Development of a technological platform for teaching and training in competitive programming contests

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Abstract. The competitive programming contests are competitions where the programming capacity and algorithm of the participants are measured. The objective of this work was to develop and implement a framework to formalize the working methodology of the competitive programming study group of the Universidad Francisco de Paula Santander and to develop a web-based training platform to monitor the work carried out within the study group. The intention with this platform is to give the students the tools they need to carry out their training, from the platform the student can study, can practice, can compete, and can improve their skills both in competitive programming, as well as in areas of programming and computer science. This work was carried out following an iterative methodology composed of the following phases: initially, the project has been formalized, analysis of the problem, preliminary details, and formation of the state of the art and theoretical reference. Then, the initial state of the group is diagnosed, a solution is proposed. After refining this solution proposal. Once implemented, information and metrics are gathered and the results are analyzed, already with a functional framework and a web platform, to detect problems and improvements, restarting the phases, for improving in each step those aspects that can be enhanced. The results obtained in the national and international contest have improved considerably and the participation and satisfaction of the students who are part of the study group were increased. The technological platform developed constitutes a confluence point for the study group, and a clear guideline to follow to advance in the process of continuous improvement that allows the university to achieve the best results in national and international programming competitions.

1. Introduction

The programming contests are competencies that test the ability of students to solve a set of problems in a given time [1]. The problems that arise in a programming contest do not focus on a single specific topic but cover a varied set of topics from different areas of knowledge and levels of difficulty, such as algorithms, computational geometry, mathematics, among others. Consequently, it is necessary that the participants have a wide knowledge base that allows them to face problems of any topic, algorithm analysis skills to analyze in real-time if the proposed solution is efficient for the problem in question; moreover, associative skills to work in team for several hours, with the tension that these contest imply. In this contest the students face different problems that must be solved through a computer program, inescapably foster collaborative learning [2] and problem-based learning [3,4], where the construction knowledge does not fall exclusively on a teacher or tutor, but arises from teamwork and

the constant sharing of knowledge among team members. The group of study in competitive programming of the Universidad Francisco de Paula Santander (UFPS), Colombia, emerges precisely as a way to encourage this type of learning within the classrooms of the university to strengthen the preparation of students in different topics that can be applied in a programming marathon and his career. Since the creation of the study group in February 2015, it has actively participated in training networks such as the competitive programming network (RPC) [5] and the Colombian collegiate programming league (CCPL) [6] in which they can compete and prepare themselves together with other universities in the country and the continent. Along with these training, a set of activities is developed, such as talks, training sessions, and consultancies in some of the necessary subjects of the competitions, all this based on the previous knowledge of the group participants and always considering the overall performance and opinions of the group participants, in this way, the group define a structure for the sessions, and their complementary activities according to the strengths, weaknesses, and needs of the students.

For this reason, constant feedback has been carried out with the participating students, consensus with the teachers who have officiated as a coach, and opinions of participants and coaches from other nationally relevant universities to answer the next research question based on the previously exposed: How to improve the algorithmic skills of the students of the UFPS allowing them to face programming marathons with satisfactory results?

Before starting the construction of a proprietary software tool, the group analyzed different existing tools that could meet existing needs. Among these are UVA online Judge, COJ Online Judge, URI Online Judge, Codeforces and HackerEarth, in [7] you can find a comparative analysis of these related works. Through these tools, it was possible to carry out the training, but there were always difficulties in coordinating all the tools we tried to make available to the students. In most platforms it was not possible to add our own exercises, being obliged to use the databases that the platforms themselves provided. On some occasions when it was necessary to deal with a complex topic, it was difficult to find exercises that fit precisely the topic explained. In the same way, any guide or additional material had to be given to the students through e-mail or link, because these platforms do not allow to add it.

This paper presents the mechanisms that dictate the strategies and steps to be followed by all the participants of the group, that allow to establish objectives for the students of the study group and to scale in the obtained results of the other universities in the region and the country. As part of this need, construction was carried out on the construction of a framework [8] that is responsible for guiding the processes carried out in the study group by formalizing and controlling the training process through the preparation, adaptation, and application of techniques, methodologies, and tools that adapt to the study group. The complete framework defines the tools and materials, the work methodology and the practices that will be accepted for the work within the group, that takes these characteristics as a starting point and is coupled to them to achieve a better performance in programming skills while strengthening the programming skills of the students.

2. Method

According to Raúl Dean [9], technological research designates a field of production of validated technological knowledge, which includes both the cognitive product, such as, theories, techniques, technologies, machinery, patents, etc. and the activities developed by engineers to produce and validate such products and knowledge [9]. From this point of view, this project is framed in the field of applied technological research as it seeks to develop and implement a framework for training students of the study group in competitive programming at the UFPS, integrating and developing technological tools to achieve this purpose. This research is carried out following an iterative methodology composed of 6 phases: 1) Formalization of the project, 2) Diagnosis of the current state, 3) Solution proposal, 4) Solution development, 5) Implementation in a real environment, 6) Analysis of results. Where the first phase is not part of the iterations, as shown in Figure 1.

Initially, the project was formalized: analysis of the problem, preliminary details, and formation of the state of the art and theoretical referent. Then, the initial state of the group is diagnosed, without a

defined framework, and a solution is proposed. After refining this solution proposal, it is carried out and implemented directly in the study group. Once implemented, information is gathered in a reasonable time and the results are analyzed in order to return to a diagnosis of the current state, already with a functional working framework, in order to detect problems and improvements, restarting phases 2, 3, 4, 5 and 6, without reinventing the work, but improving in each step those aspects that can be improved. Two complete iterations were carried out to provide the expected satisfactory results. If in the future new circumstances require changes in the framework, the same process can be followed, making a new iteration.

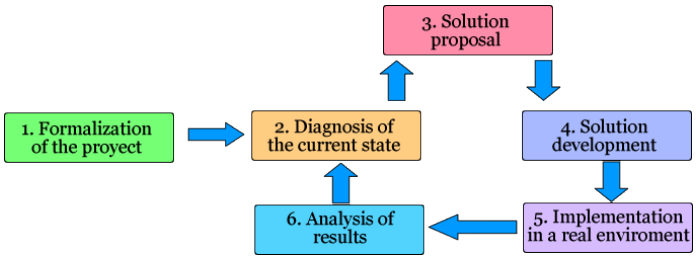

Figure 1. Research work methodology.

3. The Platform for teaching and training in competitive programming contests

The proposed solution corresponds to a web platform called "UFPS training center" and a methodological framework to be applied in the study group, it is structured in 5 axes. Table 1 summarizes each of the axes that are part of the training platform.

Table 1. Training platform axes.

Axis	Description
Axis 1: Promotion	The first axis of the framework seeks to encourage student participation in programming competitions to continue to represent the university at the national and international level.
Axis 2: Methodology	The working methodology of the group defines the way of working and the way of carrying out all the activities. This axis structures all the work to be carried out and defines how the group will be oriented over time.
Axis 3: Document production	The third axis of the framework aims to build a documentary bank that covers all the contents worked on during the semester and that serves to highlight the activities carried out.
Axis 4: UFPS Training Center	All the activities developed in the study group will have a meeting point through a web platform called UFPS training center (technology platform). In this axis of the project, the aim is to develop this platform to monitor the work carried out within the study group.
Axis 5: Integration of the Framework	The fifth axis of the project aims to design a work plan to integrate all the components developed in such a way that it can be replicated in the future.

All the activities developed in the study group have a meeting point through a web platform “UFPS training center”. It is the software component that functions as a meeting point for all the other components and axes of the platform. The training platform has practice exercises of different topics and levels of difficulty which can be sent and qualified through it, theoretical and multimedia explanations of the different topics, a learning mode guided through the different categories of exercises, monitoring the performance of students that can be used both in the group and by the teachers of the program who dictate related topics and wish to integrate it into their areas, programming skills in real-time, and ranking system to enhance learning based on problems.

The most important interfaces of the platform are presented below, the Figure 2 shows the login, where the user can enter the platform and the study material; the Figure 3 shows the interface of problems or exercises, where the user can read it, analyze it and send the solution to be evaluated by the platform; the Figure 4 shows the study topics that the user has available on the platform, they are

divided by different topics and difficulty. To enter the training platform, you can go to the following web link: http://trainingcenter.ufps.edu.co [10].

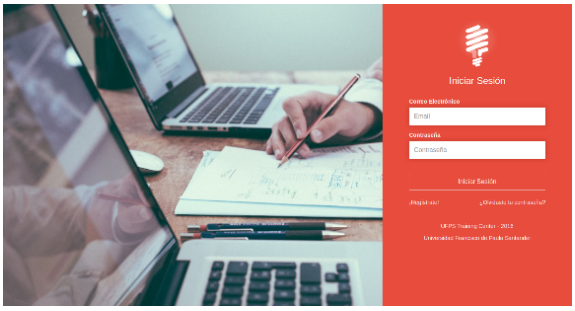

Figure 2. Log in to the "UFPS training center".

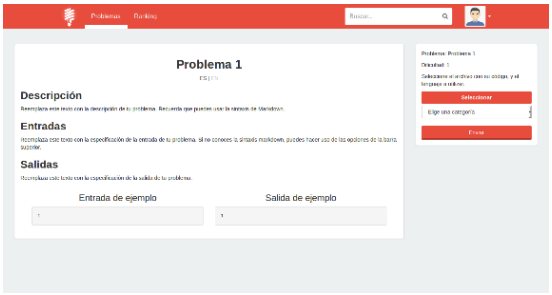

Figure 3. Problems or exercises interface of the "UFPS training center".

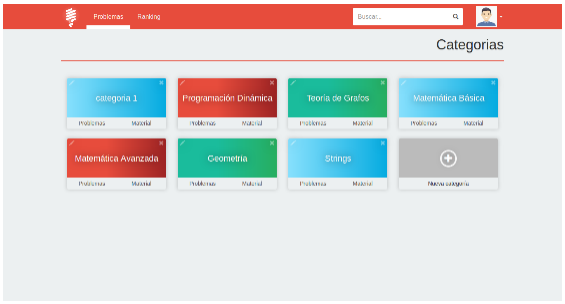

Figure 4. Categories or study topics of the "UFPS training center".

The intention with this platform is to give the student all the tools they need to carry out their training in one place, the "UFPS training center", which the student can study, practice, compete, and improve their skills both in competitive programming and in the programming areas of the career.

Table 2. Training platform modules.

Module	Description
Initialization and authentication	Initialization of the scheme, design, structure of the application, and authentication of users on the platform.
Study materials and guides	Creation, updating, revision of study materials and guides, and deployment to users for visualization.
Platform management	Tool for the administration of users, problems and guides in the platform (administrator users only).
Statistics and user profiles	Module to display statistics, rankings, user profiles, and results to teachers/coach.
Problems	Creation, editing, and elimination of problems. Visualization of the engine of qualification.
Guided mode /syllabus	Module for the supervision of the teachers/coach to the work of the students.
Contest (marathons)	Module for the creation, administration, and development of programming marathons, as well as for their execution.

In this way, the student has at his fingertips everything necessary to learn, and those who lead the group have at their fingertips all the reports of competencies and performance to make decisions in the group. In the same way, career teachers who dictate subjects related to programming or computer science can find in this platform an ally for their practical classes, tasks, and evaluations. The platform was based on the modules shown in Table 2.

4. Results

The first objective was to encourage the participation of students in the programming competitions to continue representing the university at a national and international level. Consequently, promotion strategies were established, then we analyze the impact these strategies had on the group, the participation was measured, semester by semester. In this case, two goals are pursued in the same objective: first, to have a growing number of students from which to form a sufficiently competitive group and, second, to maintain a high number of active students throughout each semester.

Figure 5 presents the graph of active and total students in the study group in the last 6 semesters. There are two behaviors to take into account when analyzing this graph: The first is that the number of students that each semester are part of the study group maintains an almost uninterrupted growth, which has been improving since the implementation of the established promotion mechanisms. Secondly, a behavior can be observed in the number of active students per semester; although the number is increasing over time, the most considerable increases always occur in the first semesters of each year. This is due, according to our analysis, to the incentives, by the academic calendar, it is mandatory to define the students who will represent the university in the national programming marathon at the latest, before going on mid-year vacation in the first semester of the year. Therefore, students have greater incentives in the first semesters, and hence this behavior.

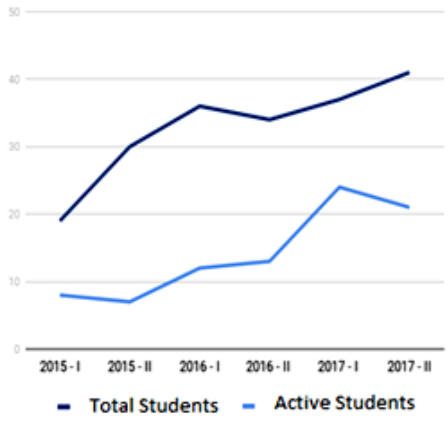

Figure 5. Chart of active and total students in the study group in the last 6 semesters.

The second objective was to improve student participation in programming competitions, we first analyzed the position achieved by the university (the best team of the university in each case) in the different competencies of RPC from the beginning of the second semester of 2016 (beginning of the construction of the framework) until now. We made this comparison only with the Colombian teams. Given that there is no fixed set of participating countries, it is variant along the competitions and therefore analyzing the data among all the countries can be biased; for example, on some occasions the RPC competitions are official classificatory in Mexico, and in these competitions the number of Mexican teams can reach 500, biasing any statistics that can be obtained in this regard. On the other hand, the number of participating Colombian teams is not a fixed number. In the space analyzed, the competition with the lowest participation had 35 teams, while the highest participation had 130. Therefore, analyzing only the position is not effective, because, for example, a position 30 would be a very low result in the first case, but medium/high in the second case. Therefore, to make an effective comparison we took as a reference the scheme used by the "Instituto Colombiano para la Evaluación de la Educación (ICFES) [11]" in your tests "Saber PRO [12]" for the evaluation through percentiles. In this test, in addition to the quantitative score that the student receives, he is given a percentile number between 1 and 100 representing his position with respect to the other students who took the test. For example, if a student is in the 72th percentile, it implies that, if we distribute the totality of students in 100 groups according to their results, being group 1 the one with the worst results and group 100 the one with the best results, the student in question would be in group 72, with better

results than the previous 71, and worse results than the remaining 18. Thus, we can have a clear report that, of the performance in each competition, but a new inconvenience arises: Divide the set into 100 percentiles is effective for the ICFES since they are thousands of students, but not in competitions where in many cases we do not reach 100 teams; in a competition with 40 teams, each team would occupy more than two percentiles. Therefore, we follow its scheme, formula and counting mode, but instead of percentiles, we use deciles, which divide the whole into 10 "significant groups", being much more adjusted for the case. This result can be seen in Figure 6 and Figure 7.

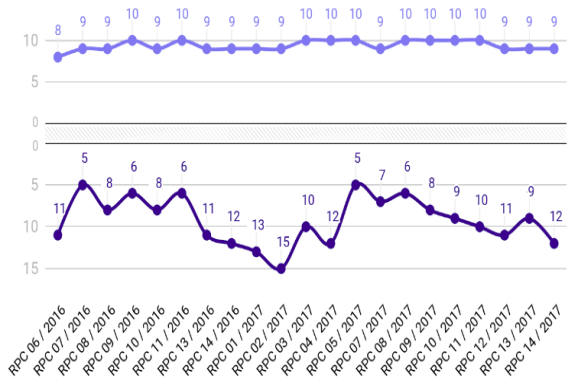

Figure 6. Best result obtained in each competition of the Competitive Programming Network - RPC years 2016 y 2017.

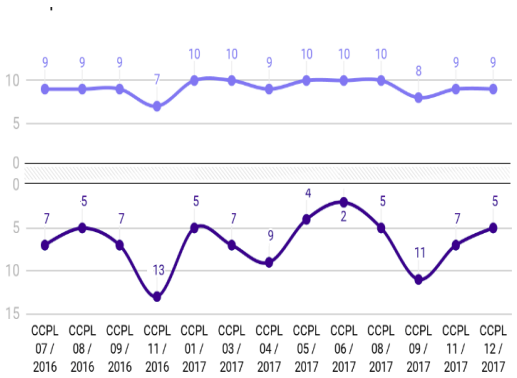

Figure 7. Best result obtained in each competition of the Colombian Collegiate Programming League - CCPL years 2016 y 2017.

From these results, there are several things to highlight: first, since the inception of the framework, the UFPS has had at least one team in the top 15 positions in Colombia in each RPC competition, regardless of how many teams competed. Better still, except in the first competition when the framework was still at a very early stage, it was possible to always keep the best team of the university in the top two deciles. The number of times the 10th percentile was reached between the 10th RPC and the 11th RPC in 2017, coinciding precisely with the moment when the study group solidifies its framework. In CCPL we have fewer competitions, as it has not been possible to participate in all (mostly due to crossing schedules with RPC). However, the results have again been satisfactory: Since the beginning of the implementation of the framework, a high decile has been maintained, most of the times between 9 and 10 (with only two occasions being below this margin, with 7 and 8). It is also noteworthy that the UFPS begins to obtain recognition for its results in CCPL at the national level, we have four fifth places, a fourth place, and even a second place.

During 2016, the objectives proposed in the national programming contest were not achieved despite being in full implementation of the framework. This led a complete retrospective analysis, with different changes that finally led to this achievement. The results obtained in 2017 exceeded expectations. In the first place, we reached the 16th place among 120 teams, which places us in the 9th place of this competition. Secondly, for the first time, a UFPS team achieved first place in the test among the teams of the Santanderes (the northeastern region of Colombia), positioning itself as a reference in the region. Thirdly, thanks to its good performance, the organization invited a second UFPS team to take part in the Latin American competition. In Latin American regional contest, the university has also played a great role. In the 4 consecutive years achieving the classification it has managed to solve at least two exercises every year without exception. Although the results last year were not as expected, for the second consecutive year a team from the institution managed to be the fastest team of all the competition in solving a problem, earning it wide recognition for this reason.

5. Conclusions

The primary purpose of this project was to improve the performance of Universidad Francisco de Paula Santander students participating in the programming contests. It requires discipline, effort and a lot of training on the part of the students. But for this effort to be worthwhile, it must be structured, built on solid foundations, take all aspects into account, and actively measure results. That is why the framework arises, to define the guidelines and actions that lead the study group in competitive programming of the Universidad Francisco de Paula Santander to be a national reference in programming competitions. Constant practice is necessary for good results. The level must improve with time, and therefore the proposed exercises are also more and more challenging so that their results are better. The training platform has been fundamental to improve the results in the programming marathons at a national and international level. The proposed training platform constitutes a confluence point for the study group, and a clear guideline to follow in order to advance in the process of continuous improvement that allows the Universidad Francisco de Paula Santander to achieve the best results in programming competencies. The results have been improved, the participation and satisfaction of the students are greater than at the beginning of the project. On the platform, students have study material, pre-established contests, exercises classified by different levels, all this allows students to improve their skills in programming and computer science.

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