Developing Industry ready skills in System Integration Lab

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Abstract— **The expectations of the industrial sector and the deliverables of the academic sector are very different from each other. It takes a lot of money and effort to transform new engineers into professionals that are ready for the market. Additionally, students' learning is hampered by the gap between academic knowledge and its practical applications. System integration is one of the key concepts in Industry 4.0-enabled industries, where multiple IoT-enabled devices need to coordinate and communicate. Providing mere knowledge about different communication protocols and their architecture without relating that to the different devices existing in the industry won't benefit the students much. Also, inculcating system integration skills among the mechatronics students helps them become new entrepreneurs, as system integration opportunities are greater in this Industry 4.0 era in India. The improvement in the affective and psychomotor behavior of students is greatly enhanced by their exposure to the configuration, programming, visualization, and troubleshooting of industrial servo drives used in industrial robots and CNC machines. The internal and terminal assessment comparisons of the system integration lab are done for 60 students of final-year mechatronics for the years 2020, 2021, and 2022 using statistical analysis techniques. The statistical results indicate that students' learning behavior has improved 5 to 16% during the year 2021 and 8 to 18% during the year 2022 compared to the year 2020 due to the inclusion of industry-ready skills in outcome-based education.**

Keywords—**Industrial servo drives; Motion logic controller (MLC); Motion logic drive (MLD); industry ready skills; problem solving skills; Anova.**

ICTIEE* Track—*Emerging Technologies and Future skills

ICTIEE Sub-Track—Preparing Engineers for a Digital and Sustainable world

I. INTRODUCTION

INDUSTRIES spent lot of efforts in terms of money and time for making the engineering graduates in to industry-ready [3]. Academic institutions that offer engineering courses also place a strong emphasis on cognitive methods of knowledge delivery, which makes it difficult or uninteresting for students to understand concepts. The laboratory courses in engineering colleges are meant for enhancing the practical skills among students. But most of the engineering colleges' laboratory curriculum narrows the scope of acquiring skills beyond a set of given experiments [4]. Also the laboratory experiments not provide the opportunity for students to develop their problem solving skills [5,6] .Now the academic institutions adopting the conceive, design, implement, operate (CDIO) frame work [7] of curriculum need to reorient their courses towards imparting more problem solving skills [8]among students.

System integration laboratory is one of the core laboratory course for the under graduate mechatronics students. In this laboratory students were exposed to practical way of integrating mechanical, electrical, electronic systems using communication protocols. This laboratory is offered in the year 2020 under the choice based credit system (CBCS) [9].Since we have adopted the CDIO frame work [10, 11] of curriculum from the year 2021, we have modified our courses towards imparting practical skills along with cognitive domain. Table 1 shows the course outcome of the system integration laboratory. The conventional method of providing this laboratory using a fixed set of 12 experiments is modified to include different exercises to fulfill the different course outcomes [12].

TABLE I
COURSE OUTCOME OF SYSTEM INTEGRATION LABORATORY

CO Number	Course Outcome Statement	Weightage *** in %
CO1	Identify the sensors, actuators, controllers and communication protocols by their specifications.	5%
CO2	Select a suitable sensor, actuator and controller for Mechatronics system integration	5%
CO3	Develop a software program to integrate all Mechatronics components using suitable communication protocol.	25%
CO4	Design a user interface to visualize and control the product and process.	20%
CO5	Integrate sensor, actuator and controller with user interface through suitable drivers.	20%
CO6	Integrate mechanisms with controller, sensor and actuator.	5%

*** Weightage depends on number of contact hours

This new approach helps the students relate their theoretical knowledge to their practical skills, [13] while also improving their problem-solving skills [14]. In this study, the integration of servo drives using controllers and different communication protocols [15] are taken as a case study to show the proposed method of conducting laboratory course enhances students learning in terms of affective and psychomotor domain. Since the 65% of course outcomes are covered in CO3, CO4 and CO5, these three course outcomes are used to compare the results. The CDIO frame work is introduced during the year 2021 and subsequent improvement is made in term of lab facilities and delivery methods during the year 2022 to provide industrial skills to make the students role ready engineers. Since the CO3 focusses on programming and communication configuration [16], CO4 focusses on creation of user interface and visualization of motion parameters, CO5 focusses on configuration of controller and drives for integration, these three outcomes are compared using the students system integration lab results during the year 2020,2021 and 2022[17].This study aims to evaluate the effect of a redesigned, CDIO-aligned laboratory framework on student learning outcomes CO3–CO5 through statistical comparison of cohorts from 2020–2022.

II. Proposed work overview and Contribution

The final year students of Mechatronics Engineering department at Thiagarajar college of Engineering undergo system integration lab in their 7th semester. This course deals with the experiments to enhance the system integration skills among the students. In the previous years, the students were given with the fixed set of 12 experiments and the assessment also based on these experiments. It is found that the students practical skills are limited much by this conventional method of providing fixed set of experiments. Also the conventional method is not satisfactorily developed system integration skills required for integrating different systems based on the given problem. This paper proposes a new approach of doing laboratory experiments by which students practical skills enhanced much. The syllabus of system integration lab is framed in such a way that students are exposed to the different instruction sets available in the given hardware and software. The creativity of students [18] is enhanced by allowing them to use different functions in the program based on the problem statement. This will allow the students to develop their problem solving skills. The flowchart of the proposed approach is given in Figure 1.

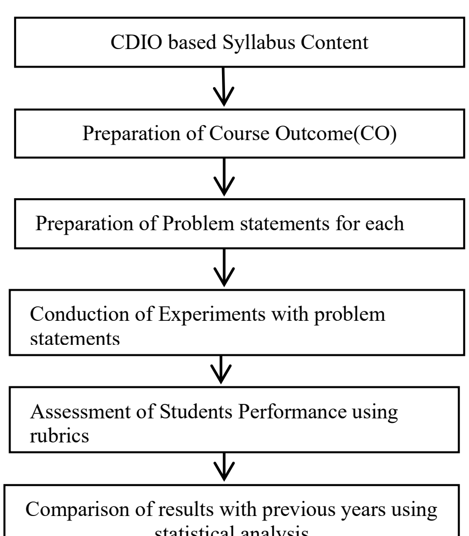


Fig.1.

System Integration lab provides the skills required for the integration of mechanical, electrical and electronics system using the standardized communication protocol. Since each vendor device uses their own protocol for data communication, integrating all the devices in a single platform is difficult task. After the development of Ethernet communication, this problem of integrating multiple devices on a single platform is solved. Industrial communication networks uses a standardized protocol such as profinet, device net, Ethercat, Etherrnet I/P, sercos depending on the device manufacturers. These protocols are used in industries for Controller-controller, Controller-drive, and Drive-Drive communication in Master/Slave mode. Theoretical knowledge about these communication protocols alone not help much for solving the data communication issues in industries. Laboratory experiments are framed in such a way to enable the students to solve all the issues related to the all the above interfaces practically.

In this work , the experiments relevant to the servo drive is chosen, as servo drives are used predominantly in industries for motion control applications such as industrial robots and computer numerical machines(CNCs).Servo drives are configured and programmed either through motion logic controller, or using its own motion logic drive. The PLC Open motion functions are used universally by all automation device providers to enhance portability between different systems [19]. Initially students were taught with the configuration of controller, drive and various PLC-Open functions used to program the drive. Students also taught for Physical verification of drive operation and visualization of drive motion parameters using the Soft oscilloscope. Then different problem statements which utilizes the above configuration, programming and visualization methods are given to the students to enable them to solve using their own novel problem solving approach. The sample problem statements given to the students is listed as given below:

Q1 Two robot joints connected with a controller need to be configured and programmed in virtual- real axis mode with the gear ratio of 1:4 and 1:2 respectively. Move the First joint at 1440° position, 200 rpm and second joint at 720° position, 50 rpm. Visualize and plot their operation using soft oscilloscope.

Q2 Configure and Program the feed axis drive of CNC machine for the below givensequence**:** Move the axis to 100 mm position with a velocity of 200 mm/sec, wait 10 seconds, then move the axis 400mm/sec with a velocity of 600mm/sec, then bring back the axis to home position. Plot the motion parameters in a soft oscilloscope.

Q3 Program and configure a robot joint motor for the following sequence: Rotate the joint motor to a position of 360° at 600 rpm, wait for 20 seconds, then move it for 120° at 400 rpm and visualize the same in a oscilloscope.

Q4 Develop a coordinated movement of two feed axis of CNC machines in Master/Slave mode with a gear ratio of 1:2 for the position of 400mm, 100 rpm and 800 mm, 200 rpm.

Since the students are provided with the basic hand-on skills [19] on the different configuration and programming methods of servo drives, students are now able to solve any kind of problems associated with the servo drive. This type of approach enhances the problem solving skills of students for real time industrial applications. The problem statements are solved by the students individually, and the individual encounter with the hardware and software configuration enables the individual learning ability rather than doing the exercises as a group activity. Servo drives exercises are divided in to three broad category as, MLC, MLD and MLD Master/Slave. Under these three categories, students were exposed with multiple problems to solve any real time industrial problems.

III. Experimental Setup for Servo Drive Operation in Different Configuration

A. Motion Logic Controller (MLC) based Servo drive

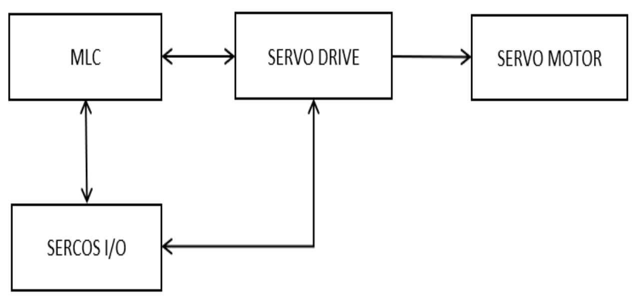


Fig.2. Block diagram of MLC based servo drive

Figure 2 shows the block diagram of MLC based servo drive [20, 21]. The block diagram consists of a Motion Logic Controller which is used to convert the ladder logic implemented in the Indra Works Software to actuate the hardware setup. A Motion Logic Controller, in general is used to control the motion of a Motor or an actuator through logical implementation. The control process is much easier due to its less complexity. In this case, the MLC is used to give commands to the Servo Drive which in turn actuates the Servo Motor. The Sercos I/O are input/output module work based on sercos communication protocol and give input commands to the Motion Logic Controller as well as it give input directly to the servo drive. This type of configuration is used in industries for operating the drives in virtual and real axis configuration

B. MLD based Servo drive

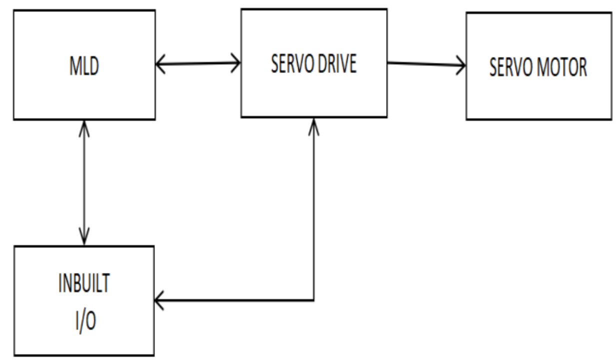


Fig.3. Block diagram of MLD based servo drive

The block diagram given in Figure 3 represents a process in which a Motion Logic Drive [22] is used to give commands to the servo drive using the ladder logic worked out in the Indra works Software and Inbuilt I/O switches can also be used for the purpose of giving input commands. The servo drive controls the servo motor based on commands received from the MLD. The Servo Drive also receives direct command from the inbuilt I/O. This type of configuration is used in industries for driving servo drives indigenously using inbuilt soft plc motion blocks.

C. MLD based servo drive in Master/Slave

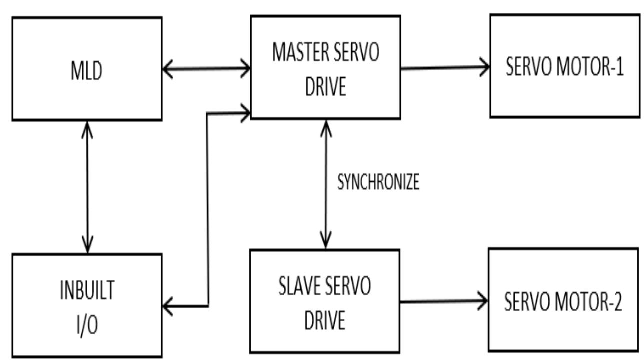


Fig.4. Block diagram of MLD servo drive in Master/Slave

The block diagram in Figure 4 represents the Motor control through Master-Slave configuration [23] using a Motion Logic drive. MLD provides commands to the Master Servo Drive which in turn actuates the Servo Motor, which is connected to the Master drive. Since, the Master Drive is synchronized with the Slave Drive, the motors connected to the Slave Drive actuate in accordance with the Master Drive. Multiple Slave Servo Drives can also be connected to the Master Servo Drive. The Master Drive can also be directly controlled through the inbuilt I/O. The inbuilt I/O also provides input to the Motion Logic Drive.

IV. Configuration and Programming of Servo drive

A. Motion Logic Controller (MLC) based Servo drive

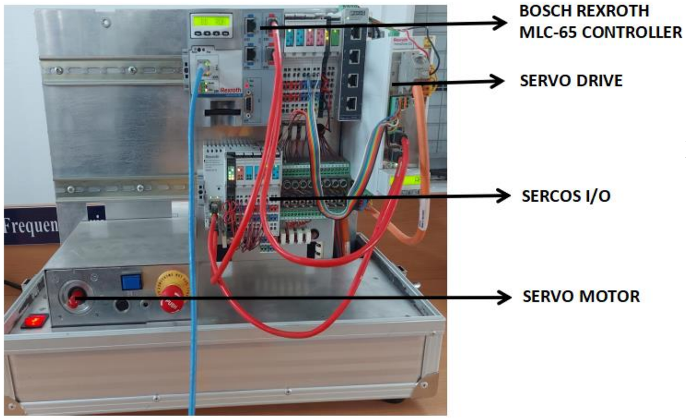


Fig.5. Hardware setup of MLC based servo drive

Figure 5 shows the hardware setup for the MLC based servo drive. It consists of Bosch-Rexroth MLC 65 controller connected with Rexroth indra servo drive and sercos I/O. The hardware is interfaced with the computer using the Engineering port of MLC 65. The MLC 65 controller, sercos I/O and sevo drive are configured using Inraworks engineering software. Figure 5 depicts the Functional Block Diagram (FBD), with the help of which the Servo motor is controlled by the Motion Logic Controller (MLC)

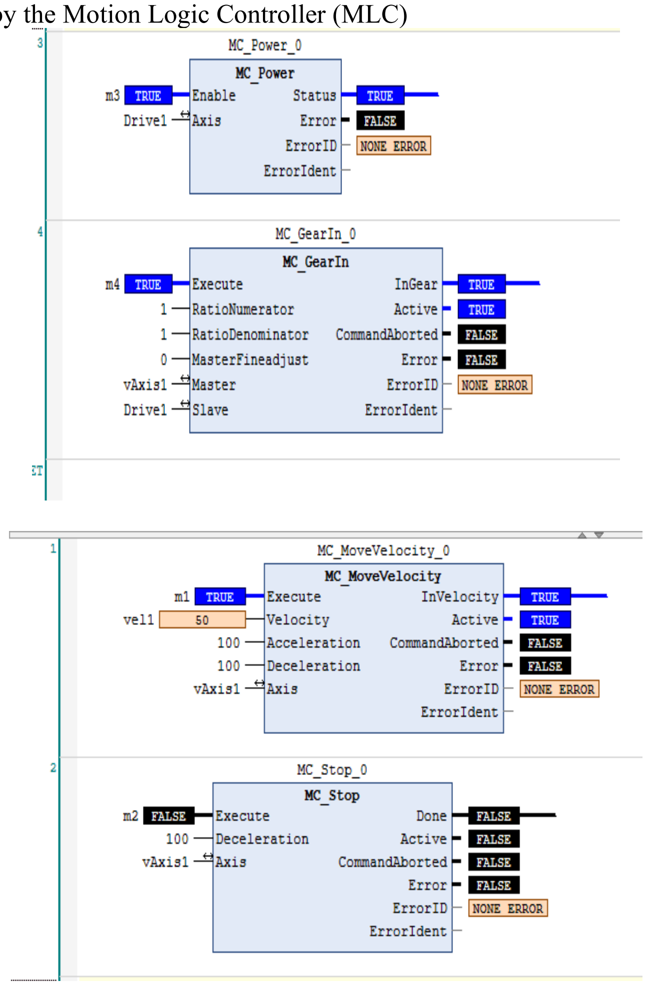


Fig. 6. MLC based Servo drive programming.

The first block represents MC_POWER where Enable is connected to switch 'm3' which is initially in the false state and the Axis is inputted with virtual axis 'Drive1'. Once the state of m3 is switched ON to true state, the status of MC_POWER becomes true and so the servo motor is powered. The second block is the MC_GEARIN which is used to set the gear ratio between the Virtual and Real axis. The Master axis is named as 'vAxis1' and the slave axis is named as 'Drive1'. The switch 'm4' is connected to Execute, which when becomes TRUE sets the gear ratio according to the given Ratio Numerator and Ratio Denominator. In our case the ratio is set to both 1:1 and 1:2 ratio. The third block MC_MOVEVELOCITY is used to provide the parameters such as Velocity, Acceleration and Deceleration. The values of the parameters are given as per requirement. When the input 'm1' which is connected to the Execute is set TRUE, these parameters are loaded into the Servo motor. The last block MC_STOP is used to terminate the motion of the Servo motor. When the input 'm2' is set TRUE, the motor stops. Figure 7 represents the Relative Position and Relative Velocity of the Virtual and Real axis drive which have a gear ratio of 1:1. From the above graph, it is inferred that, for a 360-degree motion in the virtual drive (violet colored line), the real drive also rotates a complete 360-degree motion (red colored line).

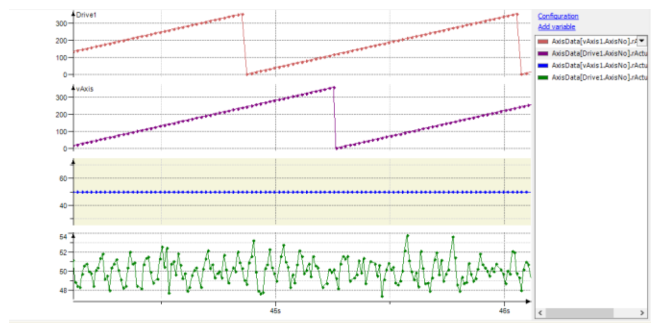


Fig.7. Plot of virtual and real axis motion parameters for equal gear ratio

Since in this case, the velocity of the virtual drive (blue colored line) is set to 50 units, the velocity of the real drive (green colored line) is also found to be almost 50 units with a minimal fluctuation due to the gear ratio of 1:1.

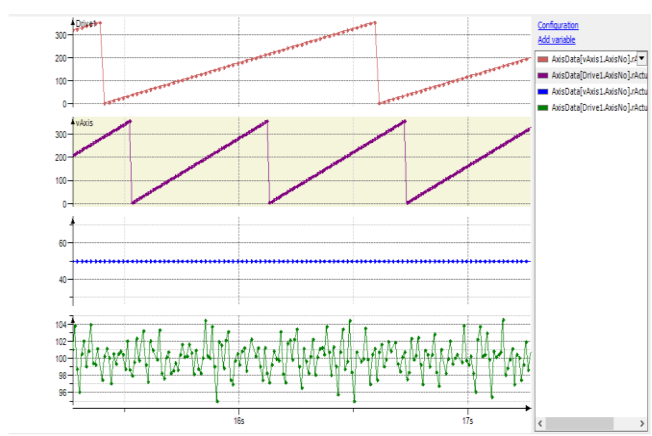


Fig. 8. Plot of virtual and real axis motion parameters for 1:2 gear ratio

Figure 8 represents the Relative Position and Relative Velocity of the Virtual and Real axis drive which have a gear ratio of 1:2.From the above graph, it is inferred that, for a 360-degree motion in the Virtual drive (red colored line), the real drive rotates 720 degree (violet colored line) which is twice as that of the Virtual drive. Also, for the velocity of 50 units in the Virtual drive (blue colored line), the real drive moves with a velocity of almost 100 units (green colored line). This is due to the gear ratio set as 1:2.

B. MLD based Servo drive

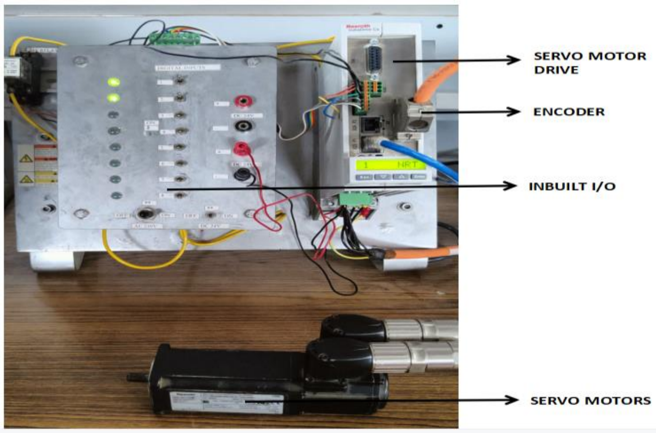


Fig.9. Hardware setup for MLD based servo drive

Figure 9 shows the hardware setup for MLD based servo drive. It consists of a servo drive connected with motor using power and encoder cables. The drive can be programmed using MLD logic and can be operated using inbuilt I/O s using proper configuration. Figure 9 depicts the FBD of the logic implemented by the Motion Logic Drive. The first block MC_POWER is used to give power to the servo motor for its operation. Once the input ‘m1’ is set **TRUE**, the motor which is connected to the Servo drive ‘Axis1’ gets powered on.

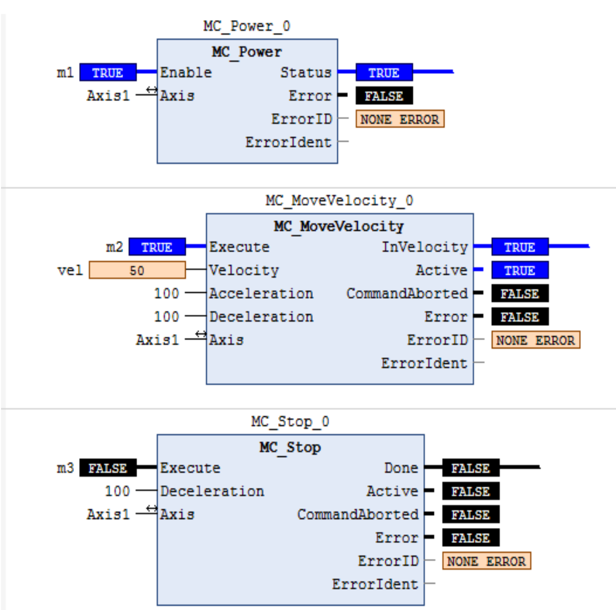


Fig.10. MLD based Servo drive programming.

The second block MC_MOVEVELOCITY is used to input parameters like Velocity, Acceleration and Deceleration. In this case, the Velocity is set to 50 units, Acceleration is set to 100 units and Deceleration is set to 100 units. As soon as the input ‘m2’ connected to this block is set to TRUE condition, these parameters are loaded into the Servo motor.

To stop the motor, the block MC_STOP must be enabled. When the Execute is set to be **TRUE**, the DONE and ACTIVE part of the MC_STOP block become **TRUE** and the CommandAborted part of the MC_MoveVelocity block also becomes **TRUE**, which stops the motor from rotating.

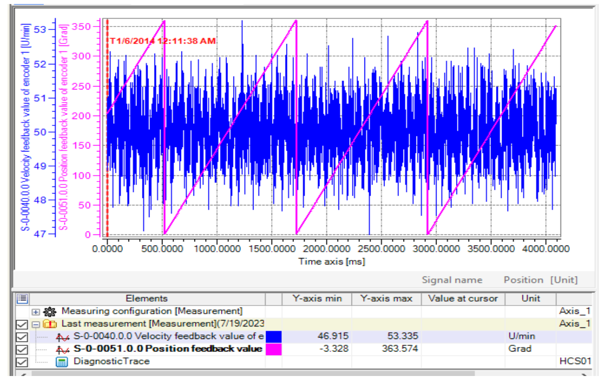


Fig.11. Plot of motion parameters for velocity of 50.

Figure 11 represents the oscilloscope reading of the Relative position (Pink coloured line) and Relative Velocity (Blue coloured line) of the Servo motor controlled by the Motion Logic Drive (MLD).The Motion of the Motor is set to **Modulo mode**, so that Relative Position of the motor is recorded only with the values between 0 to 360 (cyclic).

Since, the velocity in the MC_MoveVelocity is set to 50 units, the Servo motor rotates with a speed of approximately 50 units (between 48 to 52 units as observed in graph).

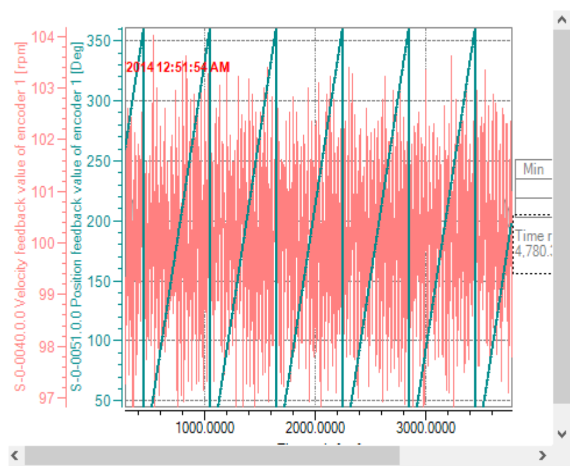


Fig. 12. Plot of motion parameters for a velocity of 100.

Figure 12 represents the Relative position (Green coloured line line) and Relative Velocity (Red coloured line line) of the Servo motor controlled by the Motion Logic Drive (MLD).The graph is same as the above one, except that the velocity of the Servo motor is set to 100 units. The velocity is observed to be varying from 98 to 103 units.

C. MLD based servo drive in Master/Slave

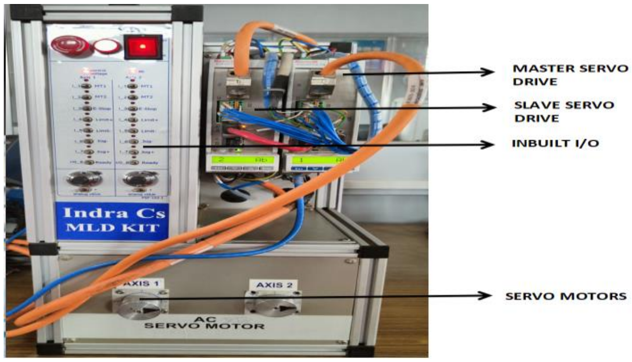
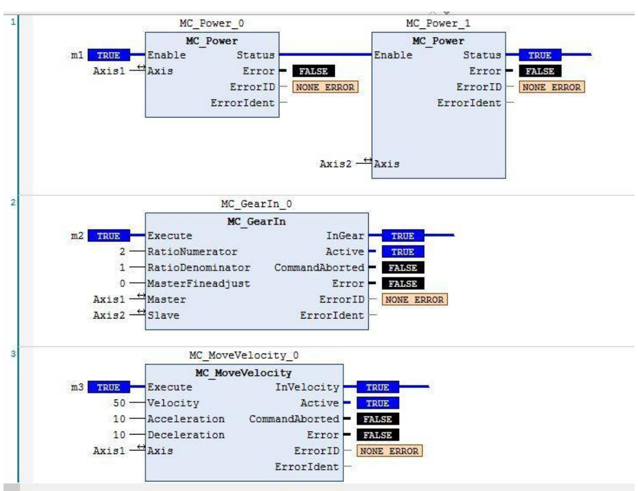


Fig.13. Hardware setup for MLD based Master/Slave servo drive

Figure 13 shows the hardware setup for MLD based Master slave servo drive. It consists of two real axis drives, one act as a master and the other as a slave .Master and slave drives are connected in a sercos communication. Figure 14 depicts the FBD of the logic implemented by the Motion Logic Drive (MLD) for the Master-Slave configuration. In the logic, two MC_POWER block is connected, one to power the Master drive and the other to power the Slave drive. When the input ‘m1’ connected to the power block is set to **TRUE**, its status becomes **TRUE**, which then makes the Enable of the second power block to become **TRUE**. This results in powering up of both the Master and Slave Servo drive. The MC_GearIn block is used to set the gear ratio between the Master and Slave drive. In this case, the Gear ratio is set as 1:2. So the slave drive has twice the velocity and motion as compared to the master drive.



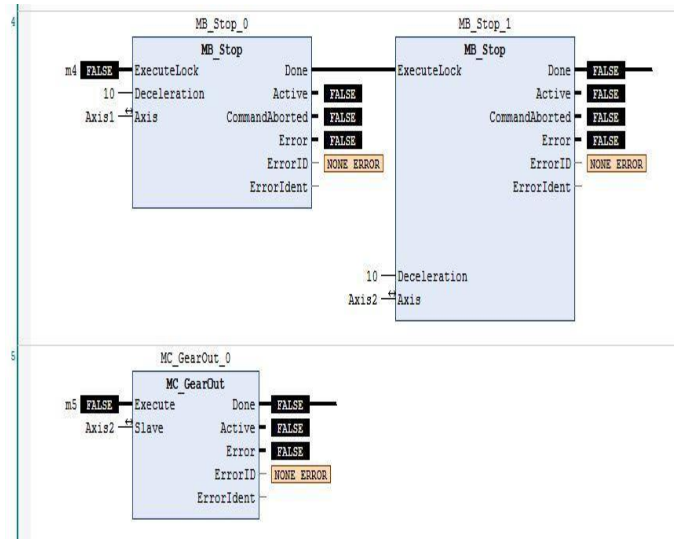


Fig.14. MLD servo Master/Slave programming

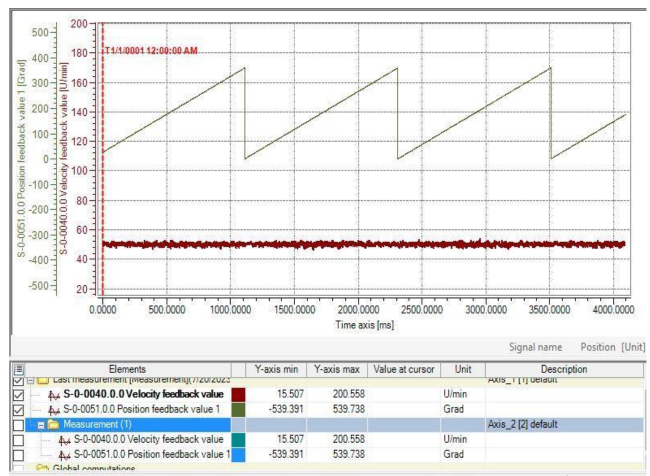


Fig.15. Plot of motion parameters for 50 units

The MC_MoveVelocity block is used to input basic parameters like Velocity, Acceleration and Deceleration to the Master drive and not to the Slave drive because controlling the Master Drive directly affects the slave drive. In this case, the Velocity is set to 50 units, Acceleration is set to 10 units and Deceleration is set to 10 units. MC_STOP is used to stop the Drives and MC_GearOut is used to remove the Gear Ratio which is previously set. Figure 15 represents the Oscilloscope reading of the Relative Position (Green coloured line) and Relative Velocity (Brown coloured line)of the Master Servo Drive. It is observed that it moves with a velocity of 50 units.

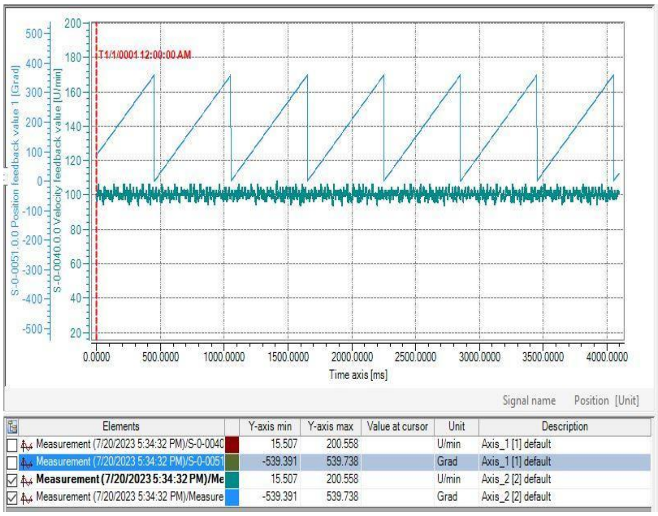


Fig.16. Plot of motion parameters for 100 units.

Figure 16 represents the Oscilloscope reading of the Relative Position (Sky-Blue coloured line) and Relative Velocity (Tiffany-Blue coloured Line) of the Slave Servo Drive. It is observed that it moves with a velocity of 100 units.

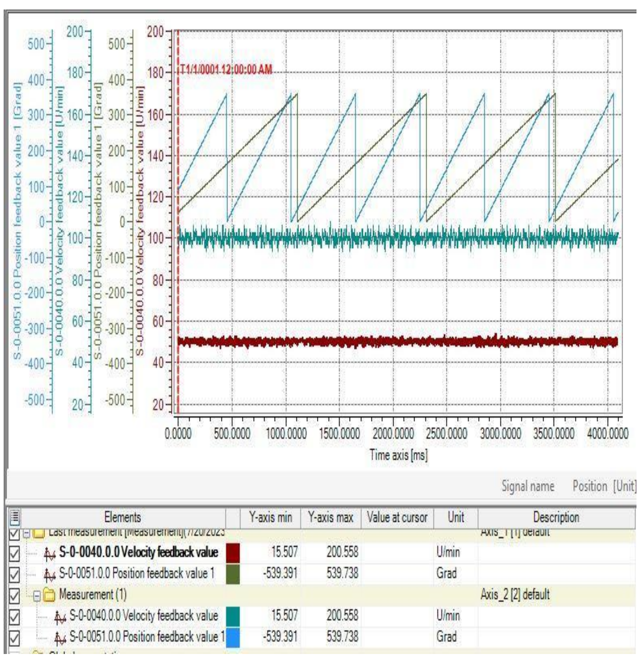


Fig.17. plot of motion parameters of Master/Slave Drive

Figure 17 represents the combined oscilloscope reading of Relative Position and Relative Velocity of both the Master and Slave Drive. Form the graph, it is inferred that, in time axis of 1000ms, the Master drive rotates 360 degree and the Slave Drive rotates 720 degrees. This is because of the gear ratio set as 1:2 and due to this configuration, the velocity of the Slave drive is also twice as that of the Master drive.

TABLE II
MAPPING OF COS WITH LEARNING DOMAIN

Sl.No	Type of Problem statements	Target COs	Learning Domain	Assessment Method
1	MLC,MLD Configuration	CO3	Cognitive	Continuous Assessment through demo
2	UI Design and Visualization	CO4	Cognitive Affective	Practical exam
3	Sensor-Controller-Drive Integration	CO5	Psychomotor Affective	Project evaluation

The problem statements are framed for course outcomes CO3, CO4 and CO5.The Learning domain and the assessment methods of Cos are given in Table II [24].

V. RESULTS AND STATISTICAL ANALYSIS

The internal and terminal marks of students are assessed using the rubrics given in Table III [25]. The marks scored by the 60 students of final-year mechatronics of 2020, 2021, and 2022 are compared against the course outcomes CO3, CO4, and CO5 using the statistical analysis tool Minitab[26].

TABLE III
ASSESSMENT RUBRICS

Sl.No	Rubrics	Marks
1.	Write up	10 Marks
2.	Configuration	20 Marks
3.	User Interface	20 Marks
4.	Integration	20 Marks
5.	Final Result	20 Marks

The Analysis of variance (ANOVA) single factor method [27] is used for comparing the results of 2020, 2021 and 2022.

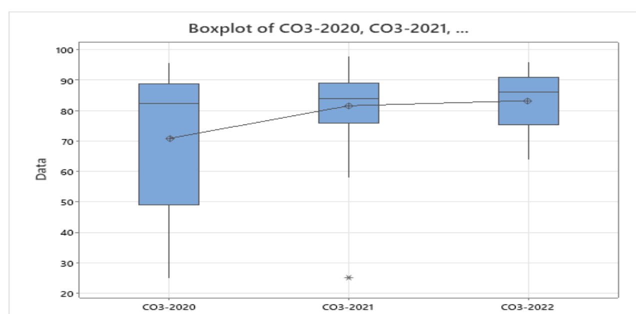


Fig.18. Box plot of marks scored in course outcome CO3

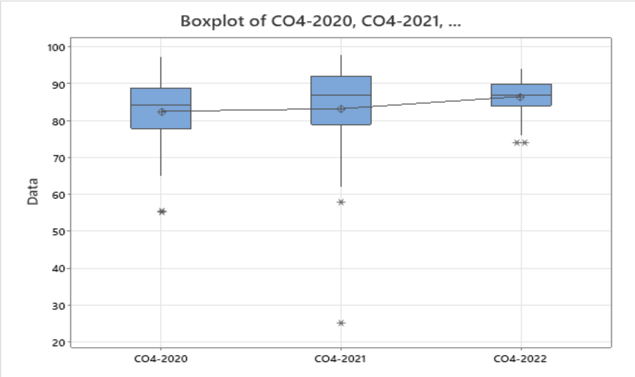


Fig.19. Box plot of marks scored in course outcome CO4

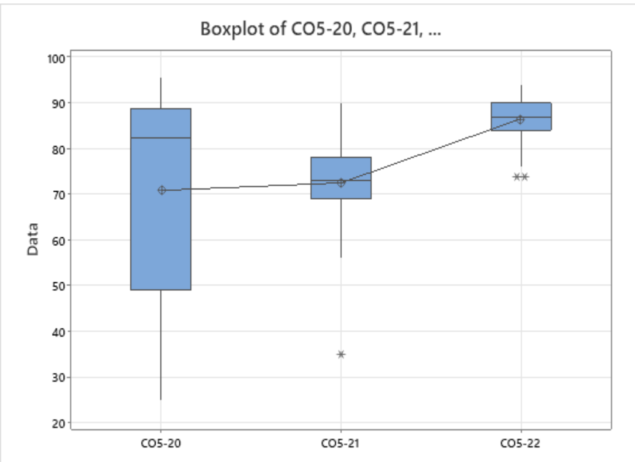


Fig.20. Box plot marks scored in course outcome CO5

Figure 18-20 gives the box plots of the marks scored by the students in course outcome CO3, CO4,CO5 respectively during the year 2020,2021 and 2022.The careful observation of results show that spread of marks more in 2020 compared to 2021 and 2022.In the year 2022 more students scored higher more than 80% compared to the previous years. This shows that students learning behavior enhanced more due to this new approach. The following hypothesis are formulated for analyzing the variance of course outcomes CO3, CO4 and CO5 during the year 2020, 2021 and 2022.

H0: Mean of the marks scored in the corresponding course outcome (CO3, CO4 and CO5) same for all years (2020,2021, 2022)

H1: Not mean marks are equal scored in the corresponding Course outcome (CO3, CO4 and CO5) for all years (2020, 2021, 2022)

The Significance level of α=0.005 is set for testing the hypothesis.The system integration results are tested for the above hypothesis using single factor anova in Minitab 21 software. The anova results of Course outcome CO3 marks are shown in Table IV. The probability value ($P<0.05$) which is less than 0.05 show that null hypothesis is rejected at 0.05 significance level. Hence the mean marks scored by the students in System integration CO3 is different in the year 2020, 2021 and 2022.

TABLE IV
ANOVA RESULT OF COURSE OUTCOME CO3

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	6072	3035.8	13.36	0.000
Error	196	44543	227.3		
Total	198	50615			

Further analysis of results using Tukey and Fisher comparison of means [28] as given in Figure 21, Table V and Figure 22, TableVI reveal that the difference of marks scored by students during 2021-2020, 2022-2020 are significantly different, but the difference of marks 2022-2021 is significant. This shows the proposed method enhances the learning skills of the students from the year 2021 and 2022.

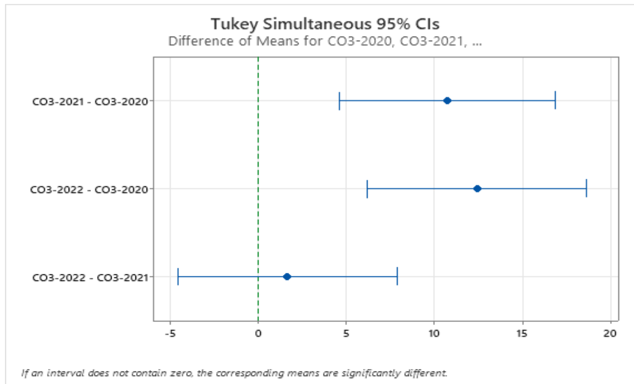


Fig. 21. Tukey difference of means plot for CO3

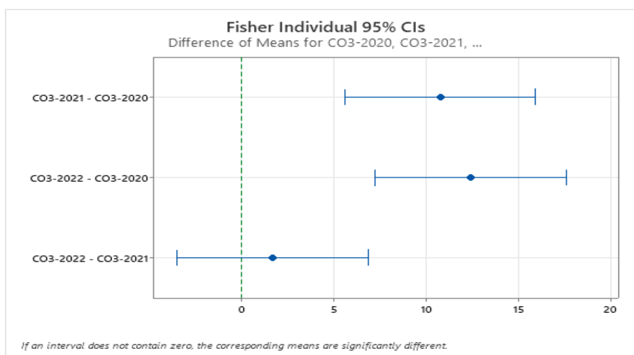


Fig. 22. Fisher difference of means plot for CO3

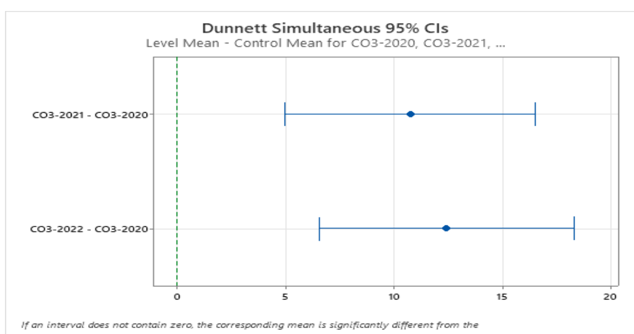


Fig. 23. Dunnett difference of means plot for CO3

Figure 23 and Table VII show that dunnett difference of mean plot using the control group of year 2020.The plot shows clearly the improvement of marks due to the proposed methodology from the year 2021.

TABLE V
FISHER INDIVIDUAL TESTS FOR DIFFERENCES OF MEANS-CO3

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO3-2021 - CO3-2020	10.74	2.59	(5.62, 15.86)	4.14	0.000
CO3-2022 - CO3-2020	12.42	2.63	(7.24, 17.59)	4.73	0.000
CO3-2022 - CO3-2021	1.68	2.63	(-3.52, 6.87)	0.64	0.525

TABLE VI
TUKEY SIMULTANEOUS TESTS FOR DIFFERENCE OF MEANS-CO3

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO3-2021 - CO3-2020	10.74	2.59	(4.61, 16.87)	4.14	0.000
CO3-2022 - CO3-2020	12.42	2.63	(6.22, 18.62)	4.73	0.000
CO3-2022 - CO3-2021	1.68	2.63	(-4.55, 7.90)	0.64	0.800

TABLE VII
DUNNETT SIMULTANEOUS TESTS FOR LEVEL MEAN - CONTROL MEAN-CO3

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO3-2021 - CO3-2020	10.74	2.59	(4.95, 16.52)	4.14	0.000
CO3-2022 - CO3-2020	12.42	2.63	(6.56, 18.27)	4.73	0.000

The similar analysis is done for CO4 and CO5 of system integration marks and the analysis results are shown below.

TABLE VIII
ANOVA RESULT OF COURSE OUTCOME CO4

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	608.4	304.19	3.68	0.027
Error	196	16188.9	82.60		
Total	198	16797.3			

TABLE IX
ANOVA RESULT OF COURSE OUTCOME CO4

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	9699	4849.4	26.54	0.000
Error	196	35808	182.7		
Total	198	45507			

Table VIII and IX reveal that P-value of test statistic is less than the significant value 0.05, hence mean value of marks in CO4 and CO5 are also different during the years 2020, 2021 and 2022.

TABLE X
TUKEY SIMULTANEOUS TESTS FOR DIFFERENCE OF MEANS-CO4

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO4-2021 - CO4-2020	0.73	1.56	(-2.96, 4.43)	0.47	0.886
CO4-2022 - CO4-2020	4.05	1.58	(0.31, 7.79)	2.56	0.030
CO4-2022 - CO4-2021	3.32	1.59	(-0.43, 7.07)	2.09	0.095

TABLE XI
FISHER INDIVIDUAL TESTS FOR DIFFERENCES OF MEANS -CO4

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO4-2021 - CO4-2020	0.73	1.56	(-2.35, 3.82)	0.47	0.640
CO4-2022 - CO4-2020	4.05	1.58	(0.93, 7.17)	2.56	0.011
CO4-2022 - CO4-2021	3.32	1.59	(0.18, 6.45)	2.09	0.038

TABLE XII
DUNNETT SIMULTANEOUS TESTS FOR LEVEL MEAN - CONTROL MEAN-CO4

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO4-2021 - CO4-2020	0.73	1.56	(-2.75, 4.22)	0.47	0.854
CO4-2022 - CO4-2020	4.05	1.58	(0.52, 7.58)	2.56	0.021

Tables X, XI,XII and Figures 24, 25, 26 shows that the students in 2022 scored remarkably well in CO4 compared to the year 2020 and 2021. It is revealed from the dunnett table and the plot, the marks of 2020 and 2021 seems to be equal in CO4.But the mean difference of 2022-2020 is significantly different. Hence the proposed method enhances students' ability to create and visualize the user interface. Fisher plot and corresponding table also show that the CO4 marks in 2020 and 2021 is significantly different from 2022 marks.

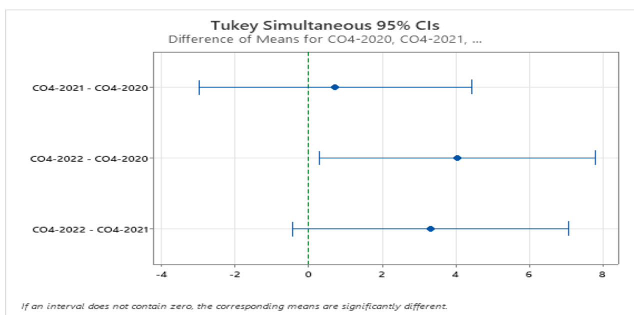


Fig. 24. Tukey difference of means plot for CO4

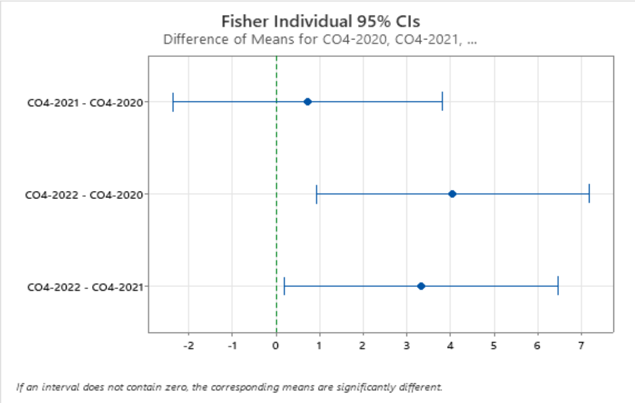


Fig. 25. Fisher difference of means plot for CO4

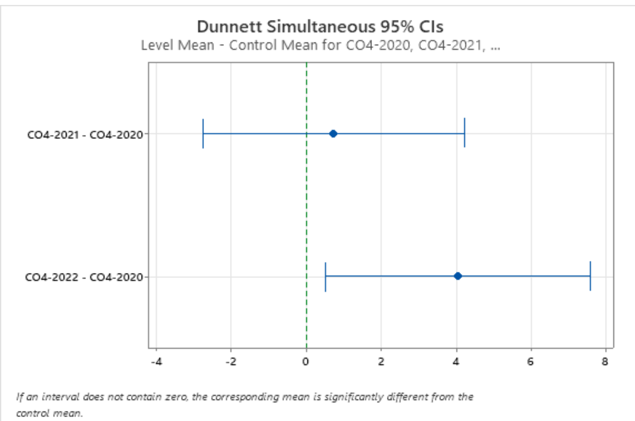


Fig. 26. Dunnett difference of means plot for CO4

TABLE XIII

TUKEY SIMULTANEOUS TESTS FOR DIFFERENCE OF MEANS-CO5

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO5-21 - CO5-20	1.66	2.33	(-3.84, 7.15)	0.71	0.756
CO5-22 - CO5-20	15.70	2.35	(10.14, 21.26)	6.67	0.000
CO5-22 - CO5-21	14.04	2.36	(8.46, 19.62)	5.94	0.000

TABLE XIV

FISHER INDIVIDUAL TESTS FOR DIFFERENCES OF MEANS –CO5

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO5-21 - CO5-20	1.66	2.33	(-2.93, 6.25)	0.71	0.477
CO5-22 - CO5-20	15.70	2.35	(11.05, 20.34)	6.67	0.000
CO5-22 - CO5-21	14.04	2.36	(9.38, 18.70)	5.94	0.000

TABLE XV

DUNNETT SIMULTANEOUS TESTS FOR LEVEL MEAN - CONTROL MEAN-CO5

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CO5-21 - CO5-20	1.66	2.33	(-3.53, 6.84)	0.71	0.699
CO5-22 - CO5-20	15.70	2.35	(10.45, 20.94)	6.67	0.000

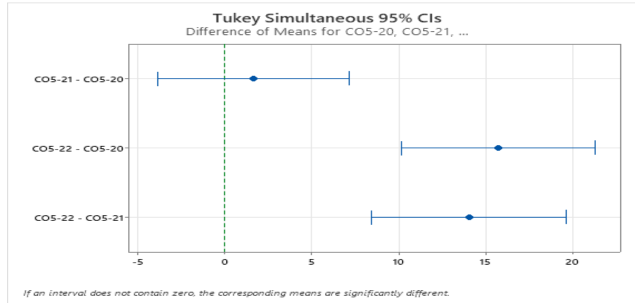


Fig. 27. Tukey difference of means plot for CO5

Figures 27, 28 and corresponding Tables XIII, XIV show that mean difference of 2022 with 2020 and 2021 is highly not significant. But mean difference of 2021 and 2020 students are significant. The same results are justified in the Dunnett method given in Figure 29 and Table XV where the difference between 2022 and 2020 is significantly different compared to 2021 and 2020.Hence we conclude that the students of 2022 system integration batch scored well in the CO5, which is integration of actuator and controller, compared to the previous two years due to the proposed way of conducting lab courses.

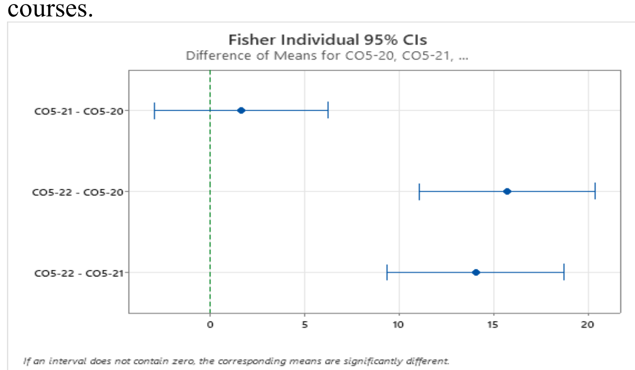


Fig. 28. Fisher difference of means plot for CO5

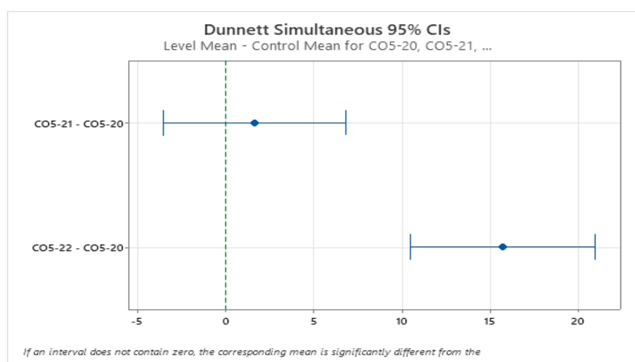


Fig. 29. Dunnett difference of means plot for CO5

The above statistical analysis of course outcomes CO3, CO4, and CO5 of system integration lab for the students of 2020, 2021 and 2022 show that students of 2022 system integration batch scored remarkably well in their internal and terminal examinations due to the introduction of skill based teaching of practical classes.

CONCLUSION

The industry expectation of industry ready engineers from academic institutions can be sorted out by providing practical courses which develops students' application skills. In this paper it is proved using the students' assessment that the development of affective and psychomotor behavior of students is improved due to the provision of industry focused skills in the system integration lab. The statistical analysis of students' outcome shows that the proposed methods enable most of the students to achieve their outcomes well compared to students of previous years. Hence it is concluded from this study that the proposed methods enhances students employability and also creates urge for learning the industry ready skills among students. The proposed approach will be extended to the other laboratory courses such as automation lab, Microcontroller lab and Robotics lab to enhance problem solving skills of students. Though this approach increases the working load of faculty, the behavioral change happen to the students for skill development will outweigh this limitation.

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