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AN INTRODUCTION TO ROBOTICS WITH NAO

A STEM INTEGRATED, PROJECT BASED APPROACH TO LEARNING ROBOTICS AND COMPUTER SCIENCE

Aligned to the Common Core State Standards Initiative

FOREWORD

Welcome to NAO.

I hope that you will find working with the NAO robot platform as interesting as my students have. Many of you may have worked with robots in the past, Robots such as Lego Mindstorms™ or FIRST™ Robotics. I think you will find this a completely different experience.

NAO is humanoid, two arms, two legs, eyes, ears, he can walk and talk. Notice how I said "He", if you are like my students you will find yourself personifying your NAO immediately. We named ours "Pablito", and for us as we created the artificial intelligence, and developed behaviors for our robot he took on the personality of his programmers. I believe it is this "humanness" that makes working with NAO so fascinating, because it can do so much that you can do, the possibilities of what you can do with the robot are limitless.

After only a few short weeks of working with this curriculum you will have your robot, walking, talking, listening, and interacting with the environment around it. Once you do that I am sure that you will come up with hundreds of uses that we could never have dreamed. Your creativity and imagination are the only things that limit what you can do with NAO, from a service robot to help children, or the elderly, the police, or fireman, to an entertainer dancing, singing and chatting with its audience.

Whatever you do, have fun and enjoy it! Put it up on YouTube® and share it we would love to see it.

Mike Beiter

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TABLE OF CONTENT

INTRODUCTION
FOR TEACHERS

Welcome to NAO.

This curriculum has been designed to allow you to develop interesting, challenging and fun projects with your robot. I have been teaching computer science for the last 20 years. I began in the days of the first PCs and I currently teach computer science to Grades 9 and 11 at a Comprehensive Career and Technical School, and as an adjunct professor of Computer Science at two Universities. Over the years I have taught with many types of technologies: Robotic arms, Lego Mindstorms, PLC's and all different types of computers. I believe this is the most exciting curriculum I have ever been involved with.

When our school district first purchased the NAO robots I was unsure about the cost versus benefit of these platforms. What I have found is that the humanoid robot generates and unparalleled interest from students. My traditional computer science students are driven to program the robot to do everything from dance to fold laundry. But it is not the traditional students that really surprised me so much as the overwhelming response to the robot from non-traditional students: I had students from our nursing and carpentry programs beating down my door for an opportunity to work with the NAO. These students were captivated by the humanoid robot in a way that traditional robotics platforms and computer software simply could not duplicate.

This curriculum has been developed with a number of goals. First and foremost it is engaging for the students. As you look at the modules I do not believe you will find a single thing that will cause students to roll their eyes and say "Do we have to do that?". Second, and just as important, is that it is project-based and aligned to the Core STEM standards as laid out in the Common Core Standards. Each module covers a set of objectives specific to learning robotics, but also includes objectives, standards, and lesson plans that cover a wide variety of academic core standards in Math and English. As a general rule you should start with Module 1 and work foreword, but other than the first module you could really pick and choose modules to fit your needs.

I hope that you will find this curriculum to be an exciting and useful addition to your Computer science or robotics classroom. I am confident that your students will find that this is one of the most enjoyable and interesting ways they have ever learned.

HOW TO USE
THIS CURRICULUM

As a general rule each module is independent. In each module you will find a set of robotics/computer science objectives, as well as related academic STEM objectives.

Both sets of objectives will identify the common core standards addressed in that module.

YOU ARE ALLOWED TO COPY PAGES AND LESSON PLANS FROM THIS BOOK AND DISTRIBUTE WITHIN YOUR CLASSROOM ONLY.

SUGGESTED
TEACHING PRACTICES

1/ HAVE STUDENTS PRE-READ THE MODULE. YOU MAY WANT TO USE THE KWL READING STRATEGY*

→ PRIOR TO READING

- *have students prepare a list of what they already Know about the subject*
- *Then create a series (1-3) questions of what they want to know.*

→ AFTER READING

- *Have student list what they Learned from the reading*

2/ PLAN PLAN PLAN

→ HAVE STUDENTS PRESENT A SHORT ALGORITHM OR STEP BY STEP INSTRUCTION SET FOR EACH MODULE

→ ASK THEM TO INCLUDE SAFETY AND BEST PRACTICES FOR KEEPING THE NAO SAFE

3/ COMPLETE THE MODULE QUESTIONS AT THE END OF EACH MODULE

4/ COMPLETE THE MODULE

→ HAVE STUDENTS COMPLETE THE MODULE WITH THE NAO AND DEMONSTRATE THE COMPLETED BEHAVIORS

→ YOU MAY CONSIDER HAVING STUDENTS DO A LAB REPORT OF THE MODULE

A. Title
The title states what the module covered

B. Introduction / Purpose
A paragraph that explains the objectives and purpose of the module

C. Materials
List everything needed to complete the module

D. Methods
Very similar to your prior algorithm a list of steps required in order to complete the module.

E. Data / Observations
What actually happened while you complete module. (record both expected and unexpected results)

F. Results
A conclusion paragraph that states what you learned from the module

* Valmont, W | 2003 | *Technology for literacy teaching and learning* | New York: Houghton Mifflin Company.
Allington, R. and Cunningham, P | 2003 | *Classrooms that work* | Boston: Allyn and Bacon.
Padak, N. and Rasinski, T | 2004 | *Effective reading strategies: teaching children who find reading difficult* | New Jersey: Pearson Education, Inc.
Buehl, D | 2006 | *Classroom strategies for interactive learning* | Delaware: International Reading Association.

1 HELLO WORLD

LEARNING

In this module, students will learn:

→ HOW TO SWITCH ON THE NAO HUMANOID ROBOT

→ HOW TO CONNECT TO THE NAO WITH CHOREGRAPHE ON A COMPUTER

→ HOW TO MAKE THE NAO SPEAK WITH CHOREGRAPHE

* *RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.*

→ HOW TO VARY THE PITCH AND SPEED OF THE NAO'S VOICE

* *RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.*

→ HOW TO PROGRAM THE NAO TO SPEAK WITH PYTHON

* *RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

* *RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

* *RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

* *RST.11-12.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.*

CONTENTS

* Reference COMMON CORE Stem standards

2 WALK IT OUT

LEARNING

In this module, students will learn:

→ HOW TO MAKE THE NAO WALK USING CHOREGRAPHE

→ THE (X, Y) COORDINATE PLANE OF THE NAO

- * *A-REI.3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.*
- * *6.EE.6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.*
- * *G-GPE.5. Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).*

→ HOW TO CONVERT AN (X, Y) COORDINATE INTO AN ANGLE TO TURN, AND A DISTANCE TO WALK (POLAR COORDINATES)

- * *G-C.2. Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.*

→ HOW TO MAKE THE NAO TURN AND WALK TO AN (X, Y) POINT USING CHOREGRAPHE

→ HOW TO USE PYTHON TO PROGRAM THE NAO TO WALK.

- * *G-GPE.7. Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula.★*

→ HOW TO USE PYTHON TO PROGRAM THE NAO TO CALCULATE THE ANGLE TO TURN AND DISTANCE TO WALK, AND THEN ACTUATE THE ROBOT TO WALK TO THAT POINT.

- * *RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*
- * *RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*
- * *RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*
- * *RST.11-12.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.*

CONTENTS

* Reference COMMON CORE Stem standards

3 HEARING THINGS

LEARNING

In this module, students will learn:

→ WHAT SPEECH RECOGNITION IS

→ HOW TO PERFORM SPEECH RECOGNITION ON THE NAO

→ HOW TO VARY THE THRESHOLD OF SPEECH RECOGNITION

→ BOOLEAN (TRUE/FALSE) OPERATIONS

→ BRANCHING CONDITIONALS (SWITCH STATEMENTS) FOR COMPLEX LOGIC OPERATIONS

→ HOW TO CREATE SPEECH-BASED INTERACTION BEHAVIORS WITH THE NAO

→ HOW TO PROCESS STRINGS IN PYTHON

→ HOW TO USE IF STATEMENTS IN PYTHON

* *RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

* *RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

* *RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

* *RST.11-12.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.*

CONTENTS

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4 LET'S DANCE

LEARNING

In this module, students will learn:

→ WHAT A KEYFRAME MOTION IS

→ APPLYING THE CONCEPT OF CENTER OF GRAVITY ON THE NAO

→ HOW TO KEEP THE NAO BALANCED WHILE ADJUSTING ITS POSE

→ HOW TO RECORD AND EXECUTE KEYFRAMES ON THE NAO WITH CHOREGRAPHE

→ HOW TO MAKE THE NAO PERFORM A DANCE ROUTINE

→ HOW TO USE LOOPS IN CHOREGRAPHE

→ HOW TO EXECUTE JOINT MOTIONS IN PYTHON

→ HOW TO USE FOR LOOPS IN PYTHON

** RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

** RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

** RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

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CONTENTS

* Reference COMMON CORE Stem standards

5 SENSE AND ACT

LEARNING

In this module, students will learn:

- → WHAT SENSORS THERE ARE ON THE NAO
- → HOW SENSORS ON THE NAO RELATE TO HUMAN SENSES
- → WHAT ACTUATORS ARE
- → HOW THE NAO KNOWS ITS BODY POSE
- → WHAT AN LED IS
- → WHERE LEDS ARE LOCATED ON THE NAO
- → HOW TO CONTROL THE LEDS OF THE NAO
- → HOW TO READ SENSOR VALUES AND BUMPER PRESSES OF THE NAO
- → WHAT FINITE STATE MACHINES ARE
- → HOW TO DESIGN A ROBOT BEHAVIOR USING A FINITE STATE MACHINE
- → HOW TO IMPLEMENT A FINITE STATE MACHINE
- → TO UNDERSTAND BINARY NUMBERS
- → TO UNDERSTAND BOOLEAN VALUES AND BITWISE-OR
- → TO STORE AND RETRIEVE STATE

** RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

** RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

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** RST.11-12.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.*

CONTENTS

* Reference COMMON CORE Stem standards

6 DO THE ROBOT

LEARNING

In this module, students will learn:

→ WHAT MULTI-TASKING IS ON A COMPUTER/ROBOT

→ HOW AN OPERATING SYSTEM PERFORMS MULTI-TASKING WITH A SINGLE CORE

→ HOW TO USE BEHAVIOR LAYERS IN CHOREGRAPHE

→ HOW TO CREATE MOTIONS THAT EXECUTE IN PARALLEL ON THE NAO

→ HOW TO CREATE COMPLEX COMBINATIONS OF ACTIONS USING BEHAVIOR LAYERS

→ WHAT ODOMETRY IS

→ HOW TO MEASURE ROTATIONAL ODOMETRY ON THE NAO

→ HOW TO USE MEASURED ODOMETRY TO UPDATE ACTIONS ON THE NAO

→ HOW MEASURED ODOMETRY DOES NOT MATCH THE ACTUAL MOTION PERFECTLY

** RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

** RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

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CONTENTS

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7 FACE OFF

LEARNING

In this module, students will learn:

→ HOW TO MAKE THE NAO DETECT FACES FROM CHOREGRAPHE

→ HOW TO LOOK IN THE DIRECTION OF SOUNDS

→ HOW TO RECOGNIZE AND DISTINGUISH FACES

→ HOW TO SCAN WITH THE NAO'S HEAD

→ WHAT QUEUES ARE

→ HOW TO USE QUEUES / LISTS IN PYTHON

→ HOW TO DEAL WITH TIME IN PYTHON

* *RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

* *RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

* *RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

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CONTENTS

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8 OBJECT RECOGNITION

LEARNING

In this module, students will learn:

→ HOW IMAGES ARE STORED ON A COMPUTER/ROBOT

→ WHAT OBJECT RECOGNITION IS

→ HOW OBJECT RECOGNITION IS PERFORMED

→ WHAT A LOGICAL-AND OPERATION IS

→ HOW TO LOOP A BEHAVIOR IN CHOREGRAPHE UNTIL A CONDITION IS MET

→ HOW TO PARSE STRINGS TO SEARCH FOR PREFIXES

* *RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

* *RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.*

* *RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

* *RST.11-12.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.*

CONTENTS

* Reference COMMON CORE Stem standards

9 GAMES AND STORIES

LEARNING

In this module, students will learn:

→ WHAT HUMAN-ROBOT INTERACTION IS

→ WHY HUMAN-ROBOT INTERACTION IS IMPORTANT

→ HOW TO MAKE ROBOTS INTERACT WITH HUMANS

→ HOW TO DO COOPERATIVE MOTIONS (HAND SHAKES AND HIGH FIVES) WITH HUMANS

→ TO ACT OUT A PLAY ON THE NAOS.

→ TO SHARE THE RESULTS WITH CHILDREN

CONTENTS

* Reference COMMON CORE Stem standards

10 FINDING YOUR WAY

LEARNING

In this module, students will learn:

→ HOW TO SOLVE MAZES

→ WHAT THE DEAD-END FILLING ALGORITHM FOR SOLVING A MAZE IS

→ HOW TO SOLVE A MAZE WITHOUT A MAP USING THE WALL-FOLLOWING ALGORITHM

→ HOW TO FIND THE SHORTEST PATH FROM THE START TO THE GOAL IN A MAZE USING THE BREADTH-FIRST SEARCH ALGORITHM

→ WHAT A VISUAL CUE IS

→ HOW TO USE VISUAL CUES TO INSTRUCT A ROBOT TO SOLVE A MAZE

→ HOW TO USE CUES OF MULTIPLE TYPES TO SOLVE A MAZE

→ HOW TO IMPLEMENT A MAZE-SOLVING ALGORITHM WITH CHOREGRAPHE

→ HOW TO IMPLEMENT A MAZE-SOLVING ALGORITHM IN PYTHON.

CONTENTS

* Reference COMMON CORE Stem standards

ABOUT
THE AUTORS

This textbook was created under the direction of Mike Beiter, Computer Science teacher at Central Career and Technical School, and 2 PHD Students from Carnegie Melon University, who created the individual lessons: Somchaya Liemhetcharat, and Brian Coltin.

MIKE BEITER

Mike is a High School Computer Science teacher at Central Career and Technical School in Erie, Pennsylvania. He is also an adjunct professor of computer science at Penn State University, and Gannon University. Mike is on the STEM development team leading the school in integrated project based learning in areas of computer science, Programmable Logic Controllers, and robotics.

BRIAN COLTIN

Brian Coltin is a PhD student in the Robotics Institute at Carnegie Mellon University. His research interests include multi-robot coordination, scheduling and path planning, sensor networks, and robot localization. He has participated in the RoboCup Standard Platform League with the NAO robots for four years as a member of the Carnegie Mellon team.

SOMCHAYA LIEMHETCHARAT

Somchaya Liemhetcharat is a PhD candidate at the Robotics Institute of Carnegie Mellon University. His research interests are in artificial intelligence and robotics, and in multi-robot coordination in particular, i.e., how multiple robots of different types can work together to solve complex problems.