineers, and philosophers, among others.

On the other hand, the moral agency is both contributions of human and technology to a moral decision, implementation, behavior, and action. Palmiche has had huge problems with the ability to replicate its components and the sustainability of its functional operation in society. It is not possible to establish a real discussion of the "extendedness" in the design of Palmiche if all the actors who are concerned about the development of this mobile robot are not involved in an ecosystem of innovation.

6.1 Limited Cuban ecosystem revisited

Núñez Jover & Montalvo Arriete (2014) and Chía (2004) propose an interesting reflection on the characteristic of the SITP in Cuba. They coincide in highlighting the same problems of the SITP model: the center of the innovation is in the research entities and the major resources financial of the R&D comes from the government.

In spite of the actualization and certain modernization of the legal frame in science, technology, and innovation, the Cuban policy remains the old up-bottom model. Research entities, such as universities, are focused on the organization of the development process, with less attention to technological management (limited ecosystem) and a low interest in the concretion, implementation, and industrialization of the technological artifacts (extended moral agency).

Also, it is controversial the real and effective impact of the government investment in R&D. According to the UNESCO science report (UNESCO, 2021), until 2018 the Gross Domestic Expenditure on research and development (GERD) in Cuba had a 56.4% from the government, 42.0% from business[1] and just 1.6% from abroad. This 98.4% represents the 0.6% of the Gross Domestic Product (GDP) for 2021 (Económicas, 2021). Recently, the CEPAL report (CEPAL, 2020) has revealed a low incremented of 2.2% in Cuba's GPD.

The same UNESCO report highlights that some countries, such as the Caribbean and Cuba, in particular, do not yet produce regular data and *this suggests that the development of Science and Technology Indicators (STI) remains below the radar of some governments.* Moreover, UNESCO recommends for Latin American governance that as government *investment levels are too low to provide much of the boost for industrial research [...] the outsourcing of innovation to other actors is becoming an option. There may be a widespread view among public and most private enterprises [...] in research and innovation* (p. 228).

The available data are evidence of what Núñez & Montalvo Arriete (2014) and Chía (2004) are pointing to Cuba needing a strong impulse in GERD. The exploitation of foreign investment in R&D could be a decisive impulse for the

[1] As Cuban government has a socialist economic model, the business financial is in most cases to State-owned enterprises. In fact, the foreign capital of private enterprises is very limited.

creation of an affordable ecosystem of innovation. Also, Chía and Núñez & Montalvo Arriete reflect on the negative results from the first and second National Innovation Surveys and they remark on the deep disconnection between different actors in the science and technology system:

a) There are no regular and systematic links to the scientific sector: research centers and universities.

b) Cuban businesses typically adhere to a traditional concept of incremental innovation that does not encompass technological change but is associated with solving practical problems to maintain production and services.

c) *The relationships with the scientific sector as well as the institutions that develop linkages continue to be irregular and unsystematic.*

d) *Firms are still not fully taking advantage of their capacities to introduce goods and services, processes, and organizational changes.* (Núñez & Montalvo Arriete, 2014, p. 163)

In the case of mobile robots and AI, the National Program *Development of the Informatization and Automation* is one of the main government priorities in R&D and it can participate in Financial Fund of Science and Innovation (FFSI). However, it is very difficult to insert in these mechanisms (the financial restrictions are one of the causes), and as a result, though Palmiche UGV has many applications in several economic sectors (as we say in 5.1) has not benefitted with this funds. That is why, the common electronic components used in robotic platforms is dramatically reduced in the creation of Palmiche.

In this line of argumentation, we propose the concept of responsibility as "swarm" (Coeckelbergh, 2011, 2020) as the connection between an ecosystem of innovation and an extended moral agency. The dynamics, interdependence and evolution of an ecosystem of innovation include the complexity of the human and non-human actors and it is useful to understand how businesses enterprises, universities and political decision-makers can work together in order to improve the technological advances such as mobiles robots and AI.

We have already established that technological artifacts are moral agents because they are connected with the moral human decisions. A decentered and extended ethical model that we developed in epigraph 2 showed us how important is the mobile robot and AI participation in ethical evaluation.

However, we can understand separately ecosystem of innovation and extended moral agency without establishing a link between each other. The notion of responsibility as "swarm" could be an ensemble between these two concepts. If we assume the idea of interdependency and extendedness as real possibility in systems and agents, we can think that it is necessary a wide concept of responsibility that integrates dynamically and ethically a mobile robot such as Palmiche UGV.

Coeckelbergh (2011), for instance, explains an agent as *distributed, collective, and emergent* (p. 273). The ethics for robot design should be modified in its methodology: robots should be *analyze[d] and evaluate[d] [in] the activity of the system, network, or swarm as a whole [...] a swarm consists of "independent" parts–there is no central controller–but like a swarm of bees or birds, all nodes are linked to every other node, and in this way, the whole can act in unison; it is self-organizing*. (p. 273)

This wider proposal of responsibility changes its traditional notion based on human intentions and actions alone (see epigraph 2). We advocate the distribution of responsibility between the robot as a moral agent, the human being as creator and user of the technology and the ecosystem of innovation where it organizes, implements and produces the robot.

The ethical evaluation of the activity and the automation of the mobile robot as Palmiche UGV *should not be limited to a discussion about how individual autonomous systems can make ethical decisions and if they should be allowed to do so at all [...] Instead, they should try to anticipate implementation of new technological-organizational concepts and adopt a methodology that consider a plurality of levels of analysis, including the level of networks or swarms* (Coeckelbergh, 2011, p.275)[2].

[2] We agree with Terrones Rodríguez (2020) that this kind of responsibility that we are advocating emerges in inclusive, innovative and reflexives societies. For instance, education and cooperation between human beings and their institutions is one of a multiple forms to *searching solutions to the present problems* (p. 829).

6.2 Motivations for a social and economic impact of Palmiche UGV in Cuba

In spite of negative results in the Palmiche "extendedness" and ecosystem environment, this mobile robot has been very useful in different scenarios (limited ecosystem-extended agency-responsibility). Palmiche UGV was born as a solution to the growing problems faced by the Psychiatric Hospital of Havana, Dr. Eduardo Bernabé Ordaz.

This hospital center (which we consider in this explanation as some specific kind of ecosystem) is classified as the largest psychiatric hospital in the world, with its 65 hectares, for what it needs for its daily operation the movement of loads (food, medicine, supplies, among others). In 2018 the institution bought 10 electric vehicles in the Asian market, with which these logistical tasks were carried out. By mid-2020, 2 of the purchased electric vehicles were already out of service at the hospital and 4 of those that remained in operation, had occasional electrical problems. This situation was getting worse, due to the absence of specialized labor, or electrical components to carry out maintenance and repairing tasks on these Chinese technology units. Another factor that affects the dynamics of the institution′s operation is the instability of the drivers. In a 2-year period, more than 50 had driven, at a rate of 2.5 drivers per year, each vehicle. This situation directly affects the lives of about 1,200 patients and the working conditions of 1,500 employees of the health institute.

The Technological University of Havana faced the challenge of providing a solution to this problem. Unquestionably, this solution could also be implemented in other institutions in the country with similar problems. To carry out this task, three fundamental characteristics were defined, taking into account the social, economic and environmental conditions faced by the Caribbean nation:

1. Autonomous: promoting the reduction of dangerous and repetitive tasks for workers.
2. Low cost: using open source elements and assimilating existing technology in the country, laying the foundations of the much desired technological sovereignty.
3. Electric: avoiding the burning of fossil fuels and in accordance with the nation's environmental policy.

These three characteristics laid the foundation of the Palmiche UGV autonomous mobile platform. We can see how a form of responsibility as "swarm" is operating here and ensembles the ecosystem and the extended agency. Two organizations share the responsibility to find out the technological solution for the movement problem at the hospital. They create a limited ecosystem when they support, produce and implement together the use of Palmiche UGV. In fact, the design of the mobile robot was thought to be used in a specific scenario with determinate moral values such as the well-being of the hospital employees and patients. The activities performed by the mobile robot mediate the behavior and actions of the people who interact with Palmiche UGV and this increments the responsibility of the workers over the technical artifacts and its evolution in the environment.

Also, the automaton offers a solution to problems related to driving optimization and fuel efficiency. In addition, the project analyzes various environments in which autonomous vehicles such as Palmiche can be used in the nation, including autonomous transport and assistance in picking up items in warehouses; open-air logistics operations such as those in cargo bays, ports, and airports; assistance to trucks and road convoys in the transport of cargo; delivery in the last mile and as a service robot in the hotel industry, key sectors of the Cuban industry. In the same way, the automaton was designed to allow its easy insertion in the work environment and linked easy and intuitive interfaces for its communication with the operators.

This vehicle, as a prototype, was put into use in the Havana Psychiatric Hospital for 6 weeks, in that institution, it traveled 0.8 km daily, on its way from the warehouse to the production area, with the necessary supplies for cooking food. Subsequently, it was employed for over 4 weeks in the Isolation Center for Suspicious Patients of Covid-19, located at the Technological University of Havana; in that center, the automaton was the means of communication and transportation of food, between the area that housed to the patients suspected of Covid-19 and the rest of the institution.

Undoubtedly, the conception and application of this project has shown that public policy is in need to design instruments to ride the new wave of innovation, adapt the workforce to the challenges imposed by technological change (new skills and continuous training) to improve the possibilities of technological adoption, minimize the costs of this transition and ensure that society benefits from this change. Moreover, "swarm" integration is the key in this context from the generation of innovation clusters, knowledge transfer, technical cooperation, regional public purchases, connection of regional networks of incubators and Small and Medium Enterprises, exploration of complementarities, regional educational networks, harmonization of regulations and standards, among others.

7. Conclusions

We present our hypothesis that an extended moral agent cannot fulfill their expectation of "extendedness" and responsibility without a dynamic and evolutionary ecosystem where the agent develops and behave properly. The Cuban mobile robot Palmiche UGV is an evidence that without a strong network between theses theoretical frameworks, the model fails due, for instance, to an inefficient financial resource that has a negative impact on the components and implementation of the technological artifacts. However, since Palmiche UGV was designed by ethical principles, it was able to develop its tasks and interact with humans and the environment. Also, our proposal based on the discussion of the new model of SITP for Cuba is that the ecosystem of innovation, the extended moral agency and a "swarm" responsibility are ensemble together. We believe that the implementation of this triad in Cuba will improve the functioning and replica of Palmiche UGV in some core area of the society.

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