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HOW COMPUTER SCIENCE UNDERGRADUATE PROGRAMS IN BRAZILIAN PUBLIC UNIVERSITIES ADRESSARTIFICIAL INTELLIGENCE AND ITS TOPICS: A PRELIMINARY REPORT

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Abstract-Artificial Intelligence (AI) is a relatively new research area in computer science. Nevertheless, AI seems to be more frequently integrated in the computer-based solutions proposed nowadays. Furthermore, AI techniques have increasingly being used in the professional market. In 2005, the Brazilian Computer Society proposed curriculum guidelines for undergraduate degree programs that have computing as core subject. That document recommends a number of knowledge areas that computing related programs must approach in their undergraduate courses. This set of knowledge areas is quite large and Artificial Intelligence (AI) is one of them. However, the experience of several lecturers, who teach in computer science undergraduate courses, shows that students have some difficulty in understanding or applying AI concepts. In this work, we present the initial results of an investigation abouthow undergraduate Computer Science programs in Brazilian public universities approach AI and its topics. For this purpose, we analyze the curricula of undergraduate programs in Computer Science in Brazilian public universities, with regard to the courses that fall in the AI knowledge area. Furthermore, we discuss the use of AI tools, methods and techniques by students and computing professionals in the Brazilian market; and the vision of some professors of undergraduate and graduate courses regarding AI topics. At the end, we also highlight how some of the best universities in the world tackle AI and its topics in their major degree in Computer Science.

Keywords-Artificial Intelligence, Education in Computer Science, Computer Science Professional Profile.

1 Introduction

Artificial Intelligence (AI) is a relatively new research area in computer science. In fact, this term was coined only in 1956. However, the AI basis was set hundreds of years ago, and they derive from well-established sciences like mathematics, philosophy, linguistics, psychology and biology. At first, the goals of the works within the AI area were quite ambitious, such as allowing the construction of computer programs to play chess or creating a general problem solver to solve logical problems of any kind. The optimism of the researchers in the area was enormous. By that time, forecasts indicated that in a few years computers would be at least as smart as human beings. Hence, computers would be capable of performing tasks such as winning a chess world championship, translating Russian to English perfectly, or driving a car through a busy road. Although, in the last years, some success has been achieved ontackling these problems, obviously a computer that can be described by anyone as reasonably intelligent has not yet been designed [Coppin, 2012].

For approaching such complex problems, AI was divided into several sub-areas of knowledge, among which we can mention some of particular importance: machine learning, multi-agent systems,artificial life, computer vision, natural language processing and planning. Nowadays, AI is around us all the time, in different forms. One can mention, among many other applications:

- The use of fuzzy logic applied in embedded devices that control various machines such as washing machines, cars, elevators, etc;
- The use of machine learning techniques in search engines in the internet or in recommender systems;
- The use of intelligent agents to scour the internet in search of documents;
- The use of natural language processing in tools for writing documents; and

- The use of AI in games.

Nevertheless, AI, hitherto addressed in the sub-areasseparately,seems to be increasingly integrated in the recently built solutions, which are basedon the available AI methods and technologies. Furthermore, AI techniques have increasingly being used in the professional market. For example, there are researches focusing on: the representation of knowledge for the Semantic Web applying machine learning for patternand knowledge extraction [Brusilovsky*et al.*, 2007]; the use of machine learning techniques for mining graphs [Aggarwal and Wang, 2010]; the use of machine learning for computer vision [Gong *et al.* 2000]; the use of evolutionary algorithms in machine learning[Bernardini*et al.*, 2008]. This does not mean that these products are smart, but they allow such products to have a more intelligent action. Nowadays, researchers still argue that AI sub-areas, such as machine learning, also known as pattern detection or analytical prediction, will lead the new wave of innovation[Manyika*et al.*, 2011].Also, diverse engineering, medical, geological and other knowledge areas make use of AI techniques and methods, what increases the importance of development of complex software solutions, which includes the use and implementation of AI techniques. In fact, the importance of AI has grown exponentially in recent years, making increasingly necessaryto strengtheneducation and training in this area of knowledge.

The Brazilian Computer Society have proposed curriculum guidelines for undergraduate degree programs that have computing as core subject, such as Computer Science, Computer Engineering and Information Systems [SBC 1996, SBC 2003, SBC 2005]. [Ramalho 1997] discusses the situation of AI in curricula of Brazilian undergraduate degree, based of SBC reference curriculum of 1996 [SBC 1996]. In that curriculum reference, AI was a technology discipline, what indicated, for [Ramalho 2007], that AI had minor importance from the SBC perspective. Analyzing the SBC curriculum reference of 2005, AI remains a technology discipline. However, according to this document, computer science graduates must be able to apply their knowledge in an innovative way, following the evolution of the sector and contributing to find solutions in different applied areas. [SBC 2005] also recommends a number of knowledge areas that computing related programs must approach in their undergraduate courses. This set of knowledge areas is quite large and AI is one of them. The document states that the content to be covered in each knowledge area may vary in depth and width, depending on each program's profile and what are the expected skills for the professionals graduating in such programs. Thus, undergraduate programs may cover the AI knowledge area in only one required course or in several elective courses.However, the experience of several lecturers, who teach in computer science undergraduate courses, shows that students have some difficulty in understanding or applying AI concepts.

In this work, we present the initial results of an investigation into the addressing of AI in undergraduate Computer Science programs in Brazilian public universities. For this purpose, we analyze the curricula of undergraduate programs in Computer Science in some Brazilian public universities,with regard to the availability ofcourses that fall in the AI knowledge area. This analysis is presented in Section 2. Furthermore, we applied questionnaires to investigate (i) the vision of some professors of undergraduate and graduate courses regarding AI topics; and (ii) the use of tools, methods and techniques in the field of AI by students and computing professionals in the Brazilian market.Details of the survey we used are presented in Section 3. The answers collected by these questionnaires, as well as the respective analysis, are discussed in Section 4. Finally, Section 5outlines some conclusions and some possible initiatives that can be undertaken in the future.

2. Preliminary Analysis

Initially, we carried out a survey regarding the number of courses related to the AI knowledge area in Computer Science degree programs ata numberof public universities in Brazil. We opted for the public universities because in the national assessment of degree program in Brazil [Schwartzman, 2009], the Computer Science degree programs in public universities are the better evaluated. We selected the programs who presented in their websites the information on their curricula. The selected ones were UNB,Unicamp, UFMA,UEM, UEPB, UNESP/Rio Claro, UERJ, UFSC, IME/USP; ICMC/USP; UFBA; UFC; UFJF,IC/UFF; ICT/UFF; UFMG; UFOP; UFPR; UFPE; UFRJ; UFRN; UFRGS; UFSCAR; UFSM and UFV. Figures 1 and 2presents a summary of the survey, where Figure 1 shows the number of AI requiredcourses (horizontal axis)per number of programs (vertical axis), and Figure 2 shows the number of AI elective courses (horizontal axis) per number of programs (vertical axis).In these graphs, "Unknown" means that, for three courses, we could not evaluate the information of how many AI courses these programs have, evaluating only their curricula available on the internet.

We can observe, from these graphs, that most degree programs (18) offer just one required course on AI. On the other hand, a large number of programs (11) have no elective course, a significant number of programs (6) have just one elective course, and less than half of the degree programs have two or more elective courses. We also counted the number of programs per each pair of required and elective AI courses. Table 1 shows each possible pair of number of required and elective AI courses and the number of degree programs. For instance, line 1 of Table 1 shows that 3 degree programs offers 0 required and 1 elective AI courses. In this table, we can notice that the biggest number of degree programs (10) have one required course and no one elective course. Besides, every degree program has at least one required or elective course. It is also worth to mention, from the collected data, that both the Computer Science programs from UFRGS and ICMC/USP offer a considerable amount of courses in the field of AI – one required course and five elective courses. At UFRGS, we could observe a large number of elective courses that have as prerequisite a required AI course. At ICMC/USP, AI elective courses are offered depending on the program emphasis. Note that such information was collected from the sites of the Computer Science degree programs from the

two universities, and so it may be not update.

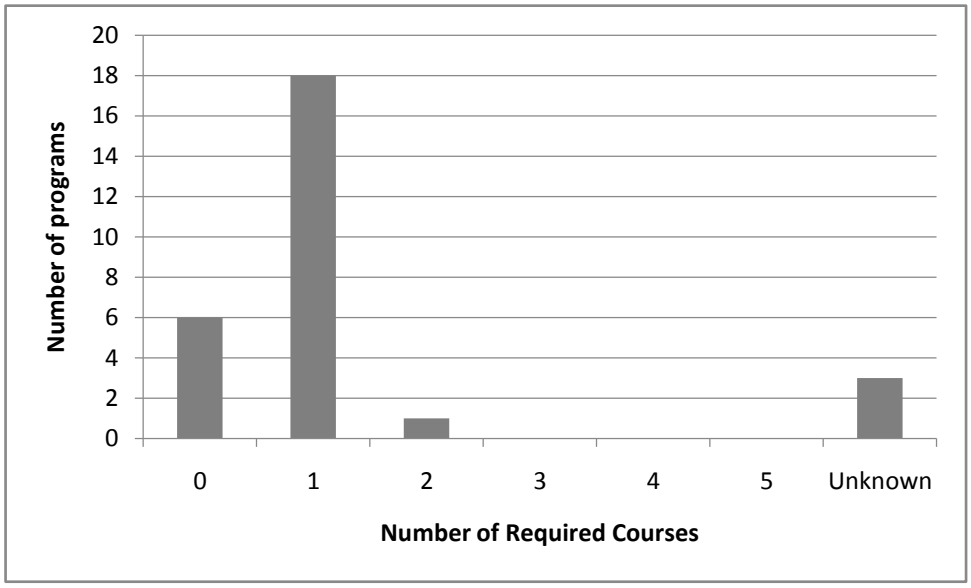

Figure 1 – Number of degree programsversusthe number of requiredAI courses

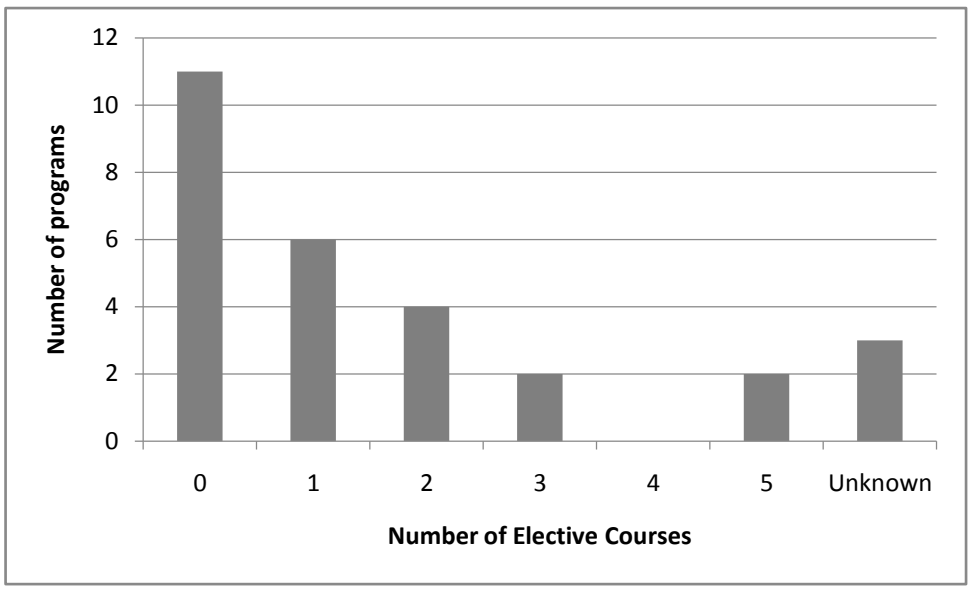

Figure 2 – Number of degree programs versus the number of Elective AI courses

Table 1.Each possible pair of number of required and elective courses and number of degree programs by each pair

Pair: Required and elective courses	Number of degree programs by possible pair
(0, 1)	3
(1, 0)	10
(0, 2)	1
(1, 1)	3
(2, 0)	1
(0, 3)	2
(1, 2)	3
(1, 5)	2

We also evaluated the syllabi of the requiredAI courses in UFMA; UEM; UFSC; ICMC/USP; UFBA; UFC; UFPR; UFPE;

UFRJ; UFRGS and ICT/UFF. With focus only on the syllabi of introductory AI courses available in the website of theseuniversities, we took into consideration just the most comprehensive syllabi, and more complete descriptions of the goals of the courses. We selected some broader topics in the area of AI, and checked which of the topicswere approached in each syllabi. The selected topics were: Evolutionary Algorithms; Machine Learning; PROLOG and / or LISP programming languages; Fuzzy Logic; NLP;Neural Networks; Knowledge Based Systems and Expert Systems; Multi-agent systems (MAS); Computer Vision; and Planning. At first, we observedthat there were some leansyllabi, which can be interesting for the student to have a general insight on some topics. On the other hand, we observed some very extensive syllabi, which hardly allow the undergraduate student to have a more detailed insight into at least some of the topics. Table 2 shows the distribution of topics in the syllabi of courses of such programs.

Table 2. Number of syllabi of required introductory AI courses in which each topic appears.

Topic	Number of syllabi
Evolutionary Algorithms	2
Machine Learning	7
Heuristic Search	8
PROLOG and / or LISP	4
Fuzzy Logic	3
Natural Language Processing	3
Neural Networks	5
Knowledge Based Systems and Expert Systems	10
Multi-agent systems (MAS)	4
Computer Vision	0
Planning	3

One can note from this table that the subject “Computer Vision” is not mentioned in any of the syllabi, which is natural because it is an area of AI that has large intersection with other subfields of computing, such as Computer Graphics. Moreover, the theme “Knowledge Based Systems and Expert Systems” and “Heuristic Search”are contained in most curricula, followed by “Machine learning”.

3. Survey Methodology

To investigate (i) the vision of some professors of undergraduate and graduate courses regarding to AI topics; and (ii) the use of tools, methods and techniques in the field of AI by students and computing professionals in the Brazilian market, we developed two (2) questionnaires. The former was created to be answered by graduate and/or undergraduate professors in the computing area, and the later were to be answered by students and/or professionals in computing[1].Both questionnaires were created based on [Bryman& Bell, 2011] methodology. In the questionnaire for professors, there were ten (10) questions, among them eight (8) closed questions and two (2) open questions. The questions were:

1. **In which undergraduate and/or graduate program(s) do you teach?**Closed question, with a choice of one of the following options: Undergraduate program in Computer Science, Undergraduate program in Information System, Undergraduate program in Computer Engineering Undergraduate, Graduate program in Computer Science (Academic), Graduate program in Computer Science (Professional); Graduate program in Computer Science (Other); Others.
2. **Howdo you assess yourself as an expert in Artificial Intelligence?**Closed question with answer based on a 5-points Likert scale [Likert, 1932], where 1 means “I only know the basics” and 5 means “I am fromthe AI area”.
3. **How many required courses in the area of Artificial Intelligence exist in the undergraduate program(s) in which you teaches?**Closed question, for choosing a single item, which can be: “1”, “2”, “3”, “4 or more”.
4. **In how many required or optional courses in the area of Artificial Intelligence did you participate?**Closed question, for choosing a single item, which can be: “1”, “2”, “3”, “4 or more”.
5. **At which level the following topics are covered in the undergraduate program(s) in which you teach?**Closed question of the grid type. Respondent should indicate from the following options, which is the most appropriate for each topic: 0-Not mentioned; 1- Mention that it exists; 2-I go into some detail; 3-I go into too much detail; 4-My goal is to form experts. The topics presented were: Heuristic search algorithms (A *, Branch and Bound, Best-First, etc.); LISP or Prolog programming languages; Knowledge Based Systems and Expert Systems; Machine Learning; Neural Networks; Fuzzy Logic; Evolutionary Algorithms; Multi-Agent Systems; Computer Vision; Natural Language Processing; Planning.

[1]The questionnairesare available at the address http://www.puro.uff.br/questionarioia.

6. **Among the following books, which do you prefer to adopt?**Closed question with a choice of one or more of any editions of the following items:
    a. Artificial Intelligence, Russel and Norvig (*in Portuguese*) [Russel and Norvig, 2004];
    b. Expert Systems, SolangeRezende (*in Portuguese*) [Rezende, 2003];
    c. Artificial Intelligence – A Machine Learning Approach, Facelli, K. et al (*in Portuguese*) [Facelli*et al*, 2011];
    d. Artificial Intelligence– General Concepts, Anita Maria da Rocha Fernandes (*in Portuguese*) [Fernandes, 2003];
    e. Fundamentals of Artificial Intelligence, João Luís Garcia Rosa (*in Portuguese*) [Rosa, 2011];
    f. Artificial Intelligence, Ben Coppin (*in Portuguese*) [Copin, 2012];
    g. Other titles in Portuguese;
    h. Other titles in English, because those in Portuguese do not meet my expectation.
7. **Recommend other bibliographic items that you find interesting for undergraduate courses.**Open question.
8. **What is the reason for your preference for the bibliographic material selected or recommended?** Open question.
9. **If you pointed at some of the topics that you expect your students to become experts, do you use practical examples for this purpose?** Select "Yes" or "No".
10. **If you answered "Yes" in the previous question, how difficultis finding practical examples and/or case studies?**Closed question with answer based on a 5-points Likert scale [Likert, 1932], where 1 means "Very difficult" and 5 means "I findeasily".

Question 1 aims to evaluate if the professors working in undergraduate Computer Science courses also work at graduate programs. It is worth to mention that in Brazil we have three types of graduate programs: academic, which have master and doctorate academic degrees; professional, which has professional master degree; and others neither academicnor professional, which we call here as *latosensu*programs. Question 2 aims to evaluate how much a professor respondent considers itself an expert in AI. Question 3 aims to know how much courses exist in the undergraduate program the respondent works at. Question 4 aims to know how much courses the respondent is responsible for. Question 5 aims to evaluate in what depth each AI topic is addressed in its undergraduate courses. Questions 6, 7 and 8aims to observe if there are some title preferred by the professors, and if the available books in Portuguese are sufficient for their courses. Questions 9 and 10 aims to evaluate how much practical their courses can be.

The questionnaire created for students and professionals, had eight (8) questions, with six (6) closed questions and two (2) open questions:

1. **What is the undergraduate program that you are attending or have finished?** Closed question, with a choice of one or more of the following: Undergraduate program in Computer Science, Undergraduate program in Information System, Undergraduate program in Computer Engineering, Graduate program in Computer Science (Academic), Graduate program in Computer Science (Professional); Graduate program in Computer Science (*LatoSensu*); Others.
2. **How long ago have you finished your last course in computing (undergraduate or graduate)?**Closed question with choice of one of the following: I am doing; Between 0 and 2 years, 2 to 5 years; Between 5 and 10 years and for over 10 years.
3. **Indicate whether you work or worked in some of the following functions.**Closed question, with the choice of one or more of the following options: Development/Programmer, System Analyst, Project Manager, Researcher in anycomputing area (excluding acting as a graduate student); Researcher in theArtificial Intelligence area (excluding acting as a graduate student).
4. **Among the topics that you know...**Closed question of the grid type. The respondent must indicate from the following options, which are the moreappropriate for each topic: 0-Never applied and unaware of possible applications; 1-Never applied, but envision applications; 2-Never applied, but I will apply soon; 3-I applied and have not had the desired results; 4-I applied and the application was successful. The topics presented were: Heuristic search algorithms (A*, Branch and Bound, Best-First, etc.); LISP or Prolog programming languages; Knowledge Based Systems and Expert Systems, Machine Learning, Neural Networks, Fuzzy Logic, Evolutionary Algorithms, Multi-Agent Systems, Computer Vision, Natural Language Processing; Planning.
5. **If you applied some of the techniques and not succeeded as desired (option 3 from the previous question), briefly describe why.** Open question.
6. **From the books in the area of Artificial Intelligence below, to what degree do you know and found easy to understand each one?**Closed question, with the choice of one of the following options: 0-Never heard; 1-I've seen but I don't know it in deep, 2-I know from having seen a few topics; 3-I know but I think that reading is not trivial; 4-I know, I like it and recommend! The titles presented were: (a) Artificial Intelligence, Russell &Norvig (Ed. Elsevier), (b)Expert Systems, Rao (Ed. Manole). Only these two were cited, as these are the titles published in Portuguese in the last 10 years most indicated in the bibliography of undergraduate programs.
7. **Tell other bibliographic sources in the area of Artificial Intelligence that you have used and would like to emphasize.** Opened question.
8. **In which states of the country you work or has worked before.**Closed question, where the respondent can answer

"not yet work" or indicate one or more states.

Although the report focuses on Computer Science, the question 1 was created to allow that students and professionals in computer-related areas also had some experience in AI topics. Question 2 aims to evaluate how much time the professional is in the labor market. Question 3 aims to evaluate the position occupied by the professionals. Question 4 aims to evaluate how much the professional masters the knowledge of each topic. Question 5 aims to evaluate how much success the professional (or student) obtained applying each topic (if any). Question 6 aims to evaluate how difficult a student or professional believes each bibliography item is to be understood, if known by the respondent. Question 7 is an open question to the respondent point out some interesting bibliography. Question 8 aims to analyze from which region of Brazil the students and/or professionals are from.

These questionnaires were sent to thediscussion list of the Brazilian Computer Society (sbc-l@sbc.org.br), to the discussion list of the Brazilian HCI special interest group (ihc-l@sbc.org.br), to the list of computingtutors of CEDERJ Foundation (tutores-comp@lists.cederj.edu.br) and to the discussion list of the AI special interest group (ceia-l@sbc.org.br) in January of 2013. We collected our data until May of the same year. Some questionnaires were also sent to several students from different federal universities. In the subsection below, wepresent summaries of the responses collected, and an analysis of these responses.

4. Summary and analysis of responses

A total of 75 people responded to the questionnaires, 38 professors and 37 students and computing professionals. In this section we summarize the results listed for each group that answered the questionnaire[2].

Group of professors

Question 1:Table 3 shows the distribution of professors pertype of program. As people could select more than one option in this matter, the sum of responses is greater than the number of people who responded to the questionnaire. We can observe from this table that the majority of professors work in undergraduate Computer Scienceprograms and in strictosensuComputer Science graduate programs.

Table 3.Distribution of professors per type of program.

Type of program		Respondents
(i)	Undergraduate program in Computer Science	19
(ii)	Undergraduate program in Information Systems	17
(iii)	Undergraduate program in Computer Engineering	13
(iv)	Graduate program in Computer Science - Academic	19
(v)	Graduate program in Computer Science - Professional	2
(vi)	Graduate program in Computer Science (*lato sensu*)	4
(vii)	Others	7

Question 2: When questioned what level of expertise of the professor in the field of AI, on a scale of 1 to 5, 76% replied that they were at levels 4 or 5, indicating that the majority of respondents are researchers in the AI area.

Question 3: On the issue of the number of required courses for the undergraduate programs where the professors works, from 38 professors, 30 responded that there is onerequiredcourse; 5 responded that there are two (2); 2 responded that there are 3 (three); and none responded that there are 4 (four) or more.

Question 4: On the issue of the number of courses of AI in which the professor has acted, undergraduate or graduate, 9 respondents who participated in four (4) or more courses; 4 respondents participated in three (3) courses;8 participated in two (2) disciplines and 16 in only one (1) discipline. These data are in the survey conducted on the sites of courses in Computer Science, showing that professors work in more than one discipline of AI in many situations, but only a required subject AI is offered to undergraduate courses.

Question 5: On the question on the topics covered in undergraduate courses in which the professor works, Figure 3 illustrates the distribution of answers related to depth of addressing AI topics in undergraduate courses. We can observe in this figure what follows: The topics "Lisp and Prolog languages" and "Computer Vision" are not mentioned by many professors, which is expected because they are topics that might intersect with other areas of knowledge of computing. The subjects with the highest number of professors who responded that go into many details were "Machine Learning", "Heuristic Search", "Neural Networks", "Knowledge Based Systems and Expert Systems". The topic"Fuzzy Logic" is approached by many professors,

[2]At http://www.professores.uff.br/fcbernardini/papers/compl/IABrasil/Graficos_Questionario.pdf all figures obtained for each question in each of the groupscan be seen.

some with many details and so many others with few details. All these topics are expected to be approched with many details to students, since they involve the foundations of AI. Theme "Multi-agents Systems" is only mentioned by some, and by others

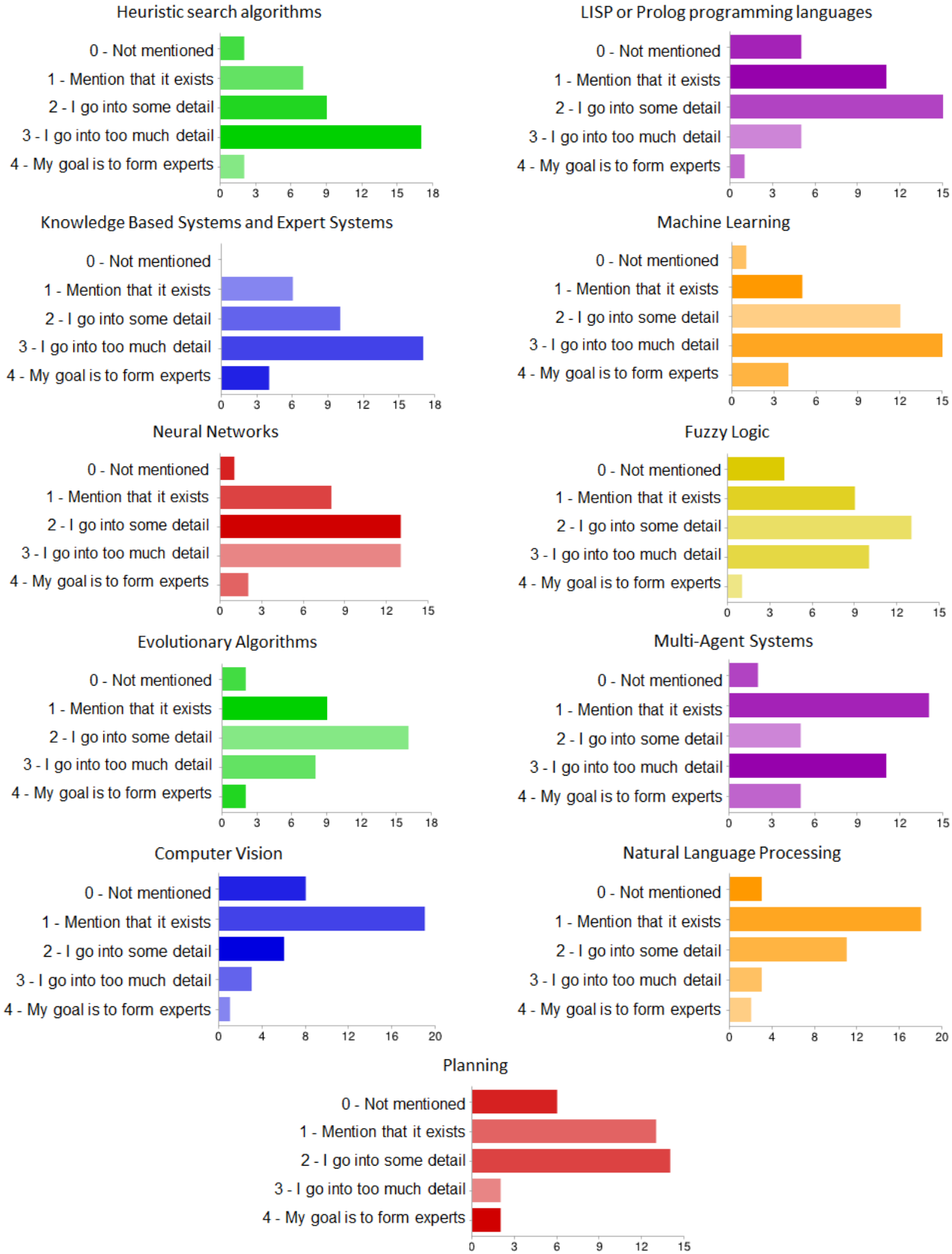

Figure 3 – Degree of each AI topic addressed by the respondent professors in its undergraduate courses

is explained in great detail. The theme "Natural Language Processing", the largest number of professors only comments that exists. Finally, the theme "Planning", only twelve (12) comment that it exists, and thirteen (13) go into some details. Such a result is also expected, because due to the short time available, the professor often address topics that holds more knowledge or going against your search area.

Questions 6, 7 and 8: As to the bibliographies used, 35 professors use the book Artificial Intelligence, by S. Russel and P. Norvig; 19 professors cited other titles in Portuguese; and 15 said they use other bibliographic materials in English, because there is no adequate material in Portuguese. We think that it is important to motivate the publication of texts in Portuguese for undergraduate students.

Questions 9 and 10: We also challenged the use of practical examples in disciplines for purposes of specialization. While 29 professors said they use such examples, but only 2 said they find such examples with ease (level 5), and 3 said they have a hard time to find them (level 1), and the rest answered the had moderate difficulty (levels 2, 3 and 4). Difficulty in finding practical examples may be related to the complexity of such examples. Thus, initiatives for sharing practices of various techniques and methods of the area in English samples (due to the difficulty of the language for undergraduate Students) may be interesting.

Group of students and/or professionals

Questions 1 and 2:Table 4 depicts the distribution chart of training in different computer courses. The largest number of respondents who answered the questionnaire completed the bachelor's program in Computer Science and Graduate program in Computer Science strictosensu. As people could select more than one option in this matter, the sum of responses to each item is greater than the number of people who responded to the questionnaire number. For how long the respondent completed his last course, 20 of them said they are still studying, which indicates that many are still students.

Table 4.Distribution of students/professional per type of program.

Type of program	Respondents
Undergraduate program in Computer Science	19
Undergraduate program in Information Systems	17
Undergraduate program in Production Engineering	13
Graduate program in Computer Science - Academic	19
Graduate program in Computer Science - Professional	2
Graduate program in Computer Science (*lato sensu*)	4
Others	7

Question 3: On the question of occupied positions and/or areas of expertise of respondents in this category, we obtained the following distribution: (i) 31 (82%) as Development/Developer; (ii) 15 (39%) as Systems Analyst; (iii) 4 (11%) as Project Manager; (iv) 10 (7%) as Research in the area of computing (excluding performance as a graduate student); (v) 7 (18%) as a researcher in AI (excluding performance as a graduate student).We observed that a large number acted as developer.

Question 4 and 5: Figure 4 shows the distribution of answers by each AI topic. On the issue level of knowledge on different topics of AI, for the theme "Evolutionary Algorithms", eight (8) selected option 0 (zero), 17 selected option 1 (one), but 11 selected option 4 (four). The theme "Machine Learning", 15 selected option 4 (four), although another 11 selecting option 1 (one). The theme "Heuristic Search", it is remarkable that 18 selected option 1 (one), and only six (6) selected option 4 (four).'s Also remarkable the high number of people who selected options 0 (zero) and 1 (one) to themes "PROLOG and / or LISP", "Fuzzy Logic", "planning", "Natural Language Processing", "Knowledge Based Systems and Expert Systems", "Multiagent Systems" and "Computer Vision". As to the theme "Neural Networks", although many have selected option 1 (one), many selected option 4 (four), which is expected as it is a subfield of AI that has many methods, techniques and tools applied in many areas of knowledge. These figures illustrate the need to take more such knowledge to undergraduates and professionals in computing, including more application possibilities.

Question 6 and 7: As to the books, we asked only about two titles edited in the last 10 years, which were [Russel and Norvig, 2004] and [Rezende, 2003]. The first title was chosen to be a global benchmark of AI for undergraduate and graduate students; and second, by having professors involved in the field of various parts of the country. Six people said they never heard of the book [Russel and Norvig, 2004] and 18 said the same about the book [Rezende, 2003].

It is important to note in the analysis of these four last questions, that reference materials and important topics in this area are unknown by many, which can lead to lack of technological development, and put in risk the continued strengthening of research in this area.

Question8: Regarding the distribution of responses by states, including students and professionals, seven people have responded that they had not yet acted professionally, a person acted in AL, two (2) in CE, five (5) in MG, one in PE, 8 (eight) in RJ, three (3) in RN, 3 (three) in RS, 8 (eight) in SP. In the other states of the country, there were no respondents.

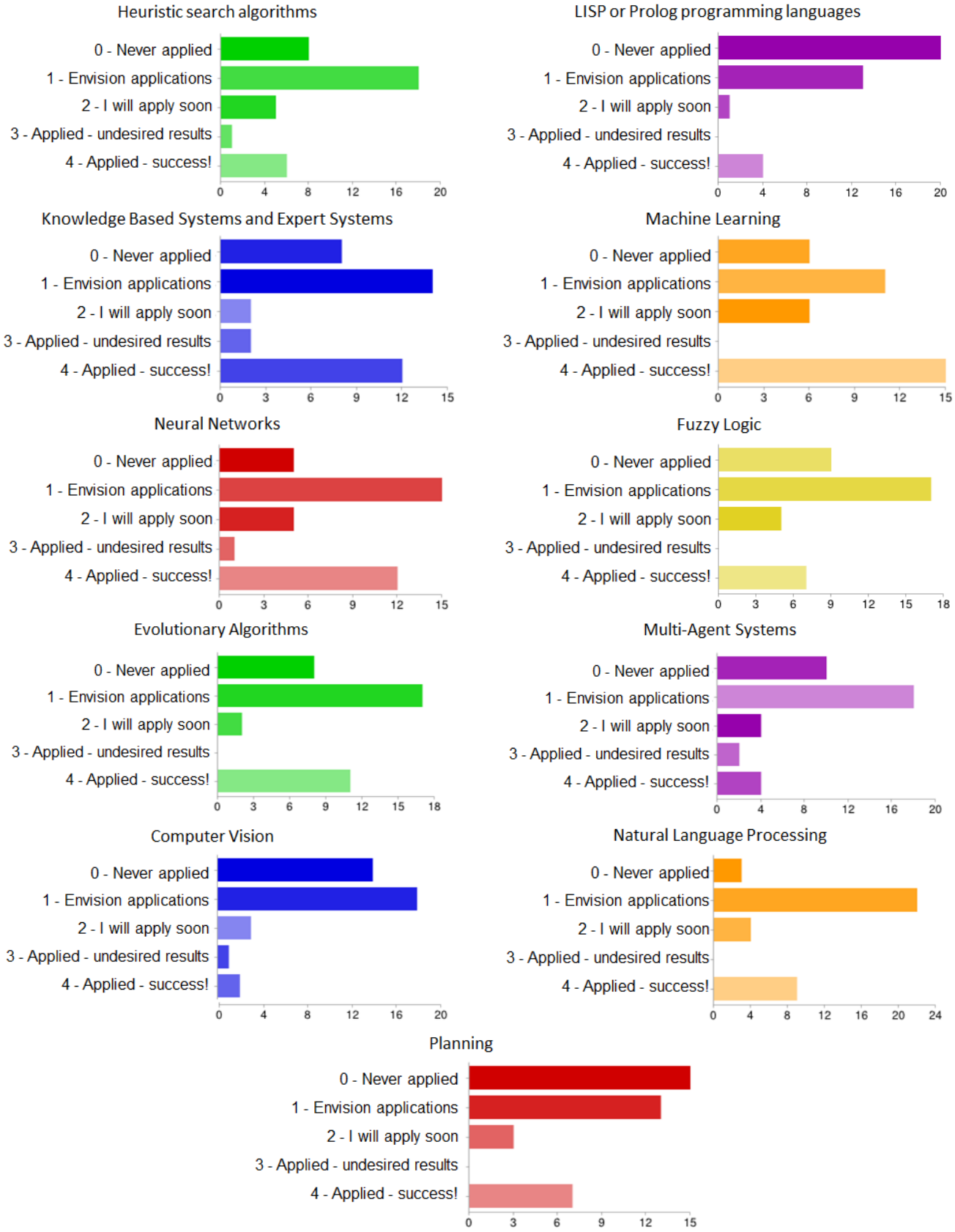

Figure 4 –Degree of knowledge of each AI topic by each student and/or professional respondent

5. Importance of AI in Brazil and in the Best Universities in Computer Science around the World

Controversially to low addressing of AI by undergraduate courses in Brazil, we can observe that AI importance is reinforced by the fact that AI is a research area presented in many Brazilian universities, and is a research area in all, except one, important graduate programs in Brazil. The Coordination for Improvement of Graduate Staff (CAPES) of the Brazilian Ministry of Education (MEC) is responsible for evaluating the graduate programs in Brazil. The grades vary from 3 to 7 to be considered recommended by CAPES. We consider that best programs in Brazil are the ones that receive 6 or 7 grades [CAPES 2014]. The programs that receive grade 6 or 7 from CAPES and AI is a research area are from the following Institutes and/or Universities: IME/USP – Institute of Mathematics and Statistics at São Paulo State University – ["Computer Science Graduate Program at IME/USP", 2014]; UNICAMP – Campinas State University – ["Computer Science Graduate Program at UNICAMP", 2014]; UFMG – Federal University of Minas Gerais – ("Computer Science Graduate Program at UFMG", 2014); UFPE – Federal University of Pernambuco – ["Computer Science Graduate Program at CIN/UFPE", 2014]; ICMC/USP – Institute of Mathematics and Computer Science at São Paulo State University – ["Graduate Program in Computer Science and Computational Mathematics at ICMC/USP", 2014], UFRGS – Federal University of Rio Grande do Sul – ["Computer Science Graduate Program at UFRGS", 2014]; and UFRJ – Federal University of Rio de Janeiro – ["Computer and Systems Engineering Program at COS/UFRJ", 2014]. Only PUC-Rio – Pontifical Catholic University of Rio de Janeiro – ["Graduate Program in Informatics at PUC-Rio", 2014] does not have AI as a research area.

[Ramalho 1997] presents how AI was addressed by the seven best computer departments around the World, which are located in USA and England. Table 5 replicates the information presented by the author. We can observe that only Oxford had only one required AI course, against the minimum of three courses at the other universities, although Carnegie Mellon only ofeered in that time optional AI courses.

Table 5. Number of required and optional AI courses in Computer Science curricula of the seven best universities around the World in 1997 [Ramalho 1997].

Course	AI Required and Optional Courses
Massachusetts Institute of Technology (MIT)	3 Required and 4 Optional
Stanford University	10 Required and Optional
Carnegie Mellon University	4 Optional
University of California, Berkeley (UCB)	4 Required and Optional
University of Cambridge	4 Required and Optional
Imperial College London	4 Required and Optional
University of Oxford	1 Required

Nowadays, according to QS World University Rankings in Computer Science & Information Systems, published in 2013 [QS 2013], the seven best universities are also located in USA and in England, and they are: Massachusetts Institute of Technology (MIT), Stanford University, University of Oxford, Carnegie Mellon University, University of Cambridge, Harvard University and University of California, Berkeley (UCB). Compared to the former list, Imperial College London nowadays appears in 17th place, and Harvard now appears in the best-seven list. In what follows we summarize how each of them addresses AI area:

MIT shows a lean curriculum ["Computer Science and Engeering Undergraduate Program at MIT", 2014], with two disciplines of AI that can be chosen by the student of one required discipline of AI (Artificial Intelligence or Introduction to Machine Learning). However, is worth to note that AI is in the core of Computer Science and Engineering curriculum, showing that AI is important for the course;

- The undergraduate major in Computer Science (CS) at Stanford treats each CS areas as course tracks ["Undergraduate Major in Computer Science at Stanford University", 2014], and AI is one of these tracks.
- The Oxford undergraduate major in Computer Science offers only optional AI courses ["Undergraduate Major in Computer Science at Oxford University", 2014], but in 3rd and 4th year all courses are optional.
- The undergraduate major in Computer Science (CS) at Carnegie Mellon University offers elective for Artificial Intelligence or Computer Vision – the student can choose only one of them["Undergraduate Major in Computer Science at Carnegie Mellon University", 2014]. However, they offer Minor in Machine Learning, Minor in Robotics and Additional Major in Robotics in their undergraduate programs.
- The undergraduate major in Computer Science at University of Cambridge addresses Artificial Intelligence in 2nd year as belonging to a core of technologies and theories["Undergraduate Major in Computer Science at University of

Cambridge", 2014]. In 3rd year the student can choose the specialized courses in one of advanced areas, and AI is one of them.

- In the undergraduate major in Computer Science at Harvard University, AI is an elective course of the required courses in technical electives group, which are computer hardware, programming languages, systems, graphics and artificial intelligence["Undergraduate Major in Computer Science at Harvard University", 2014].
- The undergraduate major in Computer Science at University of California, Berkeley (UCB) is the only one major that is not clear the role of Artificial Intelligence, as can be seen at["Undergraduate Major in Computer Science at University of California, Berkeley", 2014].

In this way, we can observe that the leading universities in Computer Science around the world is paying great attention to AI area, indicating that in Brazil we should also reassess the importance and position of Artificial Intelligence in our undergraduate courses.

6. Conclusion

Artificial Intelligence is an area of expertise in computer science whose importance has grown in recent years in the business environment. However, it is arguable how much graduates in computer science and similar programs know and can fully apply the knowledge and technologies in the AI area, as it is a reasonably wide area of knowledge. In this work, we discussed the results of an initial investigation on the topics of AI, which areapproached in undergraduate computer science courses, and how such content is understood and used by students and computing professionals.

The professionals working in AI knowledge area are aware that the content in the area is vast [Coppin, 2012; Russel and Norvig, 2004]. It was observed from the figures obtained in the surveys that many AI topics are not covered in undergraduate computer sciencedegree programs. Moreover, even for widely discussed topics, there are many students and professionals,whofind out previously unknown applications for such issues. These figures may indicate that AI still needs to be more widespread among students and computing professionals, to be more widely exploited. One possibility is to encourage specialization courses related to the AI area in general. Also initiatives such as the one of Computer Science degree program at ICMC/USP, where computer science graduates can take courses with emphasis in some area of computing.

We also analyzed some curricula of the best universities in Computer Science around the world, and we could observe that some of these courses treat some machine learning areas as minor bachelor degree,beyond major degree in computer science. Other universities address Artificial Intelligence as an area to be chosen in major degree in Computer Science. These are interesting alternatives to increase the number of AI specialists in Brazil to improve our technology development in this area.

To improvethis study, we need that more data be collected both in academia, with graduate students inComputer Science degree programs, and in the professional environment, for a more effective evaluation of how professional in ICT (Information Technology and Communication) companies see the applicability and use of AI techniques, methods and tools. We intend in future work to extend our research in both directions.

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