Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 38 (2019) 209–216

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

29th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2019), June 24-28, 2019, Limerick, Ireland.

Methods and concepts for elaborating a decision aided tool for optimizing healthcare medicines dispatching flows

Julia Cassim Pinheiro[a], Paul-Eric Dossou[a,b]*, Joao Chang Junior[c]

[a]*Icam Paris-Sénart, 34 Points de Vue, 77127 Lieusaint, France*
[b]*IFSTTAR/AME/SPLOTT, 14-20 Boulevard Newton, 77420 Champs-Sur-Marne, France*
[c]*FEI, Sao Bernardo, Brazil*

Abstract

Globalization and new technologies are causes of the development of industry 4.0 concepts. Nowadays, Industry is becoming increasingly technological, machines are reaching spaces previously destined in factories to humans. Indeed, industry 4.0 concepts based on scientific, technological, and organizational concepts & tools (Internet of thing, RFID, Cobots, decision aided tools) and including sustainability could be used in different activity sectors. Healthcare sector is being transformed by new technologies and complex problems of this sector are solved by insisting on new technological parameters. FEI and Icam engineering schools are collaborating on healthcare logistics & transport area. The idea is to use the previous approach being elaborated for industrial companies to improve healthcare logistics and transport domain (Healthcare logistics 4.0).
This paper presents concepts and tools (healthcare logistics 4.0) for solving real healthcare logistics problems. The approach elaborated is hybrid (combination of experimentation for acquiring real data and design for elaborating concepts and methods required for developing an adapted problem-solving tool). The decision aided tool is elaborated by using formalisms of artificial intelligence (such as expert systems, machine learning, multi-agent systems) in order to optimize medicine dispatching flows in a hospital.
After describing healthcare logistics dispatching problems, a literature review will be presented for choosing concepts and formalisms that could be for developing the new decisional tool. Then, an example will be given for illustrating concepts elaborated.

* Corresponding author. Tel.: +33-1-8114-1043; fax: +0-000-000-0000 .
E-mail address: paul-eric.dossou@icam.fr

10.1016/j.promfg.2020.01.028

Peer review under the responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019

Keywords: dispatching flow optimization ; decision aided tool ; machine learning ; healthcare logistics 4.0

1. Introduction

Globalization is the cause of many economic and technological changes in the world. In this context, industry 4.0 and supply chain 4.0 appear as a solution for increasing European company performance and making them able to be more competitive on the global market. Indeed, many activity sectors could be improved by using these concepts. This paper focuses of the definition of healthcare logistics 4.0 concepts. The methodology used for this elaboration is based on a combination of experimentation and conceptual concepts. The methodology is a fruit of a collaborative project between FEI University (Brazilian university), Icam (French Engineer School), and hospitals (Sao Paulo and Paris region). A decisional aided tool based on artificial intelligence formalisms is being developed for improving the hospital dispatching service performance.

After presenting the hospital problems, a state of the art will be made for finding methods and tools which could be used for solving them. Then, an existing system modelling and analysis will be shown for detecting inconsistencies and point to improve in the hospital flows. Existing methods and concepts of the literature will be combined for defining a specific approach for solving the hospital problems. Indeed, concepts of a decision aided tool will be exposed in order to show how solutions were elaborated. An example will be given for illustrating concepts and validating the tool being developed. The perspective of generalization for defining healthcare dispatching 4.0 concepts will be exposed.

2. Definition of the problem

The hospital could be considered as a complex system and its logistics problems could be solved by using general concepts and methods defined in the frame of enterprise modelling. For instance, in a hospital, it is important to have resources available, at the right time everywhere in the hospital, because human lives depend on this performance. Then, the dispatching flows, resources and workers, have to be cautiously studied and optimized.

Healthcare dispatching flows optimization implies interaction between all services of the hospital. Indeed, the dispatching service could be considered as a supplier of the other services in the hospital. Products (toilet paper, syringes, needles, medicines, etc.) are required in real time by each service. Their management and the optimization of all dispatching processes are crucial for saving lives in good conditions and increasing the hospital performance.

Indeed, most important flows in a hospital are medicines dispatching flow and medical sterile devices dispatching flow. The impact of these flows on the main hospital activity which is to save lives is very high. Then, Problems related to the quality of products delivered, the quality of service, the lead time (i.e. medicines expected delivering time), or management and procurement costs are directly concerned by these dispatching flows optimization. Besides the schedule of these flows, the occurrence of emergencies is also common. Handlers have to dispatch medicines and medical sterile devices from the pharmacy to other services. Each of their tasks and movements, has an impact on the human lives and the hospital performance and definitively has to be optimized. Human saving lives could be defined as the main objective of the system and performance optimization could be considered as indispensable for attaining hospital goals. All flows have to be combined for optimizing dispatching processes (decomposition reasoning) for insuring the global hospital performance. Staff and workers interviews have pointed out flow dysfunctions such as food delivery, laundry and medicines dispatching, waste management, etc. They all have to be taken into account for improving the entire hospital system.

This paper mainly focuses on medicines and medical sterile devices dispatching flows. They are fundamentals for all hospital services. Then, it is essential to eliminate dysfunctions in dispatching processes.

The dispatching service improvement (by solving problems detected) is necessary for insuring patient safety and satisfaction, but also for aiding doctors and medical workers in order to be confident and efficient in their mission (main hospital objective).

Some of dysfunctions detected in this hospital are about:

- Wrong medicines delivery to a department;
- Medicines loss;
- High non-added value time in the medicine dispatching service.

This paper focuses on medicines and medical sterile devices dispatching flows optimization and proposes a solution based on healthcare logistics 4.0 concepts (deduced from industry 4.0 and logistics 4.0 concepts) such as new technologies (RFID, robots, cobots, AGVs, IoT, etc.), and new organizations (data management (big data, ERP, etc.), lean manufacturing, distribution plan, etc). Concepts of the decision aided tool being developed for managing the dispatching service optimization process will be presented. Then, following problems will be solved:

- Optimization of medicines products preparation orders by pharmacists;
- Optimization of trolleys in coherence with expectations of handlers and distribution plan;
- Optimization of medicines dispatching flows for insuring the best quality of service to all the hospital;
- Optimization of medicines traceability.

3. Literature review

Concepts and methodologies used for defining the general approach of healthcare logistics 4.0 are based on enterprise modelling concepts, industry 4.0 and logistics 4.0, production management, process continuous improvement tools and decision aided tools.

Thus, a global approach is used according to GRAI methodology [1], one of the three main enterprise modelling methodologies with PERA [3] and CIMOSA [2]. The steps of this approach are:

- Acquisition of the study context (interviews, existing system observation, data acquisition),
- Existing system modelling (photo of the actual organization),
- Analysis of the existing system (detection of inconsistencies and deduction of strengths and weaknesses),
- Proposition of solutions (elaboration scenarios and choice of the adapted solution),
- Implementation (action plan definition (short, middle and long terms actions)).

This approach is adapted to healthcare logistics progressive refinement and transformation. Then, concepts and formalisms defined in the frame of industry 4.0 and logistics 4.0 could be adapted to healthcare area. An industry 4.0 general framework is being developed by Icam (French Engineer High School), in which sustainability is used as the kernel of the framework (instead of new technologies). New organizations, new technologies & tools, and flexibility & changes are associated to this kernel as industry 4.0 concepts implementation success vectors [4].

Indeed, new organization tools like blockchain have to be integrated. But, efficient tools like lean manufacturing are also adapted to increase progressively company performance, and in this case healthcare logistics performance. Lean manufacturing is mainly used for finding and eliminating non-added value in company processes and for optimizing added values utilization. Concepts of this methodology for improving supply chain performance are presented in detail in [5] ad could be applied to healthcare sector. Lean manufacturing (7 mudas) will be used in this case for solving problems related to medicines dispatching service such as:

- Wrong medicines delivery to the hospital services;
- Medicines loss;
- High non-added value time in the medicine dispatching service.

Concepts of healthcare logistics 4.0 are based on formal improvement (usual in factories) but also on how operators would improve their performance by integrating new concepts and technologies in all dispatching processes.

Then, for proposing best improvement in order to increase the dispatching service performance, it is necessary to define and elaborate a decision aided tool for supporting changes and aiding operators in their tasks. A detailed study of the literature shows that three concepts could be used for defining and developing this decision aided tool:

- Reasoning such as CBR (Case-Based Reasoning) [6], decomposition and transformation reasonings
- Problem solving method and process [5]
- Artificial intelligence as multi-agent systems [7], [8], fuzzy expert system [9] and machine learning.

This decision aided tool will be developed by using artificial intelligence. The idea is to integrate into the system, human behavior for being more efficient and aiding operators and pharmacists during their tasks.

The following attributes have to be integrated:

- To think and reason
- To use reasoning for solving problems
- To acquire knowledge and apply it to a system
- To learn and understand by exploiting real experience
- To integrate innovation and creation of good feeling
- To be reactive in new situations
- To measure and recognize the importance degree of a situation
- To treat with high efficiency incomplete, wrong or ambiguous data
- Etc.

Indeed, the decision aided system that is being developed must have ability to reason and learn autonomously from experience of dispatching service operators & pharmacists. CBR system combined with multi-agent system [10] allow to obtain this specificity in the aided tool. The tool has to propose solutions for solving healthcare logistics problems by reusing or adapting old solutions developed for previous problems. The learning characteristic is given by multi-agents.

An expert system generally serves as a decision aided tool and is able to repeat expert cognitive mechanisms in a domain. It is software able to solve problems by using reasoning from known facts and rules (figure 1).

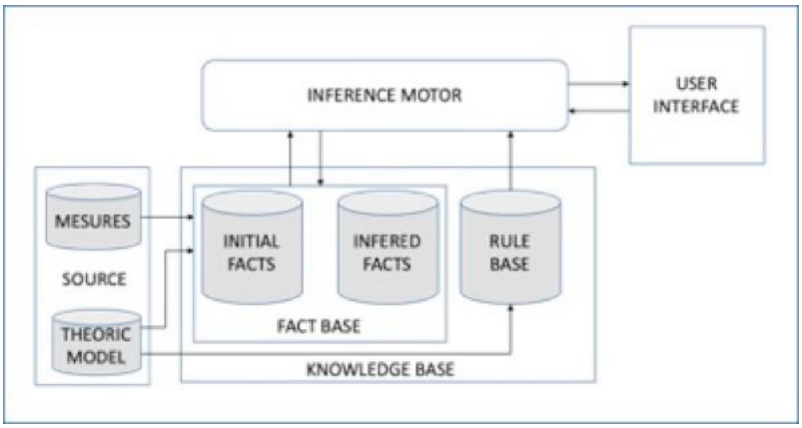

Figure 1: Expert system general architecture

Then, fuzzy logic could be integrated for providing a kind of interface between human brains and computer. The fuzzy expert system will serve for taking right decisions without knowing exactly or certainly all parameters of a problem. The system has to manage inputs, to make fuzzification, to use inference motor, to make defuziffication, to use adapted knowledge and to manage outputs [9].

Finally, machine learning is being used for managing progressive improvement by enriching the decision tool knowledge base and by learning in different situations. Indeed, machine learning consists in repeating a behavior without programming it in the software tool but by designing and developing a system able to learn from existing examples and to solve new problems. It is composed of algorithms able to learn and to manage models from a data base. All hospital dispatching services have a management software tool with a data base which would be connected to the decision aided tool in order to improve the service performance

4. Existing structure: modeling and analysis

The elaboration of the existing structure requires interviews with the people concerned by the process and the modeling of the dispatching service. From this existing structure, solutions elaborated for solving the system dysfunctions are presented. To well understand the problem, it is important to know all steps of medicines and medical sterile devices dispatching flows.

Normally, they can be divided in two parts:

- preparation of the orders
- and delivering.

Most of the hospital services are concerned by medicines and medical sterile devices flows. These services are often ordering these products. The order preparation (figure 2) is made by the pharmacist. Medicines and medical sterile devices of each service are prepared in separated boxes and when all boxes are ready the pharmacist distributes them in trolleys. The dispatching in services is done by handlers who come to take trolleys when they are ready and bringing them back to the pharmacy as soon as possible. The following figure represents the process of order preparation.

Figure 2: Order preparation process

The second part of medicines and medical sterile devices dispatching flows is the delivering (figure 3). Handlers are responsible for this process which starts in the pharmacy depart zone. Handlers must analyze how many trolleys they have to dispatch and to which department boxes must be delivered. They can reorganize products to dispatch as they want. In addition to the loss of time, the diversification of efficiency could be really measured. As the number of orders increases, the trolleys distribution complexity grows up, and it becomes difficult for them to find the optimal distribution, knowing that the hospital have more than 50 services on different floors. After trolleys separation, have to deliver each box of the trolley in the hospital services as described in figure 4.

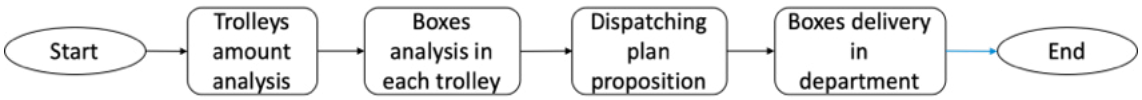

Figure 3: Medicines delivering process

Dysfunctions detected are mostly caused by the non-optimization of the whole process. As presented, the process of order preparation does not take in account the delivering process and pharmacists don't prepare orders by thinking about the delivery process. Then, the consequence is that handlers must lose time by thinking about the order distribution before making their dispatching. Having a connection between the two parts of the process is fundamental to eliminate dysfunctions.

The pharmacy does not have a process for following products dispatching and knowing if delivering times are respected. There is no product tracking. Then, the problem of medicines loss cannot be solved.

To optimize this flow the two parts of the process, preparation of orders and delivering must be connected. This means that technicians of the pharmacy must prepare boxes and trolleys by thinking about the distribution in the hospital services. The decision aided tool with allow to improve this link between both processes. The dispatching process has also to take into account the number of handlers available and how habit they have in the distribution process. The decisional aided tool will propose to calculate orders optimal preparation, trolleys optimal distribution in coherence with handlers, delivery optimal sequences and medicines optimal traceability.

4. The decision aided tool

The decisional aided tool being developed in Icam is based on artificial intelligence and will be able to improve medicines dispatching service.

This tool has to be able to eliminate inconsistencies in medicines dispatching processes and to reduce non-added value time (lead time optimization). Thus, for analyzing a dispatching service and helping its optimization, the tool must need data in inputs. These data will be transformed into outputs that can contribute to the service performance improvement.

The inputs required by the tool are:

- Medicines orders from each department;
- Location of each department in the hospital cartography (including pharmacy depart zone): the software will be able to calculate and simulate the optimal distribution of boxes and trolleys according to the department location and to find the best path that the handler should follow;
- The maximum number of medicines in a box: the software will be able to calculate how many boxes and trolleys are needed according to orders;
- The number of handlers: the software will be able to find the optimal distribution of trolleys to each handler;
- The validation of each order delivered.

The outputs of the tool are:

- Distribution of medicines in each box;
- Distribution of boxes in each trolley;
- Optimal way that each handler must follow;
- Information about the traceability of the medicines.

The software will be able to show the optimal distribution trolleys by knowing orders. It will calculate the number of boxes (from the maximum number of medicines in each box) that each department will need. From the number of handlers and the location of each department in the pharmacy cartography it will be able to calculate the optimal distribution of each trolley and the optimal way that each handler must follow.

Suggestions will be delivered to pharmacists during the boxes and trolleys preparation by the software. Instructions will be given to handlers by the software about which trolley they should take and which way and order of delivery they should follow.

The following figure (figure 4) shows more details on the software architecture and how it will be used for solving healthcare logistics problems.

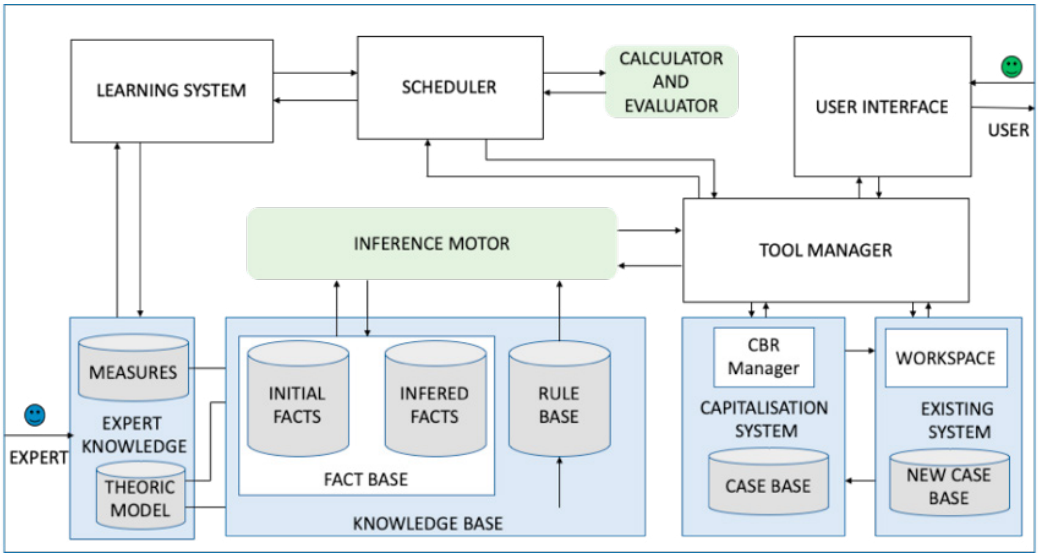

Figure 4: Architecture of the decision aided tool

The decision aided tool is composed of:

- A user interface interacting with users for introducing existing data according to the problem to solve and acquiring solution suggested by the tool.
- A tool manager for organizing the problem-solving process and giving solution to users. This module also contains, a blackboard for measuring KPIs (Key performance indicators) and managing changes.
- A kernel composed of a graphic editor for modelling the existing system and a database for capitalizing data related to the existing system.
- A capitalization system containing old cases solved by using the system

- An expert system composed of rule & fact bases and using an inference motor for solving problems related to the existing system.
- A learning system for elaborating new knowledge to be acquired by the aided tool.
- A scheduler for calculating and evaluating data associated to a new knowledge.
- And a knowledge module for continuing to acquire expert knowledge.

The decision aided tool has to be connected to the other information systems of the hospital in order to acquire data and to be coherent with the hospital global strategy. Problems as medicines traceability, orders preparation, flow optimization could be solved with this tool.

5. Illustration

For elaborating the decision aided tool, concepts and formalisms associated to this software were used on a real healthcare logistics case for validating them. In this case, data of the information system could come from other healthcare services.

As suggested in [10] the knowledge base is the most important module of an expert system because the software will only be able to solve situations which are covered by the knowledge base. The first step was to realize interviews with people working in a dispatching service for acquiring their knowledge and establishing rules that could be integrated in the software tool. From these interviews, data of the existing system were elaborated, but also generalizing reasoning was used for defining the ideal situation. Data associated to this ideal situation were put in the knowledge base. In this case, the knowledge base is composed of rules and facts. For instance, the definition in this case of N the maximum of medicines in each box could be transformed into a rule. Suggestion about possibilities of preparation by pharmacists would be be given to them by the tool. A problem of boxes optimization has to be solved but in coherence with trolleys problems and handlers charge and movements. Facts in the knowledge base are data given by the user (in this case the pharmacist). For instance, each service demand and historical data.

The inference motor will interpret rules and apply the best way (definition of the right quantity in each box). Data required for orders preparation could be transferred from the healthcare consultation system. Then, the adapted preparation will be suggested taking into account putting boxes of services that are geographically near in the same trolley and then suggesting the best path that each handler should follow to dispatching the boxes without wasting time.

In this case, the CBR base didn't contained sufficient cases for transmitting old cases as an aid. But the solution was obtained by using expert knowledge as new knowledge. The system will learn how to solve this kind of problem and capitalize the solution in order to reuse it later in similar situations. The solution will be presented to the user through the tool manager on the user interface (justification system in [10]) in a simplified language. The following suggestions will be done:

- optimal boxes distribution into each trolley;
- handler optimal way definition;
- trolleys distribution for each handler.

The medicines traceability is important to solve the problem of medicines loss. The traceability will be made in two parts:

- The first is when the pharmacist finishes to prepare trolleys (RFID puce).
- The second is when the handler delivers trolleys.

New regulations in Europe imposes to hospital (since February 2019) to check traceability of each medicine. Then an automated product scanning process is being defined from production reception to its distribution in services. In addition to the previous process, the tracking of boxes and trolleys has to be implemented.

Rules and fact elaborated for traceability are integrated in the expert system of the decision aided tool. As the software calculates and knows which medicines (and their quantity) are in each box and the number of boxes in each trolley, a schedule adapted to products dispatching is done by the scheduler and suggested to the handler. Data corresponding to the handler real distribution (could be different of the suggestion) will be recorded and integrate into the system as new knowledge. Then, products which were not distributed could be recorded and a notification would be sent to the handler. The dispatching service manager will also receive all this information. The software

will also require the validation of the service receiving boxes when a box is delivered by the handler. This system allows to control errors during distribution.

The pharmacist will start using the tool when he receives orders. The optimal preparation of orders in boxes and trolleys will be done with suggestions of the tool. Trolleys will be ranged by the pharmacist in the right place (depart zone) for the handler and after the validation by the pharmacist, the handler could start the use of the tool recommendations. The tool will directly show him which trolley he has to dispatch and the best way of distribution of each box to each service.

6. Conclusion

As presented in this paper, the dispatching service is very important for improving healthcare logistics. Indeed, the dispatching service is like a supplier for the other healthcare services. Products (toilet paper, syringes, needles), medicines, etc. are required in real time by each service. The project being developed concerns all these products but for this paper a focus was made only on medicines and medical sterile devices for explaining how dispatching service processes could be optimized.

The most important flows in a hospital are medicines and medical sterile devices dispatching flows. The impact of these flows on the performance of each service is high. Handlers have to dispatch these products from the pharmacy to the other services and their tasks and movements have to be optimized. The task of dispatching can be really complex, and hospitals can have more than 50 services spread across different floors.

The management of other flows has to be combined with medicines flows for improving globally healthcare logistics. This corresponds to the next step of this project: integration of all flow data in the decision aided tool for giving a global improvement. As described in [5], decomposition reasoning could be used for finding the optimum of each sub-system and re-composition reasoning would be used for defining the global optimum.

The real case shows that inconsistencies and non-solved problems are numerous in healthcare logistics. Due to the importance of medicines for patients, it is incredible to notice all these dysfunctions in products dispatching. The definition of healthcare logistics 4.0 will allow to use new technologies for aiding operators of the logistics chain in their tasks and increasing the dispatching quality.

Artificial intelligence (multi-agent systems, expert system, machine learning) was used to create a decision aided tool to solve these problems. This tool will be adapted for integrating all flows in the hospital and other new technologies. The solution proposed in this paper enables the improvement of this service insuring patient safety and satisfaction, but also helping doctors and workers for being confident and efficient in their job.

References

[1] G. Doumeingts, Y. Ducq, B. Vallespir, S. Kleinhans, Production management and enterprise modelling, Computer in Industry 42 (2000) 245-263.

[2] H.R. Jorysz, F.B. Vernadat, CIM-OSA, part 1: total enterprise modelling and the function view, International Journal Integrated Manufacturing, Vol. 3 and 4, (1990) 144-156.

[3] Th. J. Williams, The Purdue enterprise reference architecture, Computer in Industry, Vol. 24 (2), (1994) 141-158.

[4] P.E. Dossou, Impact of sustainability on the supply chain 4.0 performance, in Procedia Manufacturing, v. 17, (2018) 452-459, Elsevier.

[5] P.E. Dossou, M. Nachidi, Modeling Supply Chain Performance, Procedia Manufacturing 11C (2017) 838-845, Elsevier.

[6] A. Aamodt, Case-Based Reasoning: foundational issues, methodological variations, and system approaches, Artificial Intelligence Communications, 7, (1), (1994) 39-59.

[7] Ferber, J. Multi-agent system: An Introduction to distributed Artificial Intelligence, Harlow, Addison Wesley Longman, ISBN 0-201-36048-9

[8] S. SEN, G. WEISS, Learning in Multiagent Systems, G. WEISS, Ed., Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence, Chapter 6, The MIT Press, Cambridge, MA, (1999) 259-298.

[9] J. P. Poli, L. Boudet, A fuzzy expert system architecture for data and event stream processing, Fuzzy Sets and systems 343 (2018) 20-34, Elsevier.

[10] H. Grossmann Júnior, Um sistema especialista pra auxílio do diagnóstico de problemas em computadores utilizando raciocínio baseado em casos, (2002).