Musical Mimicry to learn Audio Processing

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***Abstract*—Project-Based Learning (PBL) is widely used to promote deep learning, enhance critical thinking, help students create, build and critically evaluate design solutions to a variety of problems. e-Yantra is an initiative by IIT Bombay that conducts an annual e-Yantra Robotics Competition (eYRC) for college students. Teams who qualify selection test compete over a period of five months. 208 such teams comprising 832 students were alloted one of the themes. A "theme" may be regarded as a "hardware MOOC" where skills get taught through a single-player gaming paradigm. This paper describes the methodology implemented in the 7th edition (eYRC-2018), where we designed a "theme" based on Audio processing and Machine Learning. An important contribution has been to show how to design a "scalable" theme by using automatic evaluation that made it unique compared to other themes. This paper outlines the tasks designed for the competition and describes how technology can support students as they work on a theme so that motivation and thoughts are sustained. We then analyze the effectiveness of our approach based on the performance of teams.**

***Keywords*—Project Based Learning (PBL), Online Competition, Robotics Competition, eYRC, e-Yantra, Automatic evaluation**

I. Introduction

e-Yantra is a project sponsored by MHRD under the National Mission on Education through ICT program [1]. The aim of e-Yantra Robotics Competition is to provide opportunities to the students for hands on learning [2]. The model of eYRC described in [3] uses a PBL method where students learn while competing and compete while learning [4]. All teams who come for finals at IIT Bombay for eYRC are eligible for a summer internship through e-Yantra Summer Internship Program (eYSIP) [5]. This is the biggest draw for students to take part as registrations have grown exponentially from 4384 students in 2012 to 28,692 students in 2018, from 786 engineering colleges across India and Bhutan. Every edition of eYRC comprises of different themes, each designed to solve an abstraction of a real-world problems. The 7th edition (eYRC-2018) had seven themes based on "Jungle Safari," out of which, one of them was **Mocking Bot** [6]. In the Mocking Bot theme, teams had to play notes given in an audio file using striking mechanism/s (bot) on musical instruments of their design. Problem Statement: A music file was given to teams and using Audio Processing they had to extract notes and other necessary information such as onsets and durations. They further had to communicate them to the bot. The bot strikes and plays the required notes in the given order as depicted in Fig. 1. Since a music track was imitated by bot, the theme was referred to as "Mocking Bot".

Challenges in this theme include Audio Processing, Machine Learning, Communication, Designing Instruments and Striking mechanism/s. Theme film [7] was created that included performance of one of the finalist teams with animated storyboard artwork.

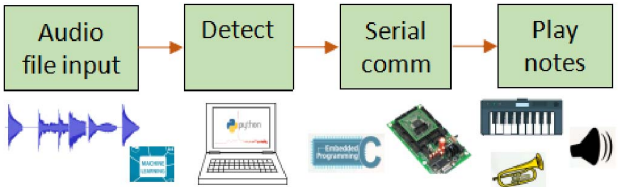

Fig. 1 Mocking Bot Theme Flow

II. Motivation and Related Work

In this technological era, robots can not only be used as a machine to reduce human work but may also be used for entertainment to play music, sing or dance for us. Paper [8] describes the piano played by robot and compared the performance of piano played by human and robot. Detailed analysis of the robotic arm used to play piano is explained in [9]. Inspired by this idea, eYRC introduced "Mocking Bot", a theme to experiment with playing music with Robots.

III. Competition Insights

Like every other theme in eYRC, Mocking Bot was divided into two stages (Stage 1 and Stage 2) as illustrated in Fig. 2. These stages were further divided into Tasks. Stage 1 had two Tasks (Task 0 and Task 1). Task 1 consisted of Task 1.1, Task 1.2 and Task 1.3. Stage 2 had four Tasks (Task 2, Task 3, Progress Task and Task 4). A team of four students from any department registered and took the online selection test. This selection test is based on C-programming, Electronics/Electrical and Logical Reasoning and

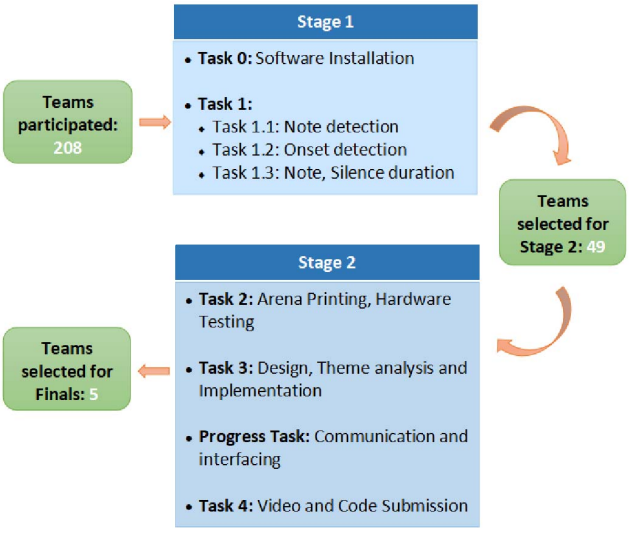

Fig. 2 Mocking Bot Theme Format and Statistics.

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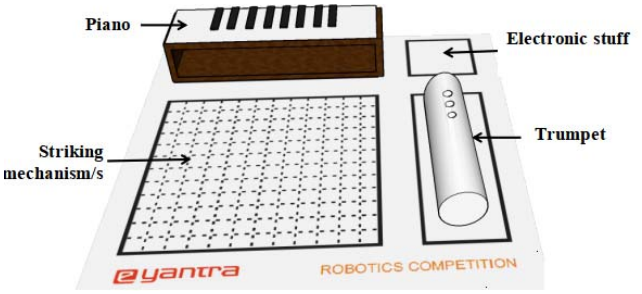

Fig. 3 Arena Setup.

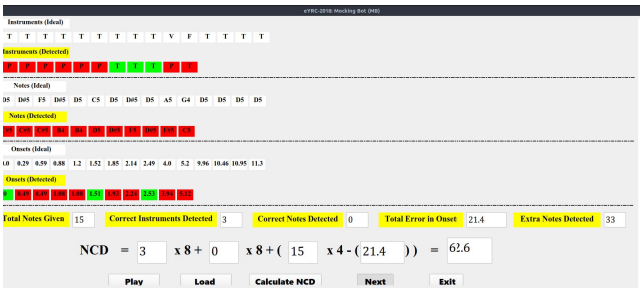

Fig. 4 Sample score

Aptitude [6]. Based on their performance, 208 teams were allotted the Mocking Bot theme. In order to guide students through the competition, a Piazza discussion forum was created. All required resources were provided with their respective tasks. As stated earlier, Stage 1 was based entirely on software. Out of 208 teams, 49 teams were selected for Stage 2 based on their performance in Stage 1. Stage 2 was a combination of both software and hardware. Hardware was shipped to all the teams who qualified for Stage 2. Resources provided helped teams to test the components and work with it (www.tinyurl.com/y5nxknku). Total of 13 teams completed all tasks, of which 5 were selected for finals that was conducted at IIT Bombay. Cost of registration, hardware, expenses for finals was taken care by e-Yantra.

A. Stage 1

Stage 1 was based on software, first task being to install and test the software used such as Python, Sonic visualiser along with some essential libraries. Resources were provided to help students understand these software and get started with basic concepts of audio processing (www.tinyurl.com/y5b5gflg). The next task was to analyze a given audio file to extract information such as notes and their respective onsets using Python. The given audio file comprised of multiple notes separated by silence. Resources based on musical note identification and video tutorials for various frequency detection methods and onset detection were provided (www.tinyurl.com/yylsesef).

B. Stage 2

Stage 2 was a combination of software and hardware. On the software side, resources were provided for next task that was to identify the instrument from which the particular note is played (www.tinyurl.com/y4ope4a8). The given audio file consisted of multiple notes of different instruments. From the hardware perspective, the task was to design two instruments (Piano and Trumpet) as well as their striking mechanism/s. The arena (as shown in Fig. 3) consisting of rectangular and square boxes represented a performance stage where music was played. An arena outline was provided for the placement of instruments and striking mechanism/s. Instructions on size constraints and materials to be used were provided along with the tasks. The last task was to put software and hardware together, combine the extracted information – notes and onsets (from Stage 1) with instruments (from Stage 2) – and communicate this to the striking mechanism/s (bot). Theme and Implementation Analysis document that consisted of nine questions was also provided. This document comprised of a few theme and rulebook related questions that the team had to answer. This was to test how well the teams have understood the theme and tasks assigned. Eventually, teams had to make a single video to showcase the output.

C. Automatic Evaluation

All the tasks were automatically evaluated except the video part. With every task, a python file was provided to the teams. They were told to run that file to make sure the output generated is in the appropriate format. Once tasks were submitted, a python script was written by the e-Yantra team to automatically generate a team score based on task performance. Another interesting part was the GUI (Graphical User Interface) design for finals at IIT Bombay. Since there were too many parameters to be looked upon while theme execution, a GUI was designed to help judges understand and the e-Yantra scorer's team to note the score easily as shown in Fig. 4. With reference to the levels and description of levels discussed in [10], TABLE I gives a summary of the tasks and learning imparted at each level along with how many teams submitted tasks.

IV. Analysis of Impact and Effectiveness

In this section, we analyze the performance of the teams based on the following parameters:

(a) **Formation of team:** Since the theme comprised of an electronics, mechanical design and algorithm development; teams with multidisciplinary members would perform better and data indicates this result. The graph in Fig. 5 shows that teams having members from three or more streams performed better than teams with one or two stream/s since the percentage that cleared Stage 1 is higher. On the contrary, the percentage of teams that "Completed all Tasks" is more for Teams with one/two stream/s.

(b) **Selection Test performance:** As themes are based on programming and electronics, selection test consists of C-programming, Electronics/Electrical and Logical Reasoning and Aptitude. Teams who scored well in the selection test had higher probability of getting into Stage 2 and completing all tasks. The cut-off for this theme was 30. As shown in Fig. 6, 48 teams scored in the range 30-35. Out of which 42 teams (87.5%) failed Stage 1, 5 teams (10.4%) cleared Stage 1 but couldn't complete all tasks and 1 team (2.1%) could complete all tasks. For the 60 onwards range, the probability of clearing Stage 1 is 50% and completing all tasks is 25%.

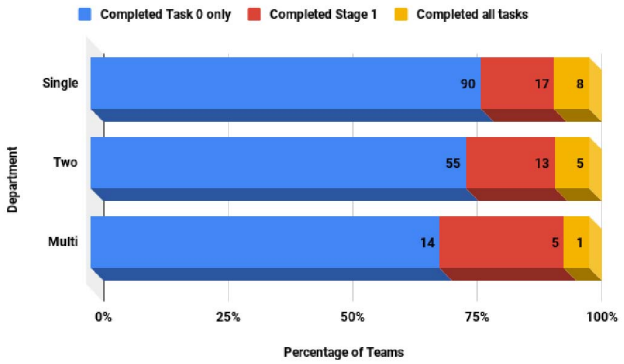

Fig. 5 Team formation graph

TABLE I: Mapping Level of Learning Outcomes to Tasks and Statistics

*Level**	*Level Description**	*Task*	*Learning Imparted*	*Task Submitted*
Imparting Knowledge	Recognition and understanding of facts, terms, definitions, etc.	Stage 1: Task 0: S/W Installation, Audio processing	Install and basic learning of Audio processing	183
Application of Knowledge	Use of knowledge in ways that demonstrate understanding of concepts, their proper use, and limitations of their applicability	Stage 1: Task 1.1: Note detection Task 1.2: Onset detection Task 1.3: Note and Silence duration	Use of Audio processing to analyze the audio file to detect Note. Also, its resp. onset with Note and Silence duration feedback provided	83
		Stage 2: Task 2: Instrument Classification	Implement ML algorithm to identify Instrument	49
Critical Analysis	Examination and evaluation of information as required to judge its value to a solution and to make decisions	Stage 2: Task 3: Design, Analysis and Implementation	Design Piano to play the required notes, Understand theme, formula parameters	36
Extension of Knowledge	Extending knowledge beyond what was received, creating new knowledge, making new inferences transferring knowledge to usefulness in new areas of applications	Stage 2: Progress Task: Comm. and Interfacing Task 4: Video and Code submission	Communicate extracted info to striking mechanism/s Strike required notes on resp. Instrument using striking mechanism/s	17

*Levels and Description of levels are taken from [10]

(c) **Previous year participation:** Along with 198 new teams, there were 10 teams (at least one of the team members) who had participated in the earlier eYRC competition. It can clearly be seen from Fig. 7, teams with a member from an earlier edition have the benefit of getting into Stage 2 and completing all Tasks easily.

(d) **Use of discussion forum:** Discussion forum helps teams to interact with e-Yantra team members as well as other teams participating in the competition. Teams can use this platform to ask questions, answer others queries, view the instructions posted by the e-Yantra team etc. Teams that were active on Piazza could easily get along the eYRC competition as shown in Fig. 8. Active simply means teams being online, views for different posts, contributions to the posts etc. Those 5 teams who could make up to the Finals, were most active on Piazza.

(e) **Knowledge of Topic:** Teams who did not have any previous knowledge related to basic electronics, python programming found it difficult to persist in competition. Fig. 9 shows out of 16 teams who had previous experience of knowledge, 3 teams (42.86%) could complete all the tasks. Out of 91 teams who had no previous experience of knowledge, 6 teams (4.62%) could complete all the tasks.

(f) **eLSI and non eLSI impact:** eLSI colleges have e-Yantra lab in their college. Fig. 10 shows there were 47 teams from eLSI colleges and 161 from non-eLSI colleges. Out of 47 eLSI teams, 13 teams (27.7%) cleared Stage 1 and 6 teams (12.8%) could complete all the tasks. For 161 non-eLSI teams, 36 teams

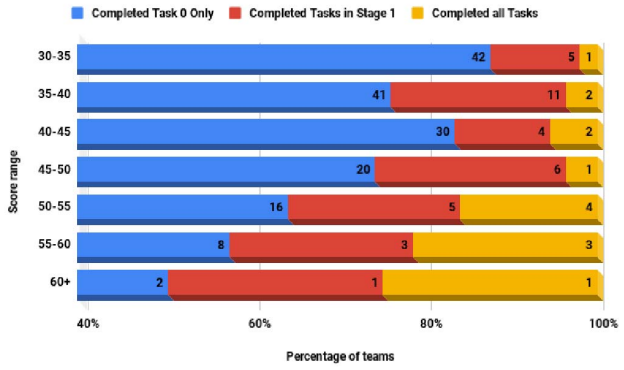

Fig. 6 Selection Test graph

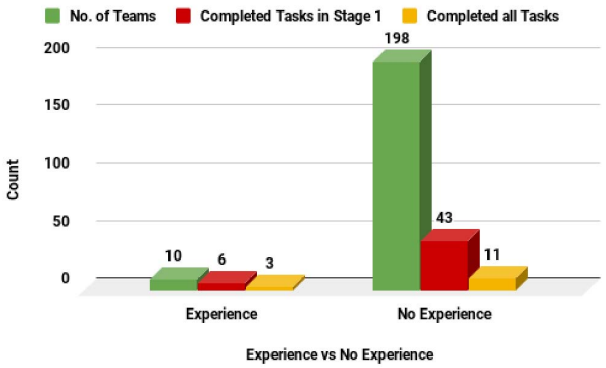

Fig. 7 Experienced teams vs Fresh teams

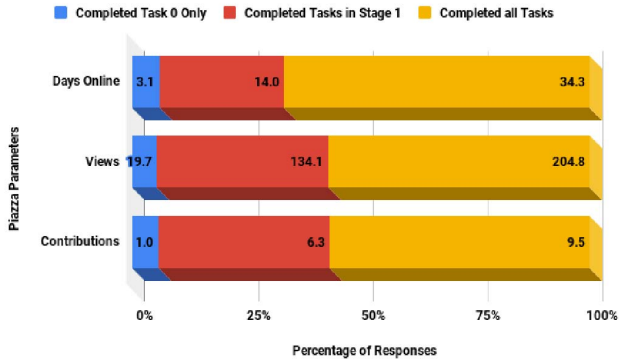

Fig. 8 Discussion forum data

(22.4%) cleared Stage 1 and 8 teams (5%) could complete all the Tasks. It can be concluded that eLSI teams have an advantage of clearing Stage 1 and completing all Tasks. Even though labs don't have audio processing in their curriculum, PBL outlook ingrained in these labs result in better performance.

V. Conclusion

Out of 208 teams who were assigned Mocking bot theme, 144 teams (60.23%) were able to learn the basics of audio processing and 17 teams (8.17%) were able to learn all the concepts related to theme such as audio processing, machine learning, designing aspects, sensors and actuators interfacing, communication. As the tasks are given in a team of four students, it becomes difficult to evaluate individual performance. The feedback from teams listed reasons for not getting into Stage 2. Some of the reasons were due to university exams they were unable to focus, since they were participating for the first time they found it difficult to manage time, lack of coordination amongst team members, task was too difficult, involved in other activities. Automatic evaluation is done at the software part (i.e. for Stage 1), but it is difficult to verify at the hardware part that limits the number of teams to be allowed for Stage 2. Similar to Stage 1, feedback after Stage 2 showed the enthusiasm amongst teams as they learnt new things from the competition such as: working with deadlines, managing academics with competition work, learning new concepts with hands-on experience, getting exposed to valuable technical skills, challenging their own limits, etc. Our experience year-on-year has overwhelmingly been that participation in the competition, though a challenging balancing act with academics, results in the

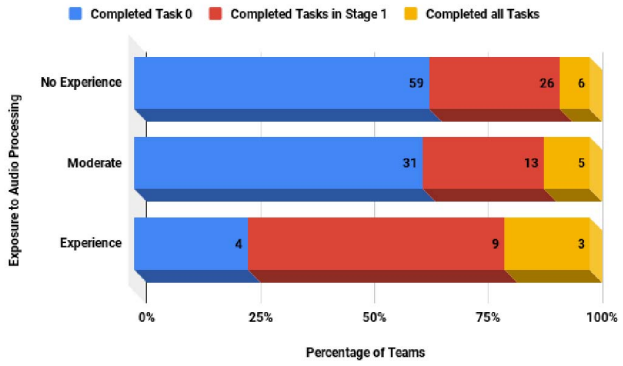

Fig. 9 Knowledge of Topic graph

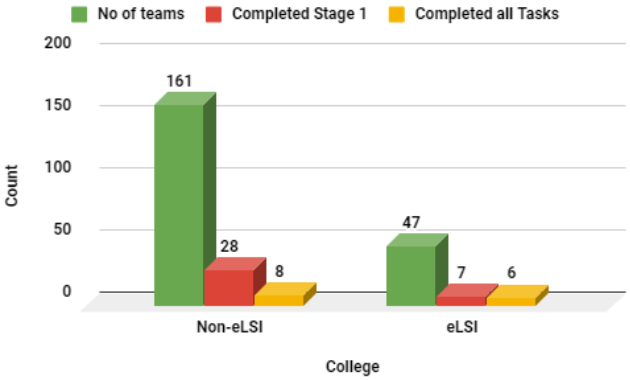

Fig. 10 eLSI vs Non-eLSI teams

acquisition of practical engineering and other skills. This positively impacts the morale and the employability of competition participants.

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