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Using Puzzles and Hands-on Activities for Teaching Concepts in Control Systems

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With more than 25 years of combined experience in the high-tech industry, government and academia Dr. Raviv developed fundamentally different approaches to ”out-of-the-box” thinking and a breakthrough methodology known as ”Eight Keys to Innovation.” He has been sharing his contributions with professionals in businesses, academia and institutes nationally and internationally. Most recently he was a visiting professor at the University of Maryland (at Mtech, Maryland Technology Enterprise Institute) and at Johns Hopkins University (at the Center for Leadership Education) where he researched and delivered processes for creative & innovative problem solving.

For his unique contributions he received the prestigious Distinguished Teacher of the Year Award, the Faculty Talon Award, the University Researcher of the Year AEA Abacus Award, and the President's Leadership Award. Dr. Raviv has published in the areas of vision-based driverless cars, green innovation, and innovative thinking. He is a co-holder of a Guinness World Record. His new book is titled: ”Everyone Loves Speed Bumps, Don't You? A Guide to Innovative Thinking.”

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Using Puzzles for Teaching and Learning Concepts in Control Systems

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Abstract

Today, conventional methods of text-based instruction may not be as effective as they have been in previous generations. As technology brings about a paradigm shift in the way people perceive and learn new information, additional methods should be explored to adapt to the students' new styles of learning.

This paper describes several illustrative examples of teasers and puzzles aimed at visualizing and comprehending math-intensive, theoretical concepts in Control Systems.

The idea is to explain themes in an intuitive and engaging manner before transitioning to textbook-like traditional material. The method is designed to be supplemental to existing educational resources, in order to promote intuition prior to introducing further mathematical analysis. It should be noted that the proposed approach is not an attempt to replace chapters in existing Controls textbooks.

Since a growing number of students have difficulties connecting mathematical representations to practice, the goal of using puzzles, as an educational tool, is to provide a richer perspective of concepts in Control Systems by promoting intuitive thinking through real-life, hands-on, enjoyable activities. Some of the puzzles in this paper are well known while others have been created by the authors. The puzzles are presented with a new twist in an attempt to promote better understanding of basic concepts in Control Systems, such as stability, steady state and feedback. They allow the instructor to introduce concepts in visual, intuitive and engaging ways.

This approach is also meant to foster an environment where students do not feel intimidated by the math-focused content and to boost their confidence while establishing intuition, which can be applied to a later analysis. This modus operandi can lead to an improved, more profound understanding of the subject matter. Some of the puzzles can also be used to clarify different control ideas, gradually explaining concepts of higher levels of complexity by looking at puzzles from different points of view.

As efforts are currently being explored by a number of educators to achieve a similar goal, this project focuses on creating a working manuscript for instructors to explain many key topics in Control Systems using puzzles and teasers. This is part of a greater effort at Florida Atlantic University, where this approach is currently being applied to different subjects in STEM.

To gauge the receptiveness of the methodology, a few puzzles and activities were used over the course of a semester in an Electrical Engineering class entitled “Control Systems 1.” The results, based on 40 student responses, were promising. Most students strongly agreed that visual, intuitive and engaging activities help them understand concepts better, and agreed that brain teasers and puzzles help them to understand and clarify concepts in Control Systems. According to an additional survey question students prefer to use PowerPoint and instructor notes, and not only rely on self-learning.

1. Introduction

Different teaching methods of explaining a subject can promote the understanding of concepts to larger audiences. There are differences in the way students grasp and understand ideas, so when a professor introduces a concept in an intuitive way (or when students learn the subject in such a way), it becomes clearer and less intimidating since the students can relate the intricate math world to add-on simple daily examples that they are familiar with.

According to Cambridge Dictionaries Online[1] a puzzle is “a game or toy in which you have to fit separate pieces together, or a problem or question that you have to answer by using your skill or knowledge.”

Puzzles are often problems that are related to real life (and their solutions can be used to help in real cases). Puzzles can help students understand difficult topics or concepts by enjoyable, non-traditional means, thereby aiding learning process and by further motivating the students to study the subject.

Introducing concepts in Control Systems by means of puzzles is a different and innovative approach. Initial presentation of Control Systems using visual and tactile puzzles also aimed to better match students’ varied learning styles, turning a theoretical and sometimes boring class into an experience that can instigate the student to enjoy the class. Some of the puzzles in this paper are well known in the puzzle literature[5,7,8]. In this manuscript the puzzles are presented with a new twist in an attempt to foster understanding of basic concepts in Control Systems, such as stability, steady state, negative and positive feedback, and closed loop systems. This visual, intuitive and engaging introduction is followed by a more traditional textbook-based approach of teaching. The puzzles also serve as means to promote students' interest in Control Systems topics, and to increase their motivation by relating them to daily experiences and applications.

It is somehow related to the process of gamification, which according to Professor Karl. M. Kapp[3] is close to "adding game elements to non-game situations or to learning situations." Gartner Group[4] predicted, back in 2012, that "By 2015, 40 percent of Global 1000 organizations will use gamification as the primary mechanism to transform business operations." Sharing a conceptually similar approach, it is expected that introducing Control Systems concepts by means of puzzles is a strategy that can foster the learning process.

It should be noted that the basic concept of relating the educational material to something that students can relate to has being recently promoted in some other subjects. For example, Tyler DeWitt, a student at MIT, and a high school teacher has been using this approach to teach Chemistry[2]. However, empirical support that shows that games help in learning is still missing[13]. According to[13], the learning outcomes were not improved when students were exposed to games. One theory is that in playing games, lack of success and too much negative feedback can cause de-motivation.

We are using puzzles in a non-intimidating, non-competitive way. Students participate in group discussions when they solve the puzzles and are engaged in hands-on fun, puzzle-based activities. The initial feedback that we received (see questionnaire results) is encouraging. We are working on more direct assessment methods to measure the effect of puzzles on student success.

2. Methodology

In this section we share puzzles and teasers that can help explain some basic concepts in control. We focus on the concept of stability, steady state and feedback.

a. Using Puzzles to Explain Stability

Let us look at the example below, which is shown in more details in[5].

Imagine a chessboard with 64 squares as in Figure 1:

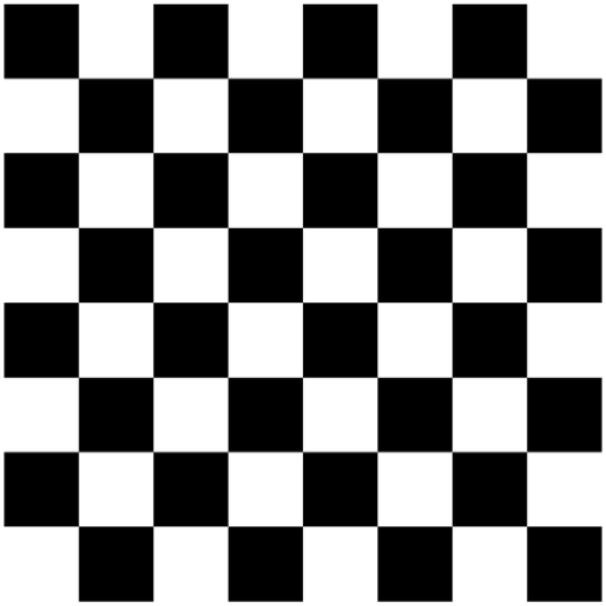


Figure 1 - Chessboard representation

Put just one bean on the first square of a chess board, two on the second, four on the third, eight on the fourth, and so on, doubling the number of beans when proceeding to the next square until all 64 squares have been filled (Figure 2). What is the total final amount of beans when all the squares are filled?[5]

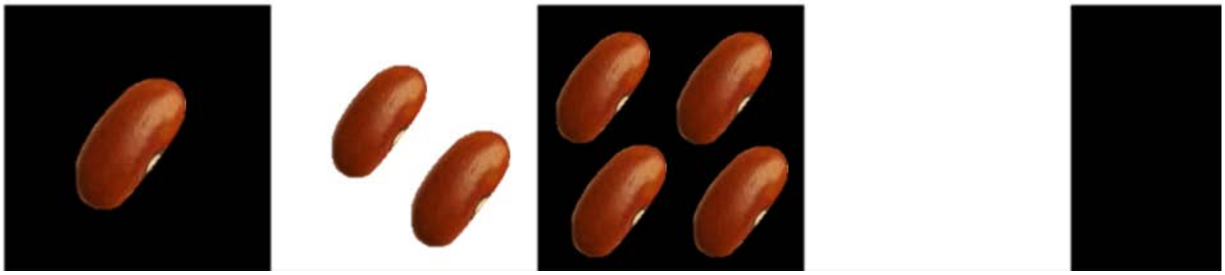


Figure 2 - Chessboard with beans

The sum of consecutive powers of 2 is given by the formula:

$$1 + 2 + 2^2 + 2^3 + 2^4 + \cdots + 2^n = \ 2^{n+1} - 1$$

As the chessboard has 64 squares, the final amount of beans is:

$$1 + 2 + 2^2 + 2^3 + 2^4 + \cdots + 2^{63} = \ 2^{64} - 1$$

This result is more than 18,000,000,000,000,000,000.

The use of the chess puzzle can help in understanding stability. If the input is the first bean on the first square (i.e., bounded input), and if the transfer function is a repetitive multiplier by a factor of 2, then the output of the system (i.e., the number of grains on the nth chess board square) is unbounded, which is a sign of instability. In other words, the system is NOT "Bounded Input Bounded Output" (BIBO) stable. Each chessboard position can be understood as a defined time interval, thus one can assume that after 64 chessboard positions (or 63 time intervals), the system will "respond" with a total quantity of $2^{64} - 1$ grains.

To get a better idea, and for visualization purposes, here is a "Fun fact[11]:"

On the entire chessboard there would be $2^{64} - 1$ = 18,446,744,073,709,551,615 **grains of rice**, weighing 461,168,602,000 metric tons, which would be a heap of rice larger than Mount Everest.

To make it even more interesting, here is some historical information:

Origin of problem[10]

- A version has the inventor of chess (in some tellings Sessa, an ancient Indian Minister) request his ruler give him wheat according to the wheat and chessboard problem.
- The ruler laughs it off as a meager prize for a brilliant invention, only to have court treasurers report the unexpectedly huge number of wheat grains would outstrip the ruler's resources.
- Versions differ as to whether the inventor becomes a high-ranking advisor or is executed.

This example can lead to explaining the idea of pole location as related to stable and unstable systems. Figure 3 illustrates this principle.

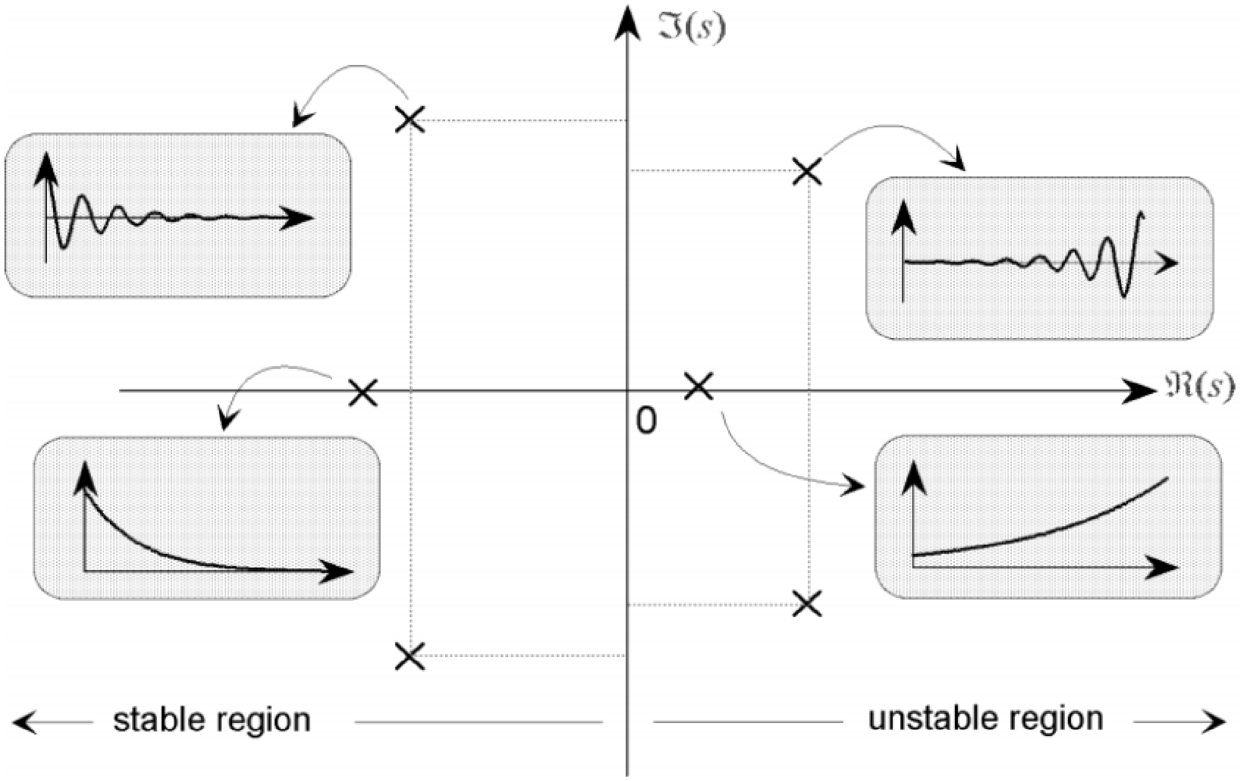


Figure 3 - Different time domain outputs based on S-domain poles' locations - Source: ONLINE[6]

The chess problem "output" is related to the right bottom drawing in Figure 3. It shows an exponentially diverging response due to system with a real pole located in the right hand side of the S-Plane (aka right hand pole). Similar to the growing value of the number of beans on the chessboard, the value of the function grows, and keeps doubling itself after a certain time interval. So even when the first square is filled with a limited and small amount of grains (one bean in the given example) the result when time approaches infinity will not be bounded. In other words, when $t \rightarrow \infty$, the output also tends to be infinite. In the chessboard example, the infinite time growth can be related to, and understood as, an infinite number of chessboard squares.

b. Using Puzzles to Explain Steady State

Example 1: Fibonacci Series.

In this example we try to find the steady state ratio of two consecutive numbers a_{n-1}, a_n (for n>1) in Fibonacci series. To illustrate it, first let us look at the series:

- Initial condition: the two first numbers of the series are $a_0 = 0$ and $a_1 = 1$.

- For $n > 1$, the n^{th} element is obtained using: $a_n = a_{n-1} + a_{n-2}$

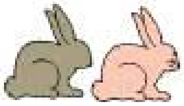
The next terms of the Fibonacci series with the given initial condition are:

$$0,1,1,2,3,5,8,13,21,34,55,89, \ldots$$

The ratio between two consecutive numbers above, for $n > 2$, is:

$$1, 2, 1.5000, 1.6667, 1.6000, 1.6250, 1.6154, 1.6190, 1.6176, 1.6182, \ldots$$

It can be shown that the ratio, when n approaches infinity, is $\frac{\sqrt{5}+1}{2}$, also known as Phi (the Greek Alphabet letter φ). This is the steady state value of the ratio between two consecutive numbers. To illustrate this example to students (and the concept of steady state), we use the rabbit reproduction example from Levitin[5]. Given a pair of newborn rabbits (male and female):



"All rabbit pairs are not fertile during their first month of life but give birth to one new male/female pair at the end of the second month and every month thereafter. How many pairs of rabbits will be there in a year?"
Let us visually observe the Rabbit population growth (Figure 4).

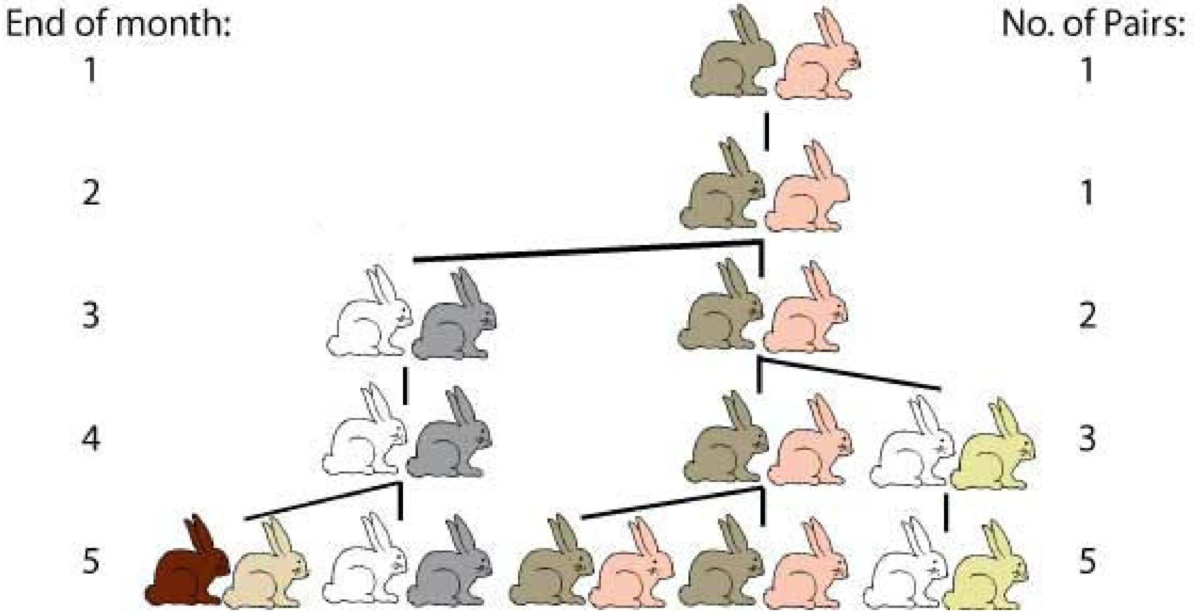


Figure 4 - Puzzle's Visual Solution

This puzzle can be solved using a very simple graphical illustration, which is presented in Figure 5:

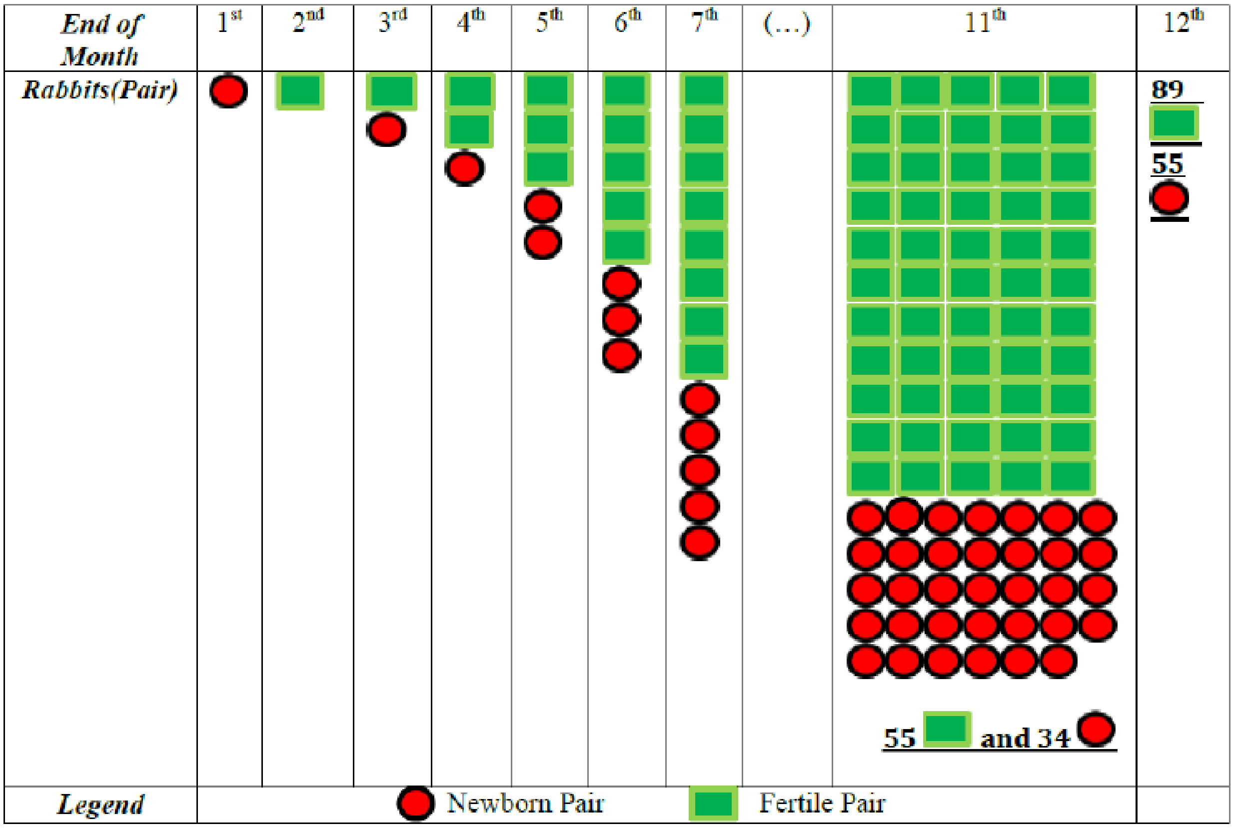


Figure 5 - Puzzle's Graphical Solution

In the solution presented by Figure 5, it can be seen that the number of newborn rabbits in a certain month equals the sum of the number of rabbits in the prior 2 months. Two simpler and more condensed notations are shown in Figure 6 and Figure 7.

As can be seen in Figure 7, the fertile rabbits` function always gives a perfect prediction about how the newborn rabbits function is going to behave. (This is what is called a Function Time Shift, which is visualized in the graph of Figure 6.)

Figure 7 is a numerical representation of Figure 6.

It is possible to represent a pictorial block diagram where the rabbits are placed initially by a system, the one shown in Figure 8, for example. The initial number of newborn pairs is the system's input. For this system, there will be three outputs. These outputs are:

- the quantity of newborn rabbit pairs in the n^{th} month,
- the quantity of fertile rabbit pairs in the n^{th} month,
- the ratio between the total rabbits in the n^{th} month and the total rabbits in the $(n^{th} - 1)$ month.

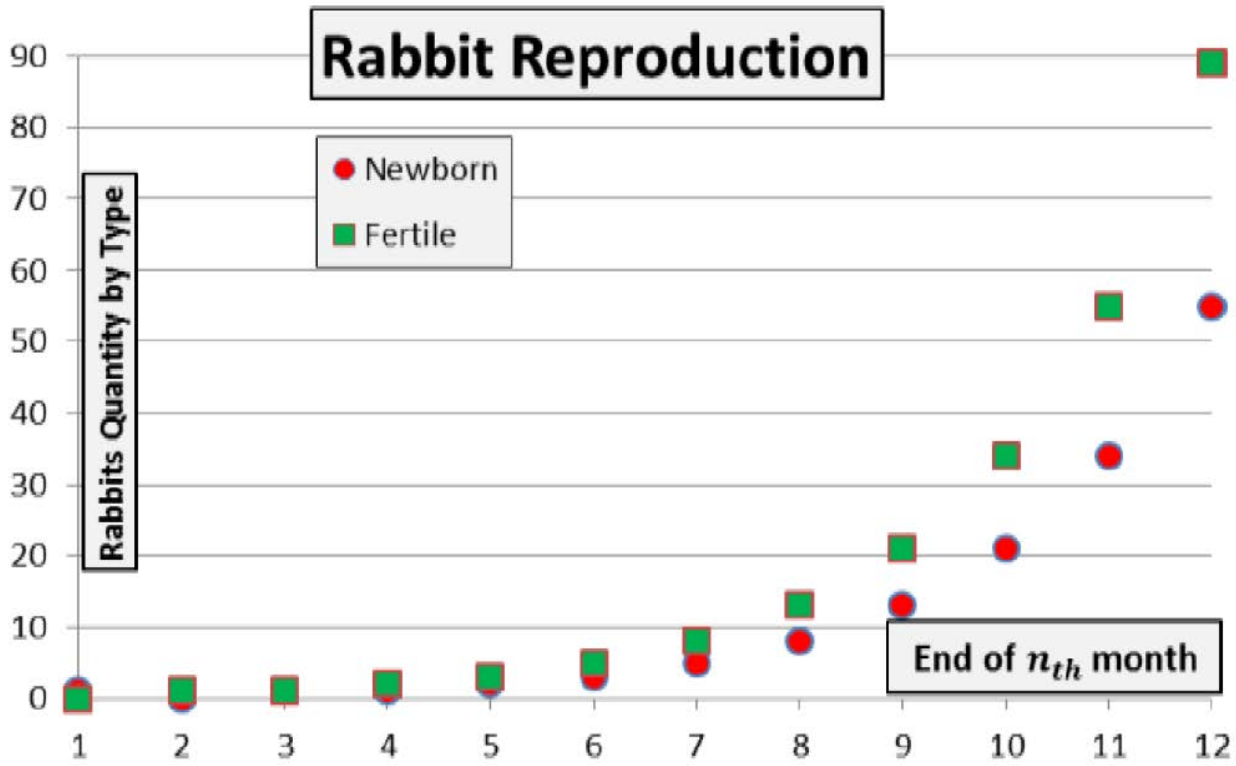


Figure 6 - Rabbits Growth Graph

End of Month	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
🔴 Newborn Pair Quantity	1	0	1	1	2	3	5	8	13	21	34	55
🟩 Fertile Pair Quantity	0	1	1	2	3	5	8	13	21	34	55	89

Figure 7 - Numerical Representation of Rabbit Growth

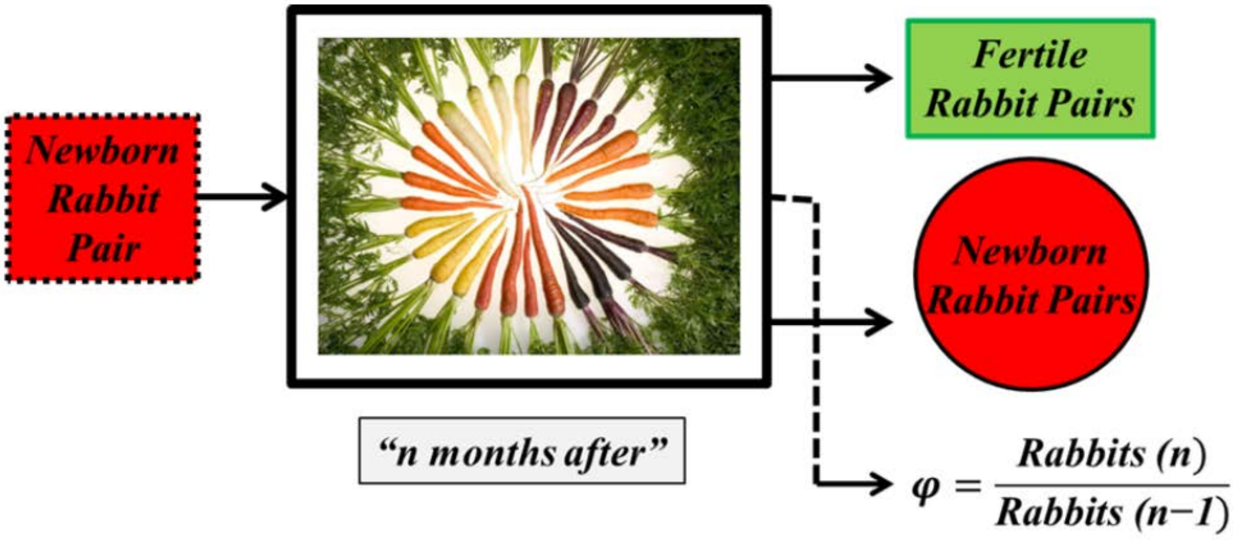
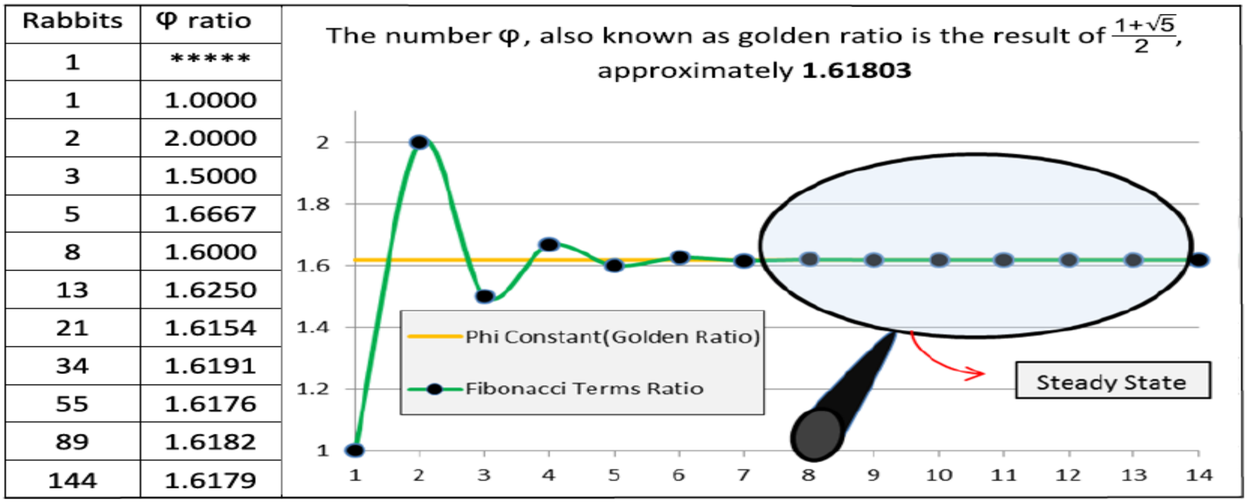


Figure 8 - System's Pictorial Representation

It can be seen that the ratio of number of rabbits between 2 consecutive months approaches the value of φ. This is the steady state value of the system. Note that despite the unbounded growth in number of rabbits, the system has a steady state value, which is φ**.**

Figure 9 shows the ratio of rabbit population growth as a function of time (in months): note that after 5 months the steady state becomes very close to the theoretical value φ.



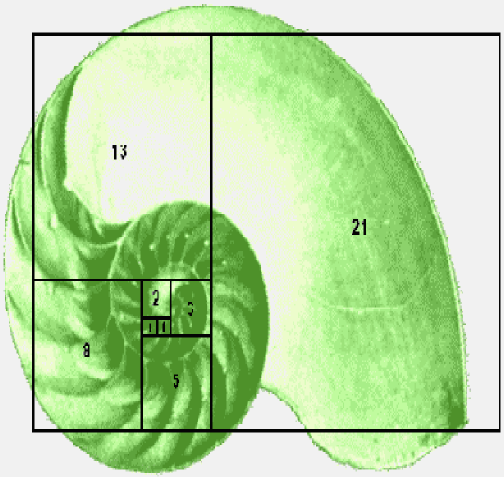
Rabbits	φ ratio
1	*****
1	1.0000
2	2.0000
3	1.5000
5	1.6667
8	1.6000
13	1.6250
21	1.6154
34	1.6191
55	1.6176
89	1.6182
144	1.6179

The number φ, also known as golden ratio is the result of $\frac{1+\sqrt{5}}{2}$, approximately **1.61803**

Figure 9 - Ratio of Rabbit Population Growth as a Function of Time (in Months)

Some fun facts about the Golden Ratio φ:

Golden Ratio can be observed in nature and in art/design. Here are some examples:



The Hailstone Sequence can be stated as follows:

Take any positive integer "n", then follow the operations below to produce a sequence:

- if n is even: next number = $n/2$.
- if n is odd: next number = $3n + 1$.

As an example let us pick any initial number, say 20. In this case the sequence will be

$$20, 10, 5, 16, 8, 4, 2, 1, 4, 2, 1, 4, 2, 1, 4, 2, 1, \ldots$$

In this case the students are asked to pick any number and follow the algorithm. In the end they will get the triple repetition, i.e., 4, 2 and 1, which can be viewed as steady state.

Another example, starting now by an odd and bigger number 113 is chosen to start the sequence. The result is as follows:

$$113, 340, 170, 85, 256, 128, 64, 32, 16, 8, 4, 2, 1, 4, 2, 1, \ldots$$

If there is a system that performs the hailstone sequence operations, there will be a steady state regardless of the input. It is interesting because when the above sequence is analyzed, there are clear fluctuations in the sequence and only after the first 6 numbers (i.e., after the number 128) the following numbers become smaller than the initial integer, moving towards the 4 2 1 steady state repetitive sequence. Note that the Hailstone “steady state” of 4 2 1 has not been proven to always be the case. However, a number that does not obey this end result has not yet been found.

c. Puzzles to Explain Feedback

Example 1: Stick Experiment.

The yardstick puzzle can be used to explain positive and negative feedback, its description is given below inspired by[7] and[8].

Part 1: Negative feedback.

Balance a smooth stick on your outstretched forefingers as shown in Figure 10a to see negative feedback in action.

Now move your fingers towards each other until they come together. Your fingers will end up touching each other right under the stick’s center of mass, and the stick will balance (Figure 10b). You can repeat the trick, changing the initial position of your fingers, but the result will always be the same.

This is an example for negative feedback. The fingers alternate in motion until they touch each other (Figure 10a). At any moment in the experiment only one finger at a time moves. The one that moves experiences less friction. This action continues until the friction between the stick and the moving finger exceeds the friction of the other finger. This leads to a switch in fingers’ roles: the moving finger stops moving, and the stationary finger starts to move. The process repeats itself until the fingers touch each other.

This is a great experiment to illustrate negative feedback. In fact it always works whatever you use – a ruler, a walking stick, a broom, or a billiard cue.

Figure 10a - Stick Puzzle: Fingers moving inward

Figure 10b - Stick puzzle: Final location of fingers

Part 2: <u>Positive feedback.</u>

Once at the center, try to move your fingers away from each other (Figure 11). When attempting to do so, an unexpected motion occurs. Only one finger moves toward the end of the stick, while the other stays at the center. This is caused by a greater friction force exerted on the stationary finger. As one finger moves there is less friction with the stick on that finger, allowing it to move farther away, exerting less and less friction on it as it moves. In addition, due to unbalanced forces, more force is exerted on the stationary finger, making it even more unlikely to change its position. This is certainly an example of positive feedback. The difference in friction forces keeps growing, therefore causing only one finger to keep moving away from the center of the stick.

Figure 11 - Stick puzzle: Demonstrating positive feedback

Example 2: Buzzer.

This example is a class quiz that engages students in a “how buzzers work” activity. It helps in understanding a simple feedback mechanism and in setting up a feedback block diagram.

In a buzzer, an electromagnet is used to electromechanically and repeatedly self-interrupt a circuit. In a way we can view it as a set of semi binary operations (“binary pulses”) that open and close an electric circuit repeatedly, leading to a series of buzzes that collectively cause the buzzing sound of the bell.

Here is how it works (discussed with the students):

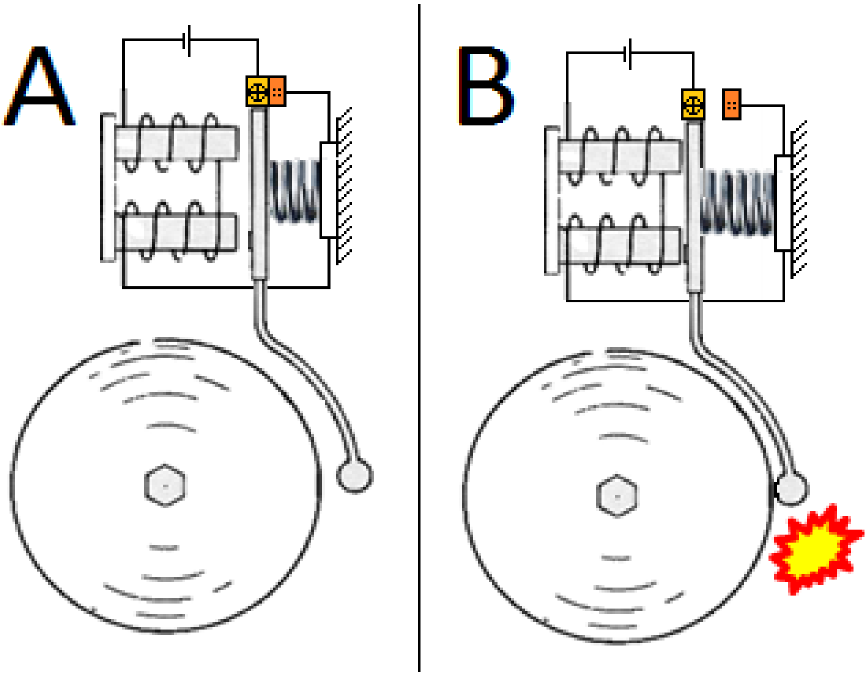


Figure 12 - Buzzer Mechanism

In the case where the battery is continuously connected to the circuit:
When the circuit is closed (as in Figure 12A), the electromagnet pulls up the contact arm. This arm movement breaks the bell circuit (i.e., makes it “open circuit” as in Figure 12B) which shuts off the electromagnet. The arm moves again to the other position, closing the circuit again. This process repeats itself. Each time the electromagnetic is activated, the bell is hit, causing the familiar bell sound.

It is like an on-off controller in a closed loop: If the circuit has just been closed, it means that at that moment the electromagnet causes the arm to start moving towards striking the bell. When this happens, the arm opens the circuit, telling the on-off controller to move back and close the circuit again. Note that this process repeats itself at a certain frequency and depends on the electromechanical time constants and some possible system delays.

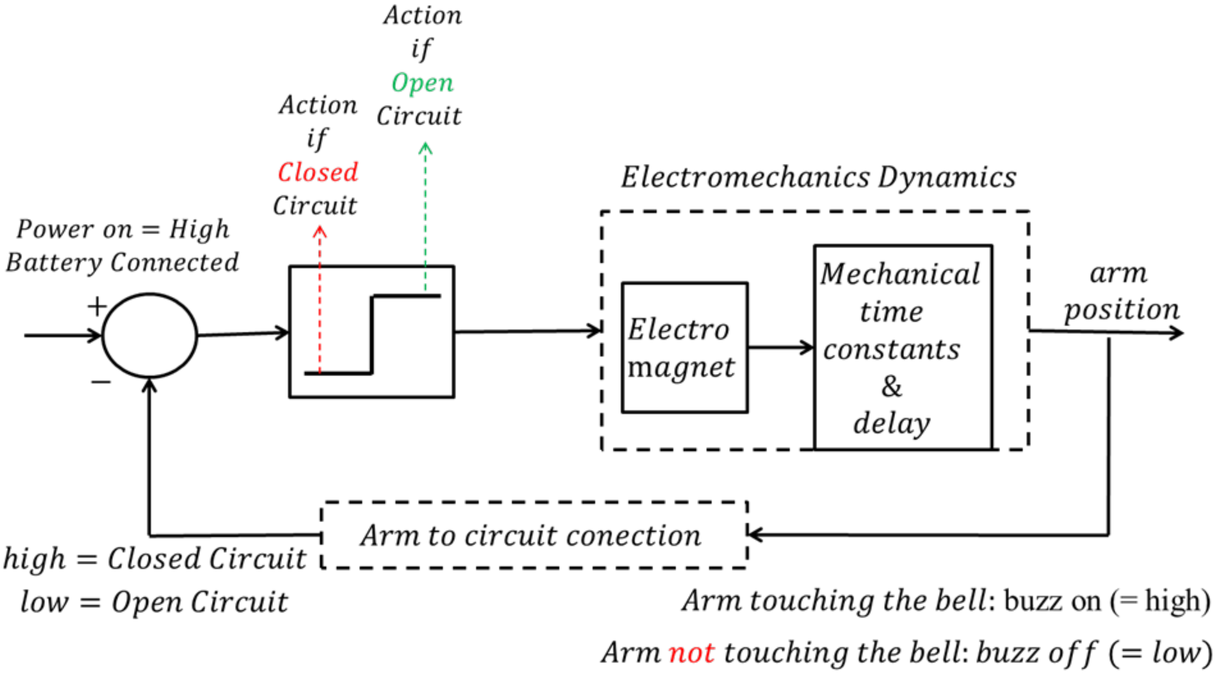
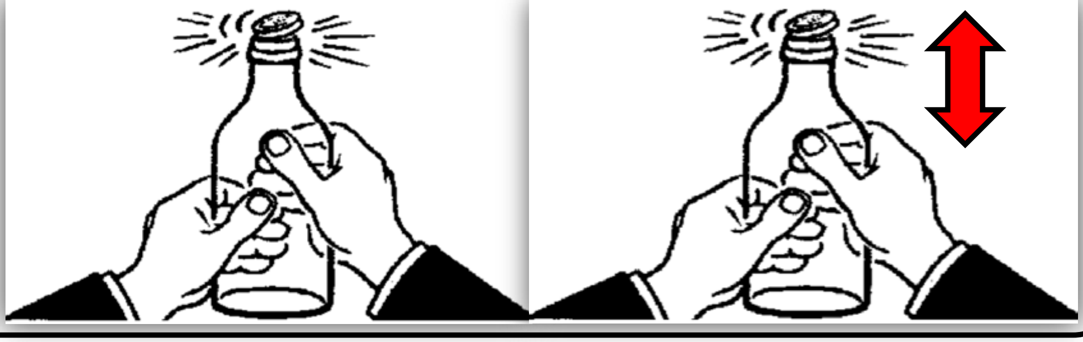


Figure 13 - Buzzer block diagram

Fun experiment/teaser to show feedback:

Place an empty glass bottle in a refrigerator for some time.
Take it out and place a penny in on top of it.
Hold the bottle in your (warm) hands and watch what happens. The coin bounces multiple times!
You have witnessed the concept of feedback!



The reason: your warm hands cause the air inside the bottle to warm up, thereby expand, and pushing the coin up for a short period of time. The coin returns to its original location to face another round of air warming, coin moving up, down, and so on.

Example 3: A Person on a Moving Escalator.

Imagine a person trying to move up an escalator steps while the escalator is moving down.

His goal is to keep a desired constant distance x_o from the starting location of the escalator see Figure 14. He is doing that by changing his own speed relative to the escalator.

Clearly, if the desired location value x_o is higher than his actual location x then he speeds up, and if the desired location value is lower than his actual location, then he slows down. At some point he becomes a better rider, and finds his "right" speed so his location x is very close to, or even equals x_o. The question is how to formulate (model) this feedback system in terms of control systems.

A simplified version of the system is shown in Figure 15. The actual location x is continuously subtracted from the desired location x_o to generate an error signal. This error signal is translated to the person's speed (by a K factor). Now to obtain the actual location x of the person, this speed value is integrated.

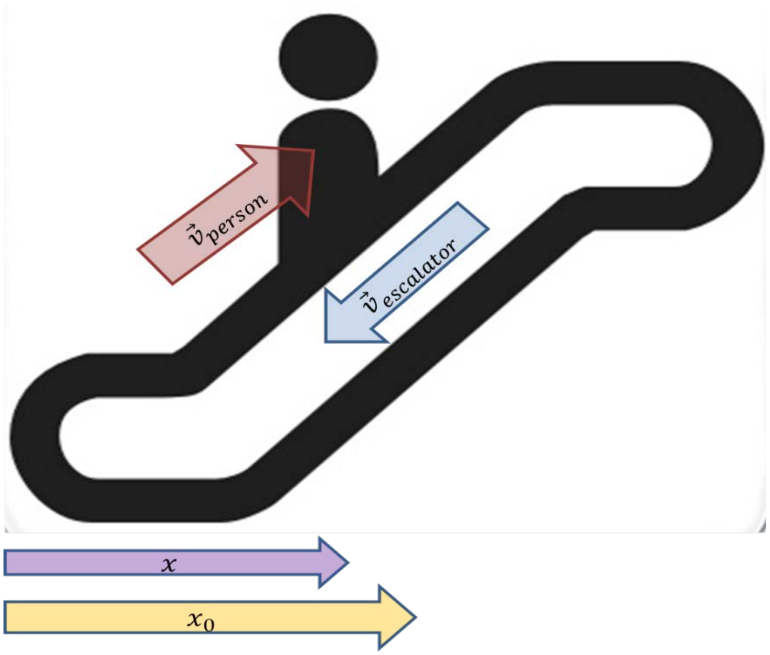


Figure 14 - Person Moving in an Escalator

This is another example for how to challenge the student with a familiar question so they can understand the concept of negative feedback. It is important to note that this feedback loop as shown in the Figure 15 tend to have a 0 steady state error. This is due to the step input (x_o) and the integrator in the loop.

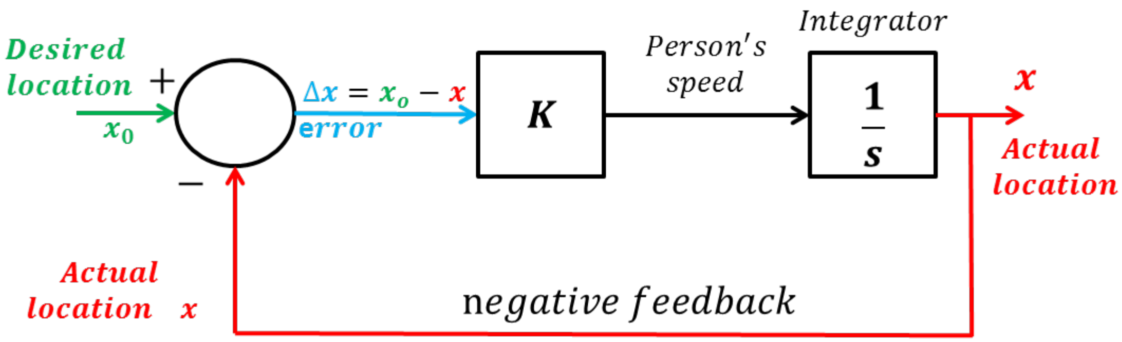


Figure 15 – Diagram of a Person Moving in an Escalator

3. Assessment

The methods and examples highlighted in this paper were implemented in a Controls Systems class taught by a co-author of this paper at Florida Atlantic University. An online questionnaire was conducted in order to gauge how receptive the students were to various learning techniques presented. The responses are based on an interactive class presentation that included the examples described in this paper. 40 students responded to the questionnaire. A summary of the survey can be found in the Appendix.

Figure A1 and Figure A2, located in Appendix, indicate the demographic breakdown of the students who participated. It shows a fair amount of diversity. Most of the students, about 62% were between the age of 21-26, although the class is also well represented by students older than 27 years, about 32%. Only about 6% of the students who answered are younger than 21 years.

The answers of the questionnaire were based on a scale from 0-4, zero being “strongly disagree,” four being “strongly agree” and two being “neutral.” The response to “I feel that understanding concepts in Control Systems is important” (Figure A3) had an average score of 3.83, and standard deviation (SD) of 0.38. The students also responded with an average of 3.55 to each of the statements “I prefer to be introduced to concepts in Control Systems in visual and intuitive ways” and “I feel that visual and engaging activities help me understand concepts better.” Both with SD = 0.67. When the students were asked (Figure A6) if they “feel that brain teasers and puzzles help to understand/clarify concepts in Control Systems,” the average score was well above neutral (2.98) with SD = 0.78. The responses to the four questions show that students agree that it is important to understand concepts in Control Systems and that it should be done by visual, intuitive and engaging methods. In addition, they support the use of puzzles and brain teasers to understand Control Systems.

After a collection of Control System related puzzles was presented to the class an average score of 2.9 and standard deviation of 0.79 was given when the students replied to the statement: “I found the puzzle and hands-on activity-based examples in the presentation to be useful.” On the other hand, when asked if they preferred to be introduced to new topics in Controls by reading relevant chapters in a Controls Systems textbook, the average was 1.58 and 1.09 SD, which is below average. When asked whether they preferred self-learning, the average was 1.23 with 1.08 SD. These results indicate that students prefer hands-on, engaging methods when it comes to learning difficult concepts over the conventional method of prescribed reading that is sometimes employed.

4. Conclusion

As visual media has changed the way people view the world and get information from it, it is necessary to adapt teaching methodologies to students' learning styles. Easy access to web-based information (videos, images, lectures) encourages teaching to be more dynamic and innovative. It does not mean that reference books and textbooks will be abandoned. Instead, it means that teachers should find new ways to embrace students' preferences for learning. The introduction of puzzles to teach Control Systems can make the classroom more engaging, closing the gap between traditional teaching methods and students' learning styles.

Using a puzzles-and-teasers approach is not an attempt to abandon the traditional Control Systems textbooks. Instead they aim to foster a stronger engagement and interest from students before facing complicated concepts in control systems. Presenting a less aggressive introduction, rather than going straight to formulas and long enunciates, may make students more comfortable with Control Systems, promoting more self-motivation that can positively affect students' academic achievements.

Results of a questionnaire at Florida Atlantic University have shown that students, who were exposed to the new way of introducing Control Systems concepts, support a more nontraditional approach to teaching. We plan to further assess the educational value of the puzzles as related to Control Systems. Specifically, we plan on pre and post class tests, in addition to short questions in tests/quizzes to explore the effect of puzzles. This will be explored with experimental and control groups (see[12]).

The authors intend to explore more puzzles for more Control concepts, with a goal of publishing a larger scale manuscript similar to the referenced book[9].

5. Acknowledgements

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6. References

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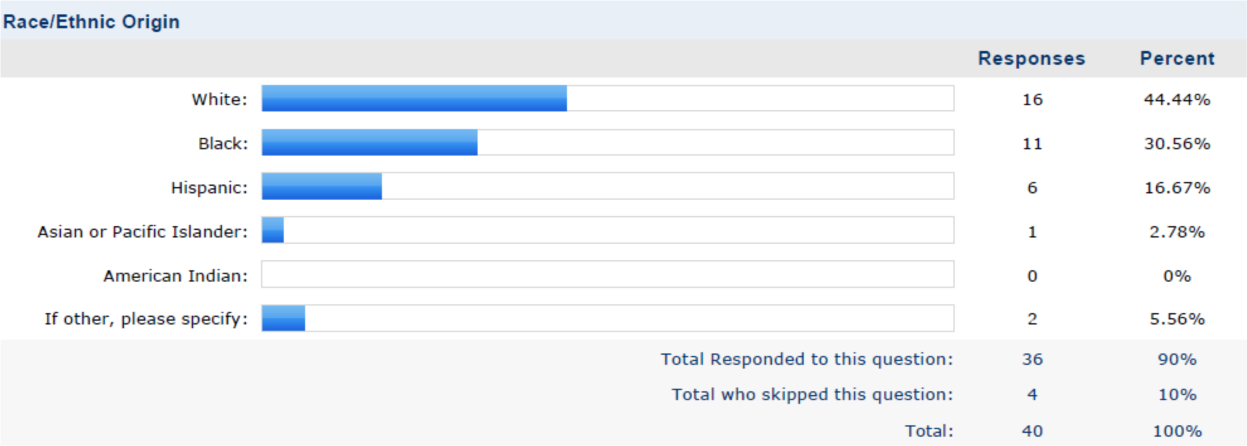
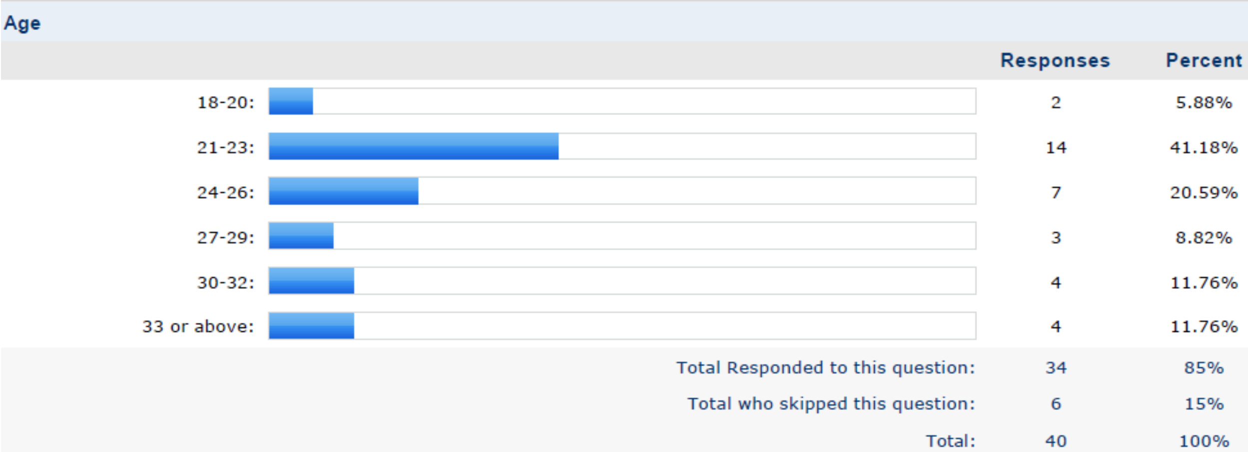
Appendix: Assessment Results



Race/Ethnic Origin

	Responses	Percent
White:	16	44.44%
Black:	11	30.56%
Hispanic:	6	16.67%
Asian or Pacific Islander:	1	2.78%
American Indian:	0	0%
If other, please specify:	2	5.56%
Total Responded to this question:	36	90%
Total who skipped this question:	4	10%
Total:	40	100%

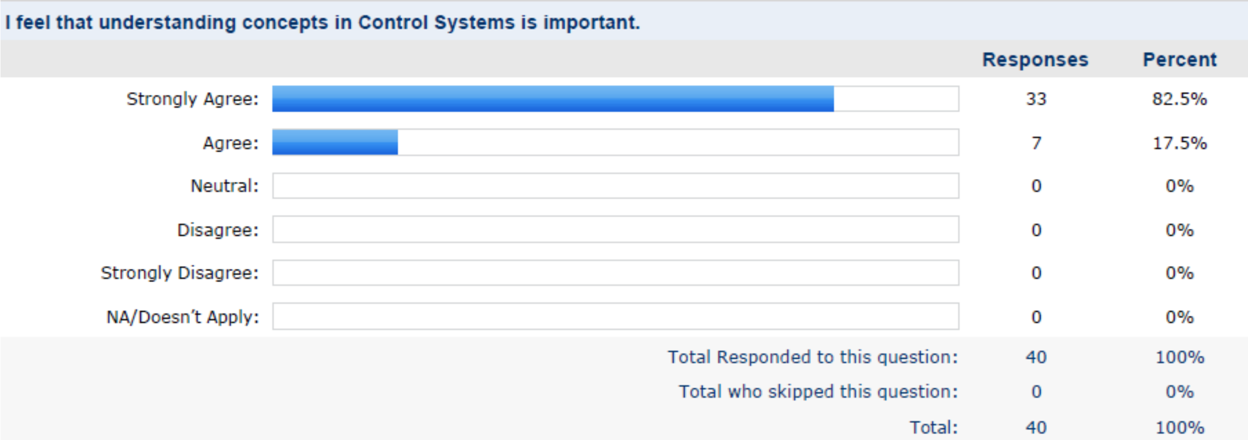
Figure A1 - Students' Ethnic Distribution



Age

	Responses	Percent
18-20:	2	5.88%
21-23:	14	41.18%
24-26:	7	20.59%
27-29:	3	8.82%
30-32:	4	11.76%
33 or above:	4	11.76%
Total Responded to this question:	34	85%
Total who skipped this question:	6	15%
Total:	40	100%

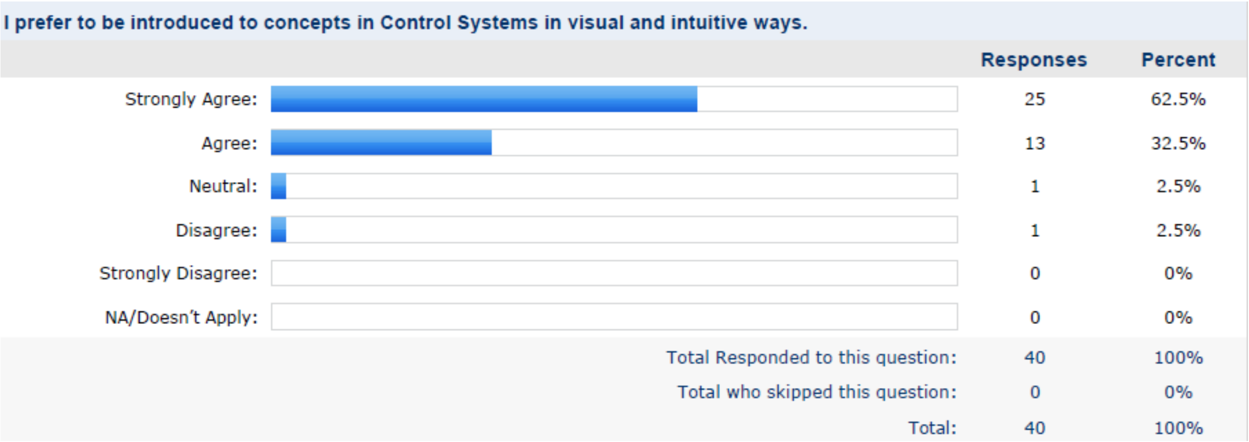
Figure A2 - Students' Age Distribution



I feel that understanding concepts in Control Systems is important.

	Responses	Percent
Strongly Agree:	33	82.5%
Agree:	7	17.5%
Neutral:	0	0%
Disagree:	0	0%
Strongly Disagree:	0	0%
NA/Doesn't Apply:	0	0%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

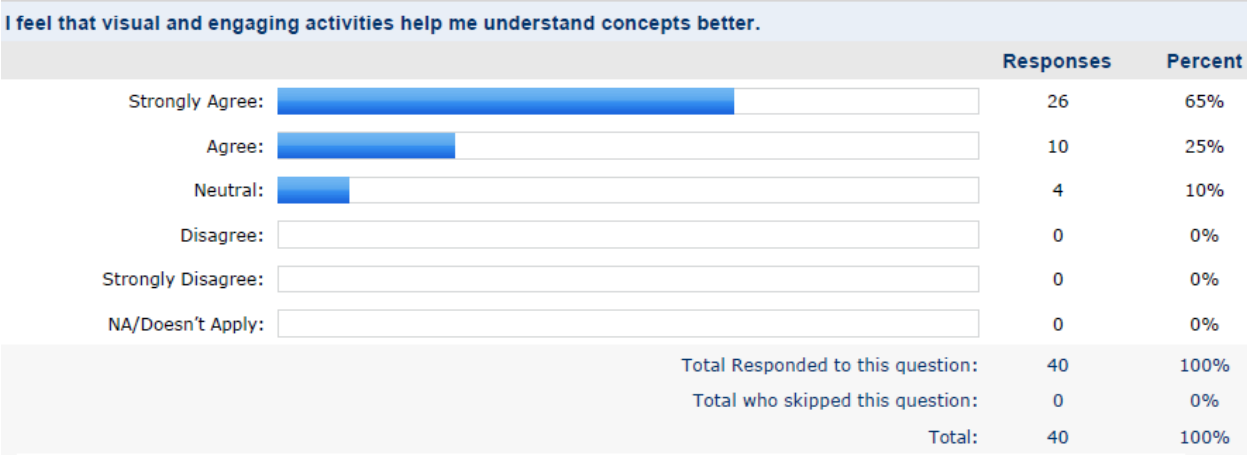
Figure A3 - I feel that understanding concepts in Control Systems is important.



I prefer to be introduced to concepts in Control Systems in visual and intuitive ways.

	Responses	Percent
Strongly Agree:	25	62.5%
Agree:	13	32.5%
Neutral:	1	2.5%
Disagree:	1	2.5%
Strongly Disagree:	0	0%
NA/Doesn't Apply:	0	0%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

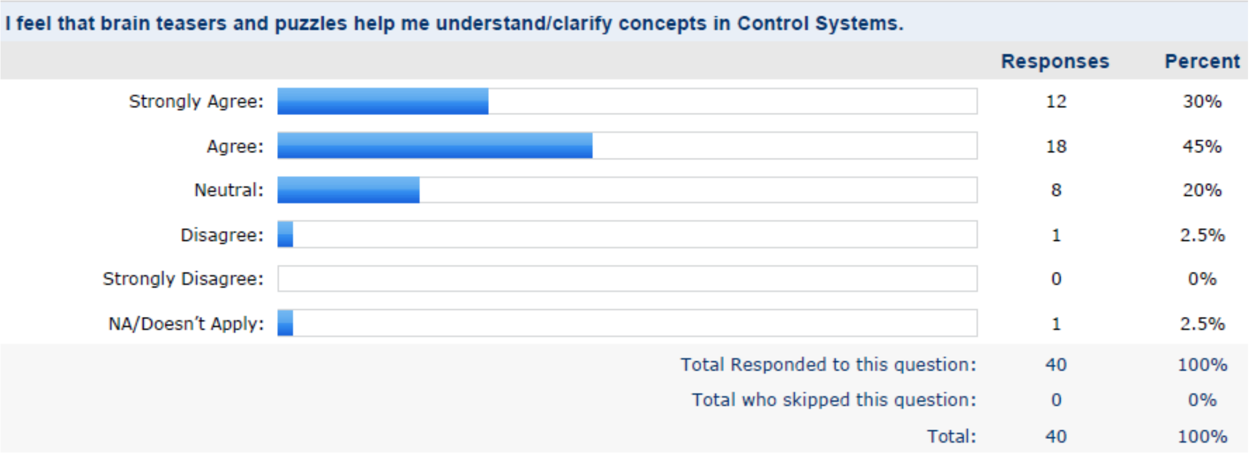
Figure A4 - I prefer to be introduced to concepts in Control Systems in visual and intuitive ways.



I feel that visual and engaging activities help me understand concepts better.

	Responses	Percent
Strongly Agree:	26	65%
Agree:	10	25%
Neutral:	4	10%
Disagree:	0	0%
Strongly Disagree:	0	0%
NA/Doesn't Apply:	0	0%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

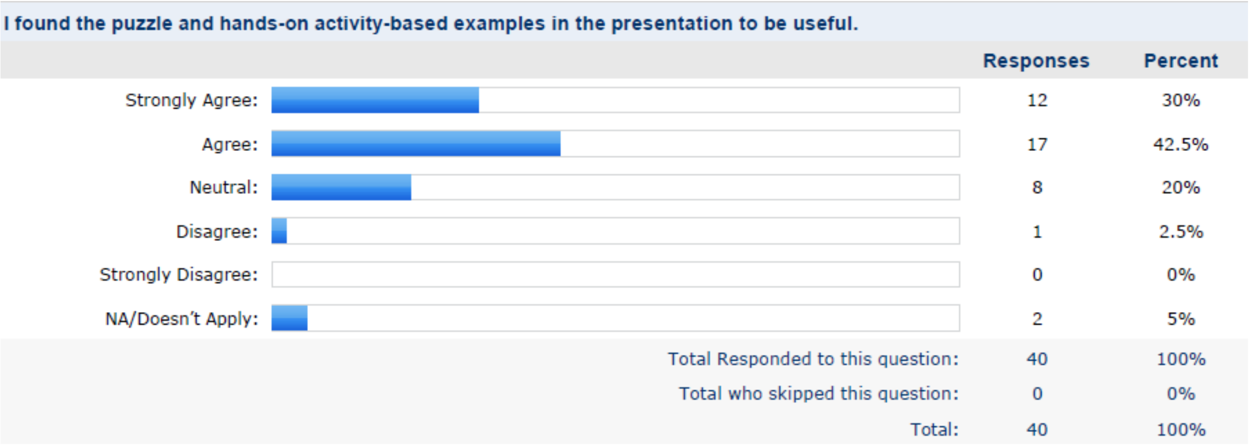
Figure A5 - I feel that visual and engaging activities help me understand concepts better.



I feel that brain teasers and puzzles help me understand/clarify concepts in Control Systems.

	Responses	Percent
Strongly Agree:	12	30%
Agree:	18	45%
Neutral:	8	20%
Disagree:	1	2.5%
Strongly Disagree:	0	0%
NA/Doesn't Apply:	1	2.5%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

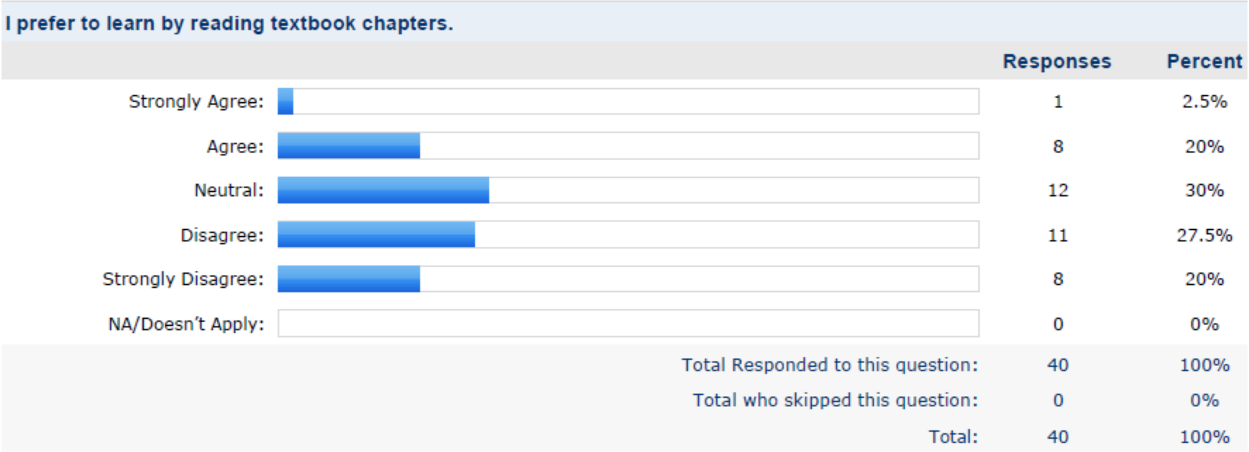
Figure A6 - I feel that brain teasers and puzzles help me understand/clarify concepts in Control Systems.



I found the puzzle and hands-on activity-based examples in the presentation to be useful.

	Responses	Percent
Strongly Agree:	12	30%
Agree:	17	42.5%
Neutral:	8	20%
Disagree:	1	2.5%
Strongly Disagree:	0	0%
NA/Doesn't Apply:	2	5%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

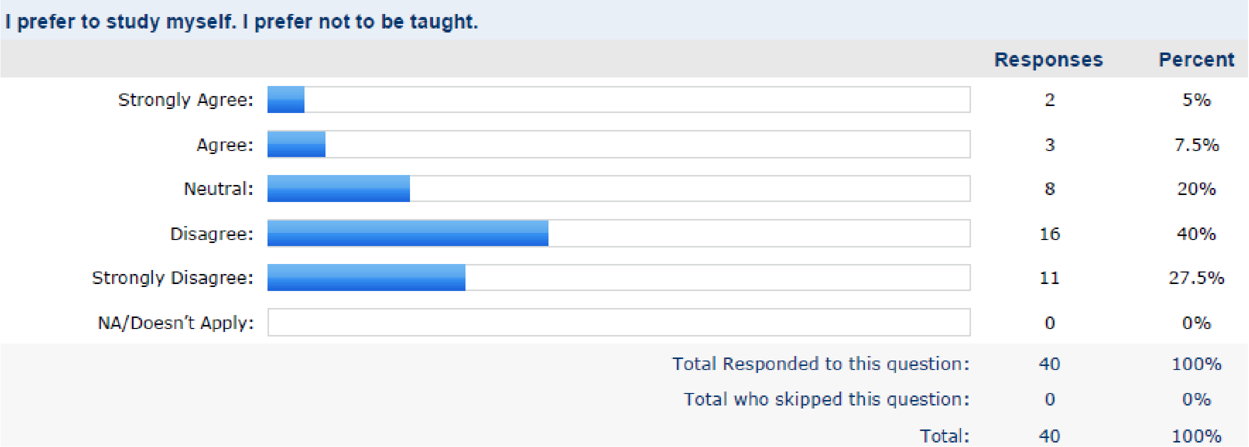
Figure A7 - I found the puzzle and hands-on activity-based examples in the presentation to be useful.



I prefer to learn by reading textbook chapters.

	Responses	Percent
Strongly Agree:	1	2.5%
Agree:	8	20%
Neutral:	12	30%
Disagree:	11	27.5%
Strongly Disagree:	8	20%
NA/Doesn't Apply:	0	0%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

Figure A8 - I prefer to learn by reading textbook chapters.



I prefer to study myself. I prefer not to be taught.

	Responses	Percent
Strongly Agree:	2	5%
Agree:	3	7.5%
Neutral:	8	20%
Disagree:	16	40%
Strongly Disagree:	11	27.5%
NA/Doesn't Apply:	0	0%
Total Responded to this question:	40	100%
Total who skipped this question:	0	0%
Total:	40	100%

Figure A9 - I prefer to study by myself. I prefer not to be taught.