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José De Camargo, Estéfano Vizconde Veraszto, Adriano Aparecido Lopes, Tainá Vedovello Bimbati

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José Tarcísio Franco de Camargo[1], Estéfano Vizconde Veraszto[2], Adriano Aparecido Lopes[3], Tainá Ângela Vedovello Bimbati[3]

[1]Regional University Center of Espirito Santo do Pinhal, Sao Paulo, Brazil
{jtfc@bol.com.br}
[2]Federal University of São Carlos, Araras, Sao Paulo, Brazil
{estefanovv@cca.ufscar.br}
[3]Municipal Faculty "Professor Franco Montoro", Mogi Guaçu, Sao Paulo, Brazil
{adrianoalopes2008@yahoo.com.br, tavbimbati@gmail.com}

ABSTRACT. Separation, collection, processing and disposal of waste considered recyclable are currently one of the greatest challenges of human beings in their quest for sustainability. With consumption levels in ever-higher levels, the reutilization of recyclable waste, which would likely target the garbage, becomes an obligation of society as a whole. Thus, addressing in an appropriate manner the issue of selective collection of recyclable materials can contribute to the solution of several problems associated with it – mostly under the views of environmental, social and economic ways. This way, the Project iCARE (Instrumentation for the Assisted Collection of Recyclable Waste) is based on an experiment that aims to provide computational tools that could significantly contribute to the issue of the reuse of solid recyclable waste. Specifically, the iCARE software aims to contribute to the integration between donors and collectors of recyclable materials, establishing a communication channel where ordinary people or companies may announce the availability of recyclables to collectors. These, in turn, can check through the same software the availability of certain wastes, coming to contact consumers for possible collection and subsequently forward the waste to processing companies. This software also offers a "routing module", which allows the collector to establish an optimized collection route according to certain criteria. All software developed in iCARE's framework must provide a user friendly interface, making its use very simple. iCARE is a project of free use and also a social tool, which seeks to contribute to the solution of the complex problem of disposal of recyclable waste.

Keywords: Waste disposal · recycling · computational tools · sustainability.

1 Introduction

Nowadays, there is a consensus that the sustainability of life on the planet necessarily passes by the rational use of the limited resources available. The human being realized that the unbridled consumption inevitably will lead to a depletion of the natural sources. Thus, separation, collection, processing and disposal of waste considered

recyclable are, currently, one of the great challenges of humanity in the quest of sustainability. With high levels of consumption, the reutilization of recyclable waste, which would likely target the landfills, has become an obligation of society as a whole [1-3].

In this way, the planning and implementation of programs dedicated to the selective collection of recyclable materials can contribute to the solution of various environmental, social and economic problems. Under the economic point of view, the selective collection effectively promotes the solution of some problems relevant to society, considering that discarded materials can go back to the cycle of consumption, thus reducing the use of natural resources in the manufacture of new products.

Under the environmental point of view, the reuse and recycling of materials would probably promote direct impact on the preservation of natural resources, conserving raw materials, water and energy in production processes and, consequently, a decrease in the amount of trash sent to landfills as well as its useful life [2]. In the social aspect, the selective collection has positive impact on socioeconomic conditions of recyclable material collectors, who are the first actors in the selective collection and recycling chain.

In this context, this work presents an experiment carried out in a city in Sao Paulo State, Brazil. The work that is being carried out includes the creation of computational tools which intend to support the process of selective collection of recyclable materials. At first, a software called "iCARE bulletin board" was developed, which aims to promote the integration between "consumers" (recyclable waste producers) and "pickers" (responsible for the collection and disposal of waste). The following section presents the fundamentals of this project within the region where it is developed.

2 Science, Technology and the Environmental Issue

Having the Club of Rome as an important delegate, environmentalists from the decades of 1960 and 1970 gave emphasis that world growth was limited due to accelerated population increase, to deficiency of agricultural production (aggravating to hunger), the exhaustion of natural resources, the destruction of the environment and the increase in global industrial production. This vision, transparent in the work of Meadows [4,5] had a remarkable accession in the postwar period, with questions about the side effects of technological development on society and economy. The dangers brought by pollution and by widespread environmental degradation were key factors for a resumption of the Malthusian paradigm, whose central idea stressed that the saturation of the world growth would be in a hundred years [6,7]. From the years 1970, began a series of investments in clean technologies or alternatives in various countries in response to the demands of the environmental movement. In the decades of 1980 and 1990 the debate on environmental issues was expanded and relations with the technology got new directions. The Bariloche Group, along with other world references, was pointing out that the economic system has self-regulatory mechanisms that allow modification or reversal of patterns before the system reaches the point of catastrophe [3,8]. In the decade of 1980, sustainable development was defined and

studies aimed at reducing poverty and alleviating social problems were initiated [1]. However, it was only in early 1990 that the concepts of previous years have been implemented. The concept of the role of technology on environmental issues has changed, enabling the belief that it is possible to recover degraded areas and increase the efficiency of natural resources in parallel with the increase of productivity. The technology thus is seen not as an external factor, but as an integral element of the decision-making processes. The development of S&T adapted to environmental issues then must know how to handle these challenges and dilemmas by internalizing the environmental variable in the process of innovation and seeking efficiency and quality in the development of new products, processes and/or services. (Passing not only by raising awareness about environmental issues, but also considering legal and economic aspects) [2,9,10]. In view of the foregoing, we can establish relationships with other works [11,12] to point out that both the technology and social organization can be managed and improved in order to provide a new era of economic growth, so that humanity will be able to make sustainable development possible.

Thus, environmental, scientific and technological developments are not separate challenges. Making the environmental issue the record on political agendas is an item of great importance with regard to the economy and resources [11-13].

The development of the S&T front of environmental issues can become more efficient if supported by a strong and articulate public policy. It is also necessary to create and maintain mechanisms to link research and development in the sectors of production to their demands, as well as the creation of new energy sources and new materials, in order to seek solutions to social problems [7,9,14].

It is in this sense that the work proposed here is developed. Thus, the aim of this paper is to contribute to sustainability through methods and techniques that promote technological innovation and social inclusion. These are the points that will be presented in the sequence.

2.1 A Local Context to the Issue of Waste Recycling

The steps in the process of collection and disposal of recyclable waste can be viewed in a simplified way, as follows:

1. **Separation:** this is the step where each citizen must separate, from non-reusable waste, those materials which can be recycled. This is a step based on education and awareness of people about the need to reuse materials that can go back to the cycle of consumption.
2. **Collection and Disposal:** this step has a "logistic profile", since it involves several costs for those that are collecting reusable materials. Collect which materials? Which is the minimum amount viable for collecting? How to collect and give destination? These are some of the main questions to be considered at this stage.
3. **Processing:** as well as the collection and disposal stages, this one can also be seen as a "business", where a particular company may have focused on the reuse of recyclable waste and its subsequent commercialization. This is the step of the recycle

chain that is more distant from "ordinary people", considering that here the "main actor" is a businessman.

In this chain, the "picker" (or "collector") is the leading actor in the production of recycled materials, making approximately 80% of all the work, collecting an average of 600 kg of materials per day [15].

The project dealt with in this paper was born in the city of Mogi Guaçu, Sao Paulo State, Brazil. It is a medium-sized town, with an expanding industrial pole and a large number of companies in the service sector. This city has possessed, approximately fifty years ago, an economy almost entirely based on agriculture, and experienced an intense population expansion on the last forty years, when the population jumped from about 30,000 to 130,000 inhabitants. This expansion was due mainly to the migration of people from other states of the country, searching for new jobs, which actually ended up experiencing social exclusion. As a consequence, the population of recyclable materials collectors came to be composed mostly by migrants who come from other regions to work in the rural area and ended up facing unemployment. Excluded from school for avoidance or lack of access, they are also excluded from the labour market and therefore of society. To escape from hunger, these people found the possibility to work in the city from collecting discarded materials.

Regarding the problem of the garbage generated and processed in the city, according to data presented by the Secretary of Municipal Services, the rate of garbage collection in the city is around 99%. Among the total municipal waste generation, the share of production of household garbage by the population is approximately 105 tons/day, of which 32% are recyclable materials, 52% are organic and 16% are considered waste.

In this scenario, a matter that can be displayed is: how to integrate consumers, who generate such amount of potentially recyclable material (that is currently going to junk), and collectors, who while may give the appropriate disposal waste can also improve their source of income? It is in this scope that iCARE presents itself, as a technological arm that aims to generate computational tools that will contribute to the solution of socio-economic and environmental issues, among them the problem of proper collection and disposal of recyclable materials.

3 Computational Tools to Support Selective Collection

Although described in a simplified way in this paper, the complexity of the presented chain induces specialization from "actors" involved in the same. The proposal here introduced intends to contribute significantly to the integration of the actors responsible for the second step: consumers who generate recyclable waste and pickers who dispose of these materials.

Currently, with the expansion of the internet connection services, a considerable part of the population has access to the World Wide Web in their own homes, and among the most common habits of this population, is the communication through social networks. These new mechanisms of communication have promoted the exchange of messages and information in a manner so intense that its potential currently

transcends social barriers. Even the lowest economic classes of the population have access to cheap portable devices which allow access to all these networks.

In this scenario, the software created under this project aims to contribute to the integration of "producers" and "pickers", establishing a communication channel where ordinary people or companies may announce the availability of recyclables to possible collectors. These, in turn, can check via software the availability of certain wastes, contact consumers for collection and subsequently forward the waste to processing companies.

In order to facilitate the collection and disposal of waste collected, this software also offers a "routing module", which allows the collector to establish an optimized collection of routes, according to certain criteria (distance and time of travel, for instance).

This software was built to provide a "friendly" interface, making its use very simple. In its current stage, the only preconditions for this software to be used are a "JAVA ready" device and an internet connection for access to data.

This software aims as well to keep a democratic and decentralized spirit. Democratic in the sense that its use and sharing is free for anyone, either to announce or to collect recyclable or reusable materials; and decentralized because any community can implement its own network, answering specifically the subject of a particular region.

4 Introducing iCare

As mentioned previously, iCARE means "Instrumentation for the Assisted Collection of Recyclable Waste". This software provides a tool for the communication between donors and collectors of recyclable materials, in this case, a Java application that is a virtual "bulletin board", through which users can make and schedule waste collections, and a database, which will store data about recyclable materials offered for disposal. Any community may set up its own database in a local server, providing data to the local citizens or companies.

To provide data, a local server must run "Apache Derby", an open source RDBMS that is based on Java technology and SQL, which will manage the database where all information will be stored. This database will serve users through a "bulletin board", written in Java, which will promote the interaction among users.

Currently, this bulletin board was built in order to provide the following functionality for its users:

- an "interface for sending messages", through which an user can offer the donation of materials that can be recycled;
- an "interface for receiving messages", through which an user can check the materials available for collection and contact the respective donors to this schedule;
- a "route generator interface", through which a collector can establish a collection of routes through certain criteria.

The interface for sending messages is presented in Figure 1.

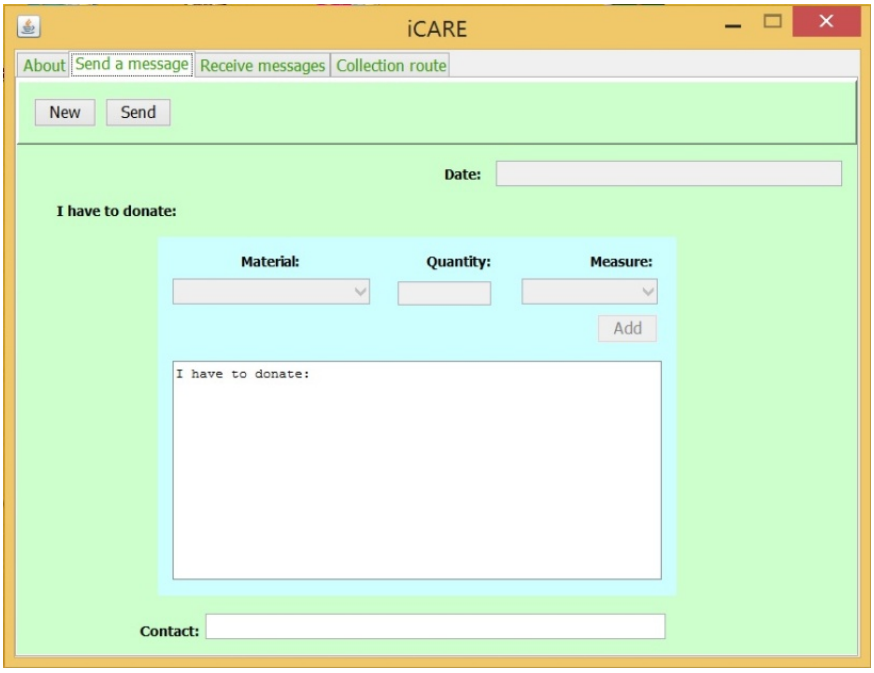

Fig. 1. Interface for sending messages.

Through this feature, the user can send to the Bulletin Board a list of recyclable materials that would be available for collection. The user can select from a list the materials that he wants to make available, indicating the available quantity. The user can insert more than one type of material for target.

The interface for receiving messages is shown in Figure 2.

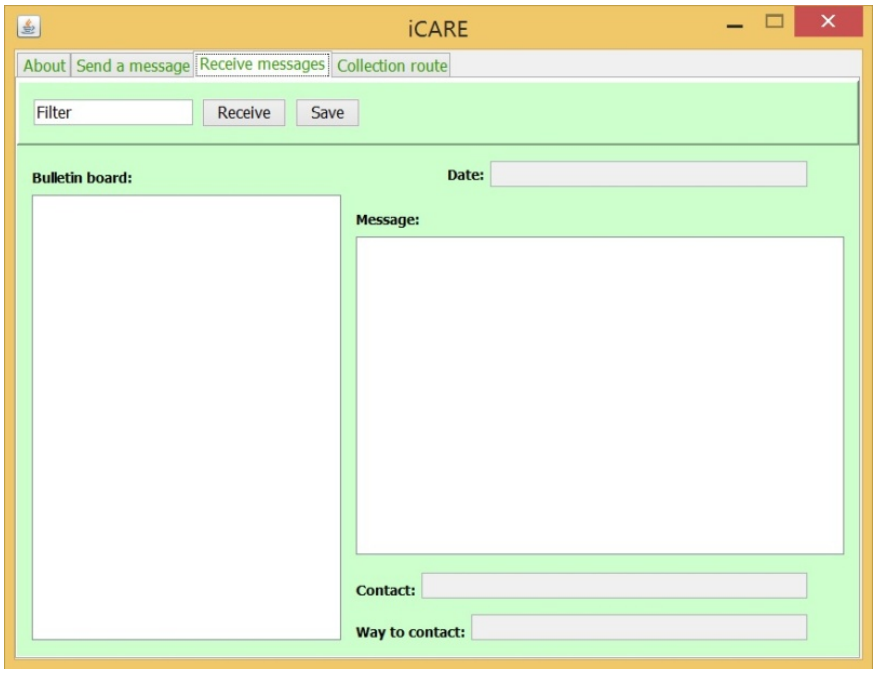

Fig. 2. The interface for receiving messages.

The feature "Receive Message", allows collectors to receive these messages on their devices and, in this way, select the materials that interest them and contact the respective disposers to schedule a pickup.

The last feature available is the interface for creating collection routes, where is possible to schedule the gathering of recyclable materials. The problem then becomes the definition of the best way to carry out the collection and disposal of materials. The interface for creating routes allows the user to enter multiple addresses for collection and an optimized route will be calculated. This feature is based on Google Maps Javascript API. Figure 3 presents a picture of the interface for calculating routes.

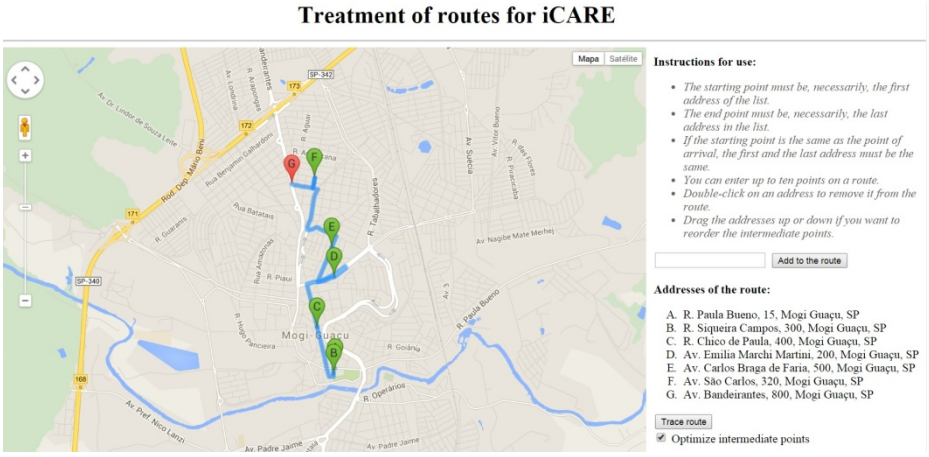

Fig. 3. Interface for route calculation.

5 Concluding Remarks

The iCARE project aims to contribute with the separation, collection and proper disposal of solid wastes, as a way to minimize the socio-economic and environmental problems arising from the inappropriate treatment of waste.

The use of this software has allowed the operation of a structure for the collection and disposal of waste, which has been organized by the Association of Collectors of Mogi Guaçu, SP, Brazil, ensuring the entry of materials to the collective work of everybody involved. The proposal of a programmed logistics makes selective collection activity itself less impressive due to the reduction of fuel consumption and emission of greenhouse gases in the collecting of materials with the planning of routes.

Considering the Brazilian national solid waste policy [16], in compliance with the law Number 12,305/2010, regarding the separate collection, recycling, reverse logistics and the strengthening of the concept of shared responsibility, the software comes to interact with companies and organizations in the area of social and environmental responsibility for the correct disposal of waste generated by its activities, with the obligations of all links in the production chain. There is also a reformulation of the concept of waste, because it happens to be seen by society as a material of value, and that the generator is responsible for their proper disposal.

The iCARE project is still in an early-stage and seeks to involve the largest possible number of people interested in the collection and disposal of recyclable waste. Other initiatives are planned for future work within the scope of the project. Among them we can mention the mapping of disposal points, which could be coupled directly to the module "Bulletin Board".

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