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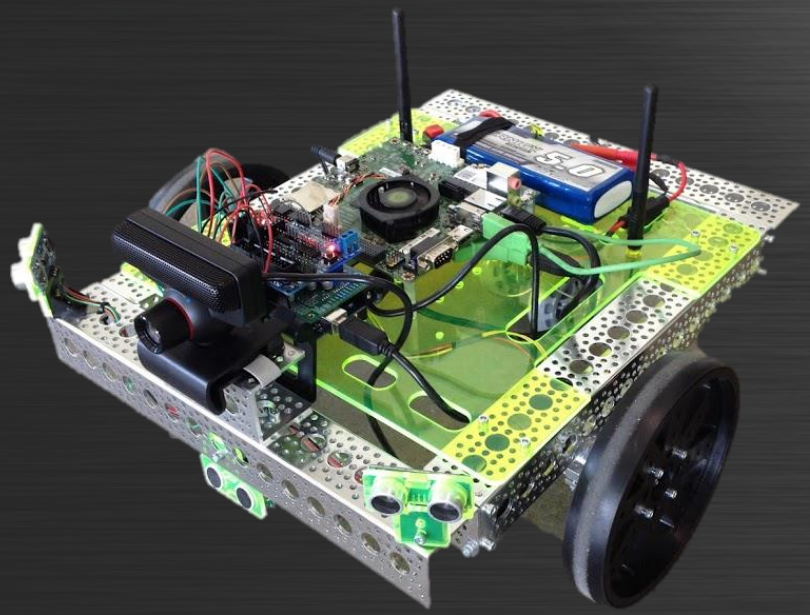


Robotics Teaching Kit with ‘Jet’ for Educators

Joe Bungo (NVIDIA) and John Seng (CalPoly)

AGENDA

Introduction to NVIDIA's GPU Educators Program and GPU Teaching Kits

Robotics Teaching Kit with 'Jet' Syllabus Overview

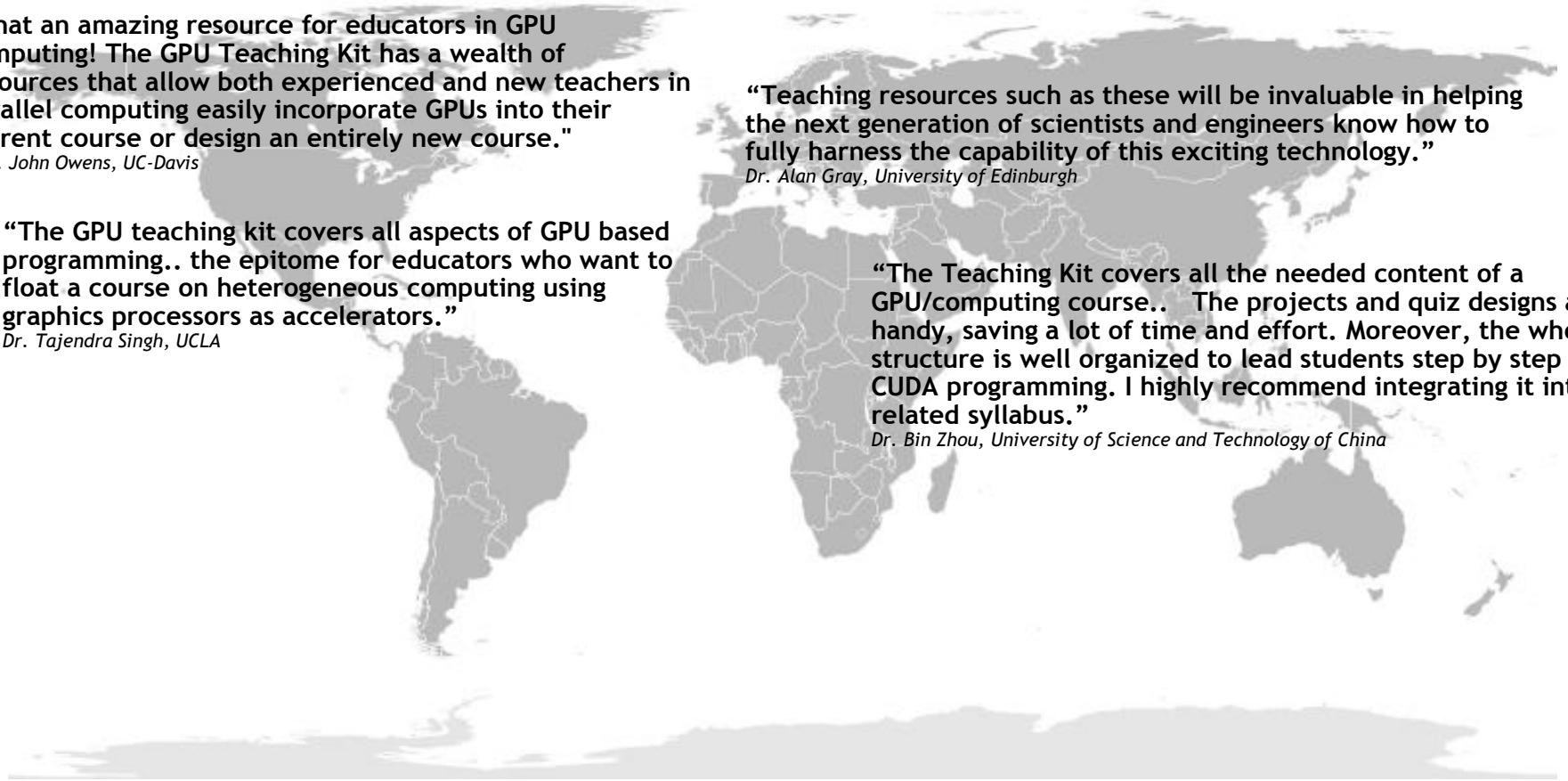
Introduction to 'Jet'

'Jet' Teaching Kit Contents

Cal Poly Activities, Q&A

GPU EDUCATORS PROGRAM

Advancing STEM Education with Accelerated Computing



"What an amazing resource for educators in GPU computing! The GPU Teaching Kit has a wealth of resources that allow both experienced and new teachers in parallel computing easily incorporate GPUs into their current course or design an entirely new course."
Prof. John Owens, UC-Davis

"Teaching resources such as these will be invaluable in helping the next generation of scientists and engineers know how to fully harness the capability of this exciting technology."
Dr. Alan Gray, University of Edinburgh

"The GPU teaching kit covers all aspects of GPU based programming.. the epitome for educators who want to float a course on heterogeneous computing using graphics processors as accelerators."
Dr. Tajendra Singh, UCLA

"The Teaching Kit covers all the needed content of a GPU/computing course.. The projects and quiz designs are handy, saving a lot of time and effort. Moreover, the whole structure is well organized to lead students step by step in CUDA programming. I highly recommend integrating it into a related syllabus."
Dr. Bin Zhou, University of Science and Technology of China

FLAGSHIP OFFERING: GPU TEACHING KITS

Breaking the Barriers to GPU Education in Academia

Co-develop with academic partners

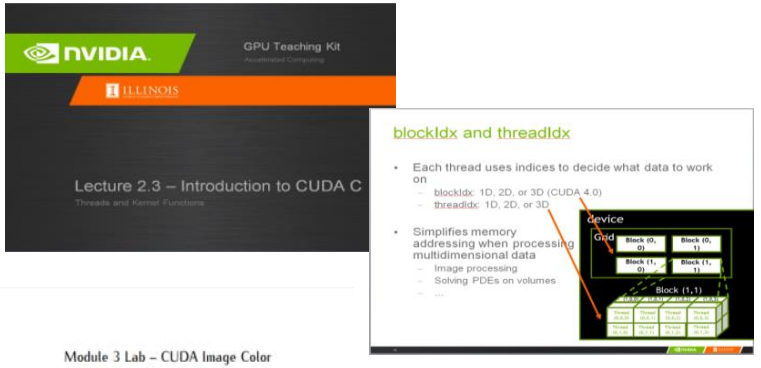
Comprehensive teaching materials

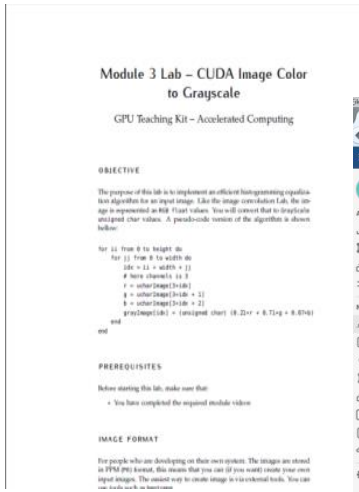
- Lecture slides and notes
- Lecture videos
- Hands-on labs/solutions
- Larger coding projects/solutions
- Quiz/exam questions/solution

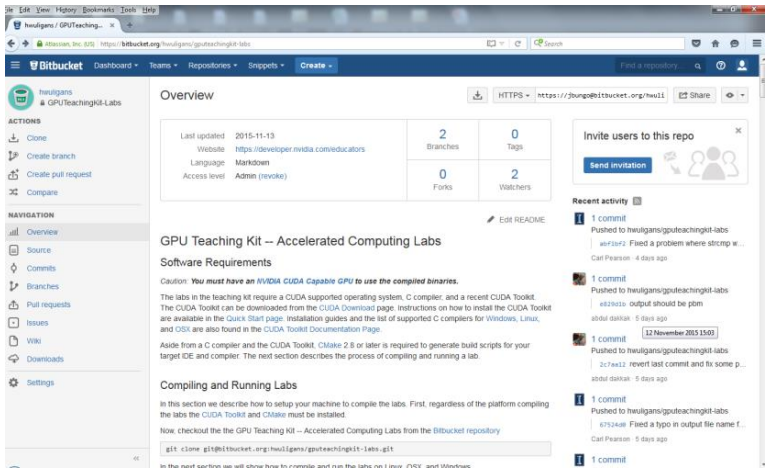
Possible GPU resource

Software tools

Textbooks and/or e-books







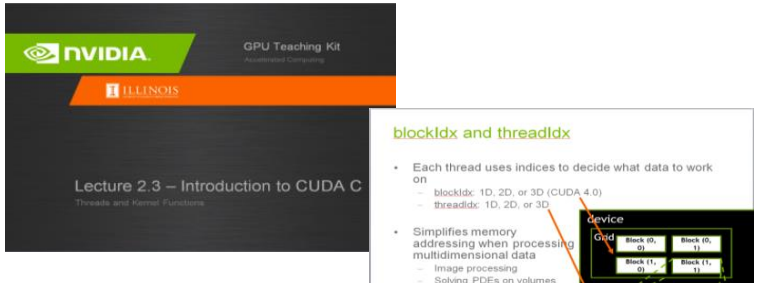
FLAGSHIP OFFERING: GPU TEACHING KITS

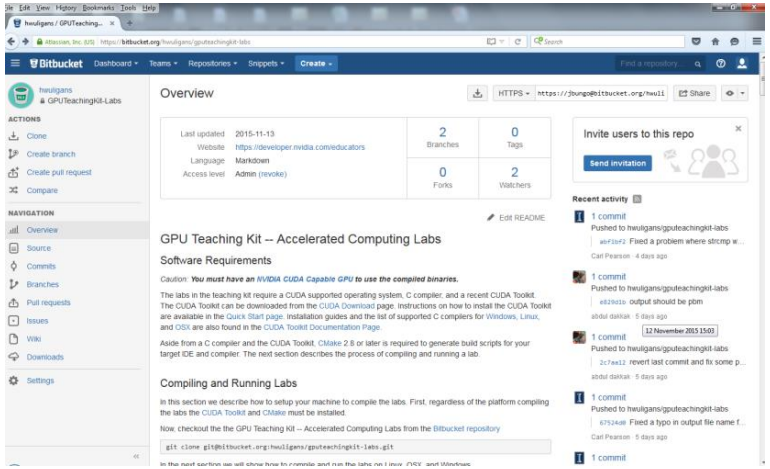
Breaking the Barriers to GPU Education in Academia

Different kits for different courses

Accelerated/parallel computing
Robotics
Machine/Deep learning
Computer graphics
Computer architecture
Computational domain sciences
Etc.

Localization plans in progress





OTHER PROGRAM OFFERINGS

Collaborative Opportunities and Supporting Expertise

Instructor workshops, conferences, sponsorships and exhibits

Enablement web pages

Getting started guides/videos

Email updates

Feedback and enhancement requests

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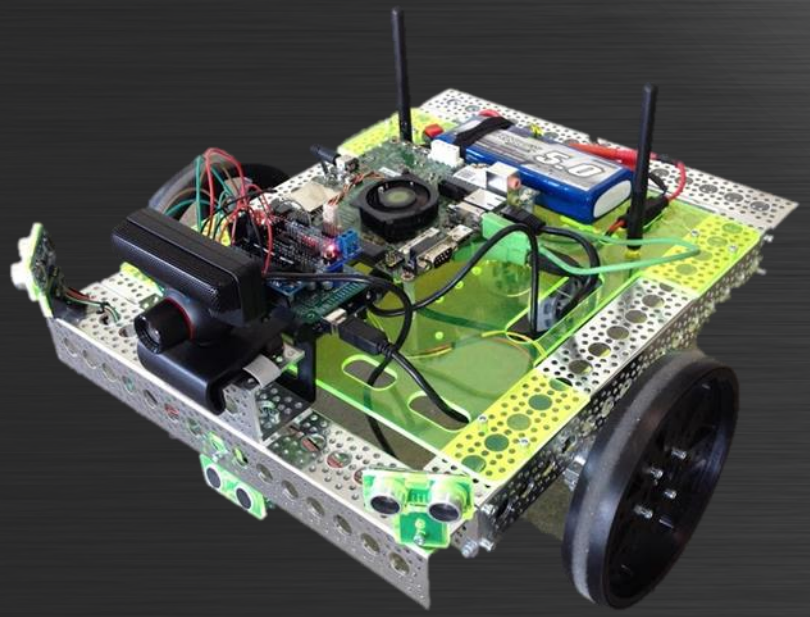


Robotics Teaching Kit with ‘Jet’

Available to Instructors Now!
developer.nvidia.com/educators

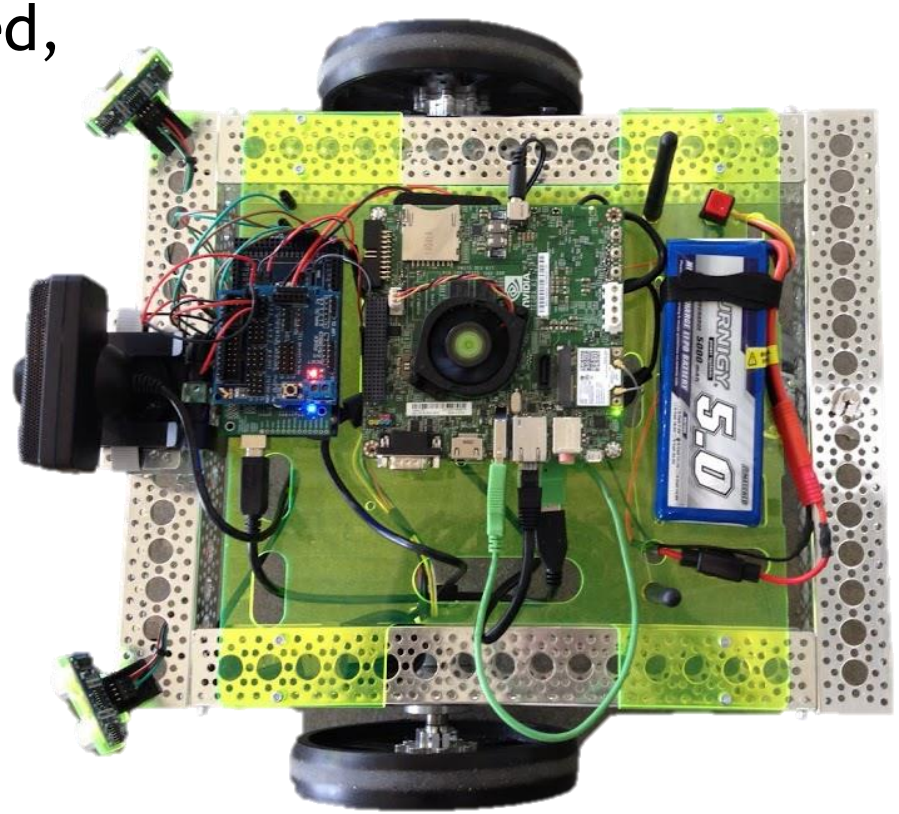
ROBOTICS TEACHING KIT

Module Goals

Learn interdisciplinary, GPU-accelerated, autonomous Robotics

Technical subjects

- Sensors
- Computer Vision
- Machine Learning
- Dead Reckoning
- Path Planning
- Localization
- Control
- Obstacle Avoidance



TEACHING KIT MODULES

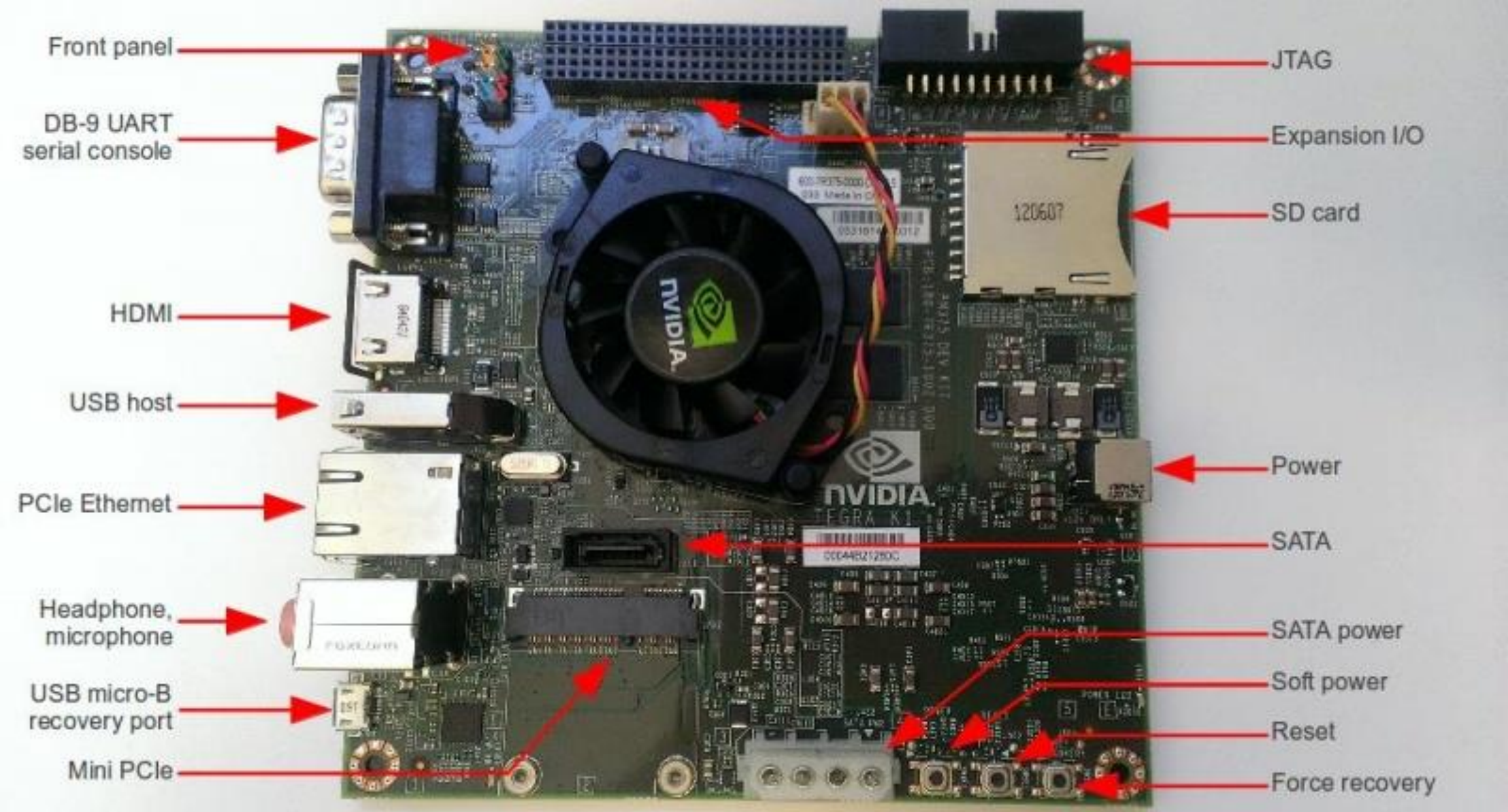
Robotics with ‘Jet’

Module 1 Course Introduction	• Course Introduction and Overview • Introduction to Robotics • Jetson TK1/TX1 and Toolkit Basics • Introduction to ‘Jet’ • ROS	Current Release
Module 2 Sensors and Actuators	• Sonar • Camera • Accelerometer • Gyroscope	Current Release
Module 3 Computer Vision	• Introduction to Computer Vision • Image Representation • Edge Detectors • Hough Transform • Image Filtering and Moments	Current Release
Module 4 Machine Learning	• Machine Learning with Neural Networks • Neural Networks Models • cuDNN • Training and Usage	Future Release

TEACHING KIT MODULES

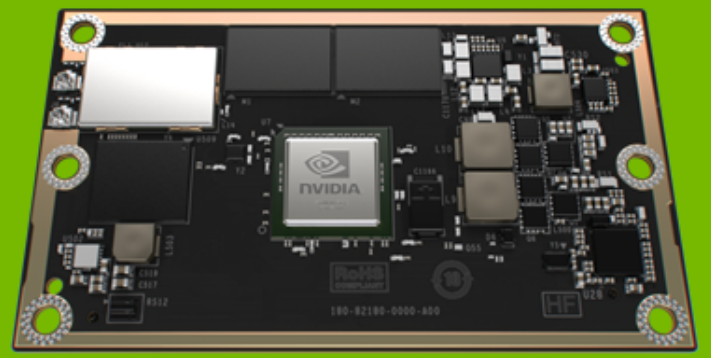
Robotics with ‘Jet’

Module 5 Dead Reckoning	• Dead Reckoning • Odometry Model for Differential Drive	Future Release
Module 6 Path Planning	• Path Planning • Wavefront Path Planning	Future Release
Module 7 Robot Localization	• Robot Localization • Monte Carlo Localization • Particle Filters	Future Release
Module 8 Control	• Control • PID Control	Future Release
Module 9 Obstacle Avoidance	• Smooth Obstacle Avoidance • Obstacle Avoidance and Navigation	Future Release
Module 10 Final Project	• Motivation • Robot Capture the Flag Game	Current Release



Pinout Diagrams Courtesy of Corneliusz Jarzebski

Jetson TX1



	JETSON TX1
GPU	1 TFLOP/s 256-core Maxwell
CPU	4x 64-bit ARM A57 CPUs | 1.6 GHz
Memory	4 GB LPDDR4 | 25.6 GB/s
Video decode	4K 60Hz H.264
Video encode	4K 30Hz H.264
CSI	Up to 6 cameras | 1400 Mpix/s
Display	2x DSI, 1x eDP 1.4, 1x DP 1.2/HDMI
Wi-Fi	802.11 2x2 ac
Networking	1 Gigabit Ethernet
PCI-E	Gen 2 1x1 + 1x4
Storage	16 GB eMMC, SDIO, SATA
Other	3x UART, 3x SPI, 4x I2C, 4x I2S, GPIOs
Power	10-15W, 6.6V-19.5VDC
Size	50mm x 87mm

JET OVERVIEW

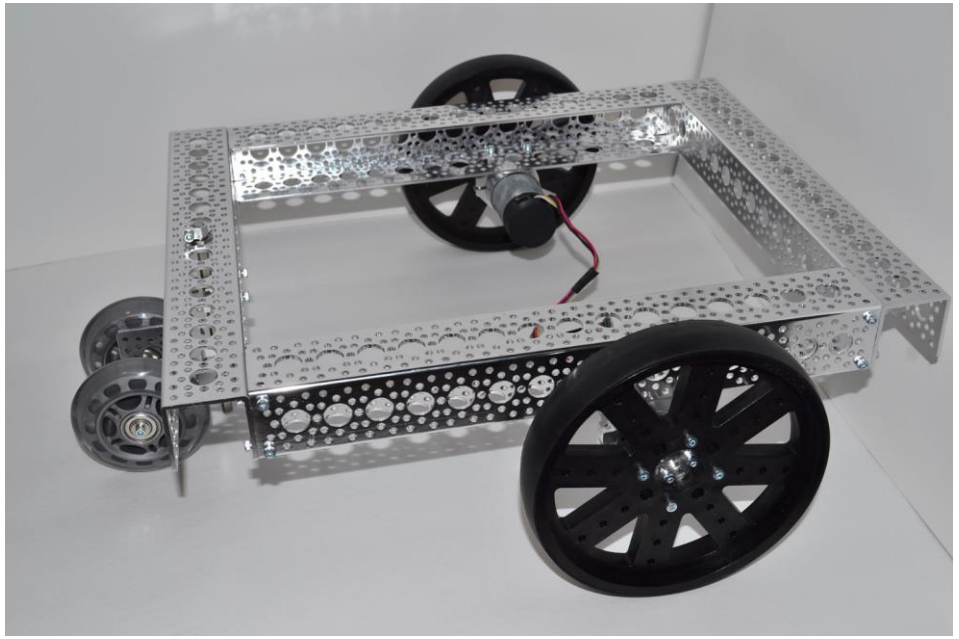
Chassis

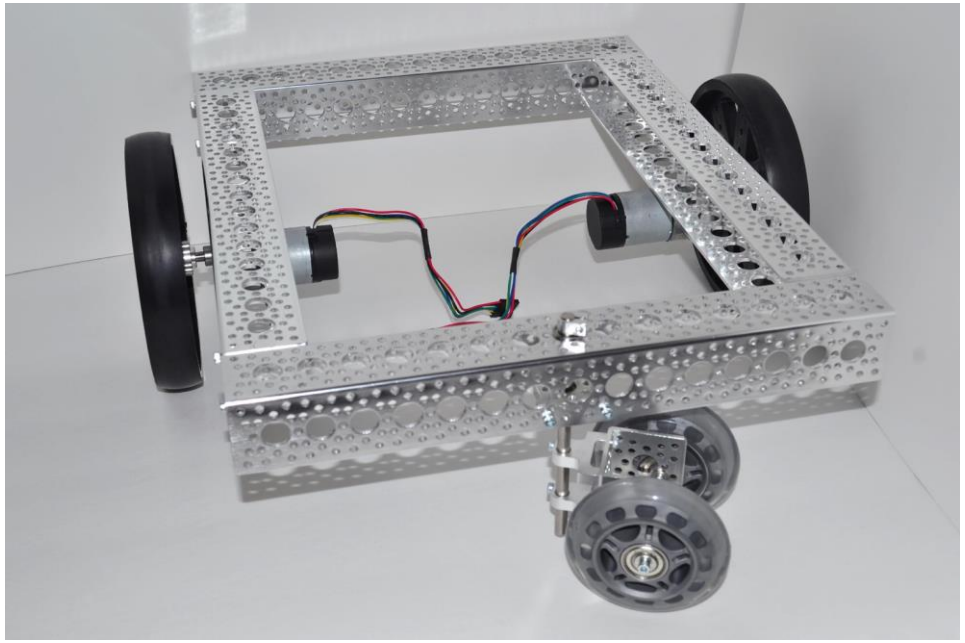
Jet chassis is constructed using Actobotics parts

These are machined metal parts with various aluminum channel, hubs, wheels, and brackets.

JET OVERVIEW

Chassis



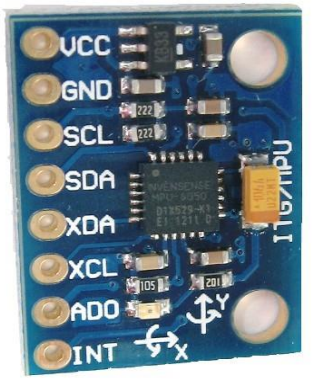


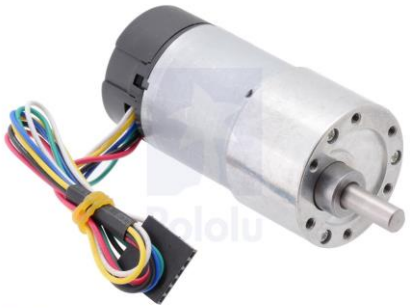
JET OVERVIEW

Electronics

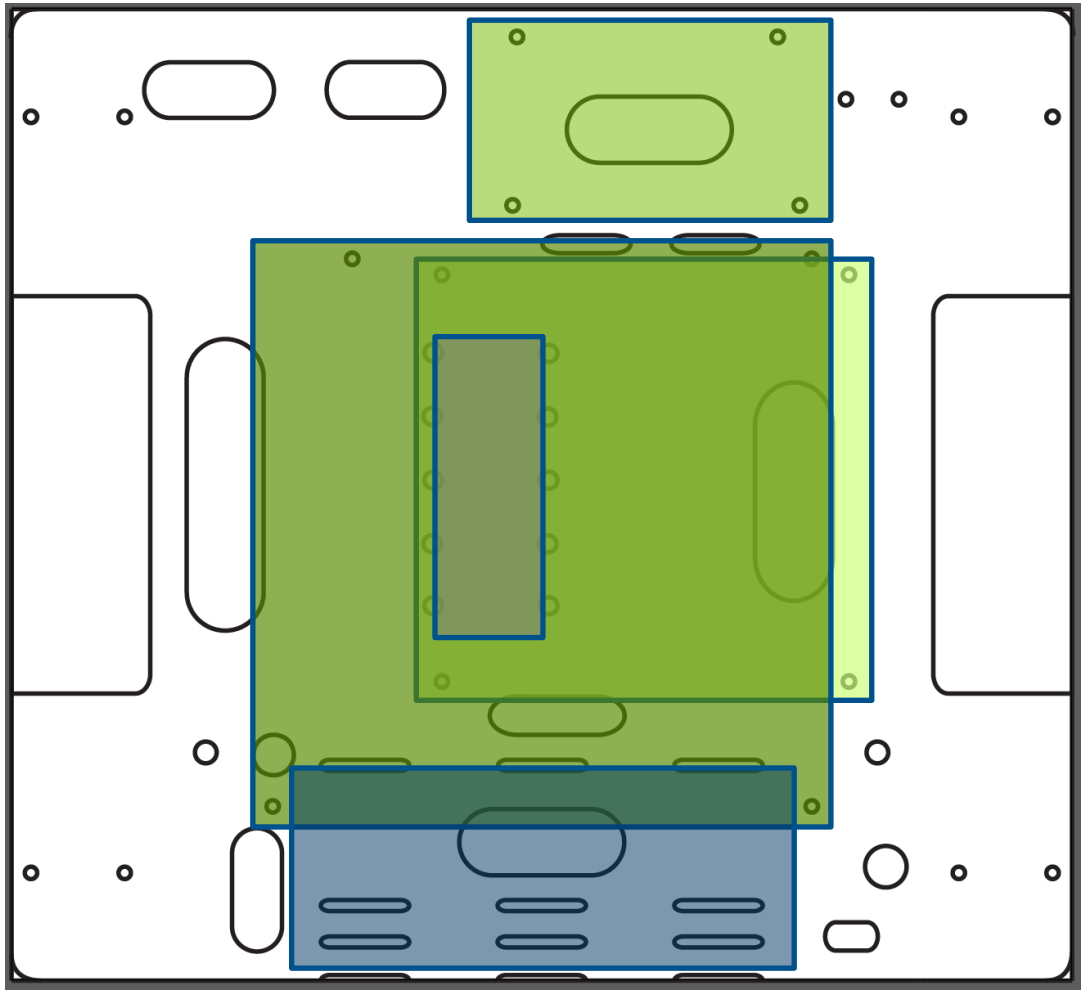
Jet electronics consists of:

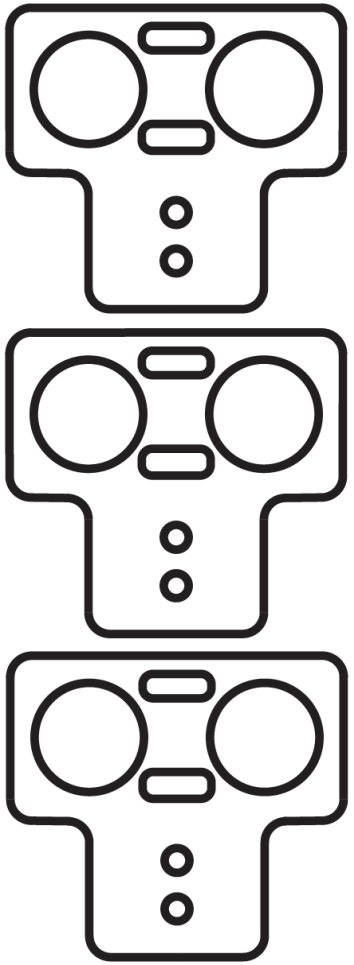
- NVIDIA Jetson TK1/TX1
- Arduino Mega
- H-bridge and motors
- 3 sonar sensors
- GY-521 accelerometer/gyroscope
- Single Webcam
- 3S (11.1V) 5000mAh LiPo battery





JET OVERVIEW





JET OVERVIEW

Software

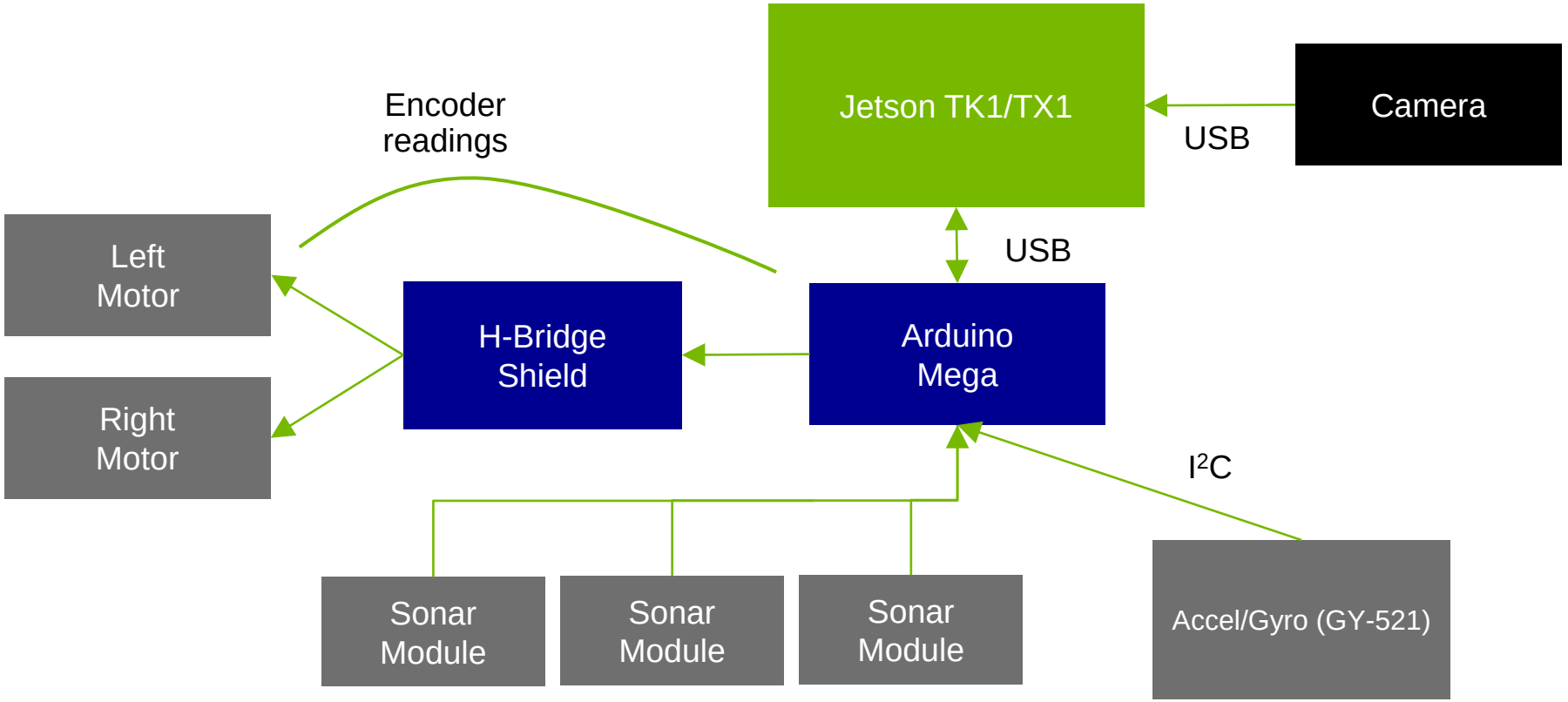
Jet runs ROS

Lecture material includes ROS introduction

Lab assignments provide starter code

JET OVERVIEW

Architecture Design



CURRENT JET BOM

Retail prices shown

Amazon lists:

http://amzn.com/sl/16YHGMBK62X6G (TK1)

http://amzn.com/sl/2QNJMQAAMVYRN (TX1)

Single-source, discounted bundle coming soon!

Bill of Materials	Category	Source	Cost	Quantity	Subtotal
Battery	electronics	Amazon	$35.76	1	$35.76
Battery charger	electronics	Amazon	$25.60	1	$25.60
Jetson TK1	electronics	Amazon	$192.00	1	$192.00
Arduino Mega	electronics	Amazon	$17.99	1	$17.99
Pololu motor	electronics	Pololu	$39.99	2	$79.98
Pololu H-bridge	electronics	Amazon	$49.95	1	$49.95
Camera (placeholder)	electronics	Amazon	$4.99	1	$4.99
Camera mount	electronics	Amazon	$4.49	1	$4.49
Mini-PCIe wireless	electronics	Amazon	$28.00	1	$28.00
USB hub	electronics	Amazon	$6.99	1	$6.99
Power cable	electronics	Pololu	$1.95	1	$1.95
Sonar sensors (3pcs)	sensors	Amazon	$8.50	1	$8.50
Gyro (GY-521)	sensors	Amazon	$3.35	1	$3.35
Sensor shield	electronics	Amazon	$14.50	1	$14.50
Jumper wire	electronics	Amazon	$9.99	1	$9.99
Wireless antenna	electronics	Amazon	$8.50	1	$8.50
16AWG wire		Amazon	$6.70	1	$6.70
HXT connector	electronics	Amazon	$5.99	1	$5.99
1" standoffs		Servocity	$0.79	4	$3.16
1/2" standoffs		Servocity	$0.59	4	$2.36
12" channel	chassis	Amazon	$9.99	4	$39.96
clamping motor mount	chassis	Servocity	$6.99	2	$13.98
6" wheels	chassis	Amazon	$9.99	2	$19.98
1/4" screws	chassis	Amazon	$1.69	3	$5.07
6-32 nuts	chassis	Servocity	$0.05	24	$1.20
90 dual mount bracket	chassis	Servocity	$5.99	2	$11.98
6mm wheel hubs	chassis	Amazon	$7.99	2	$15.98
hub adaptor	chassis	Amazon	$4.99	2	$9.98
1/4" shaft clamping collar	caster	Servocity	$4.99	1	$4.99
1.5" channel	caster	Amazon	$2.99	1	$2.99
caster wheel	caster	Amazon	$2.59	2	$5.18
flanged standoff A (pair)	caster	Amazon	$2.99	1	$2.99
non-flanged bearing	caster	Amazon	$1.99	2	$3.98
parallel tube clamp	caster	Amazon	$5.99	2	$11.98
1/4" bearing pillow block	caster	Amazon	$6.49	1	$6.49
1/4" flanged ball bearings	caster	Servocity	$2.39	1	$2.39
5" x 1/4" D shaft	caster	Amazon	$2.49	1	$2.49
Fuse	electronics	Servocity	$3.99	1	$3.99
power switch	electronics	Amazon	$1.99	1	$1.99
power jack	electronics	Servocity	$3.99	1	$3.99
Total					**$678.34**

Jetson Robot

192.168.100.100:5000

Jetson Robot

Settings Help

Speed (0 to 400)

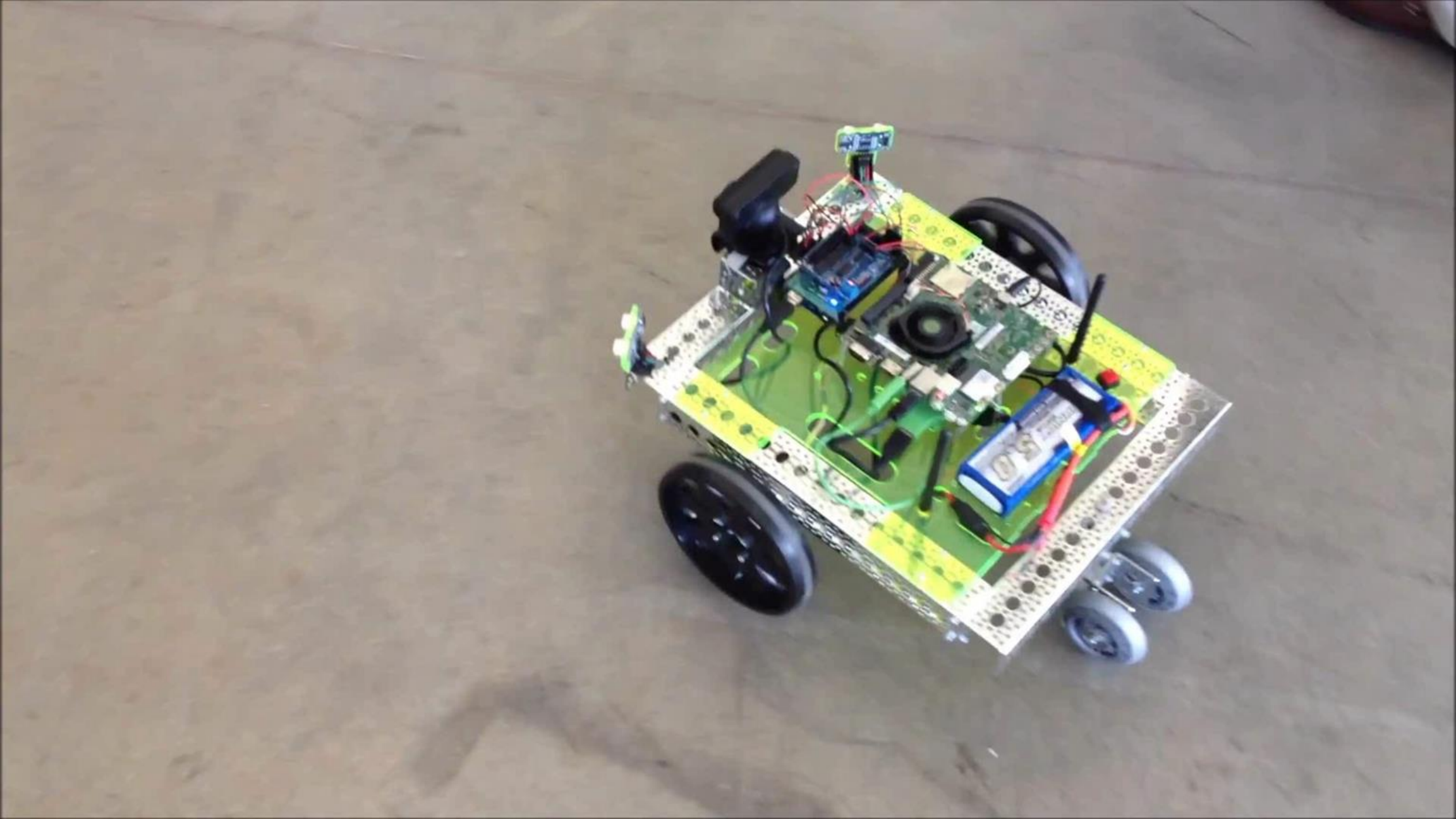
70

Duration (in ms)

400

Video Source

/cv_camera/image_raw



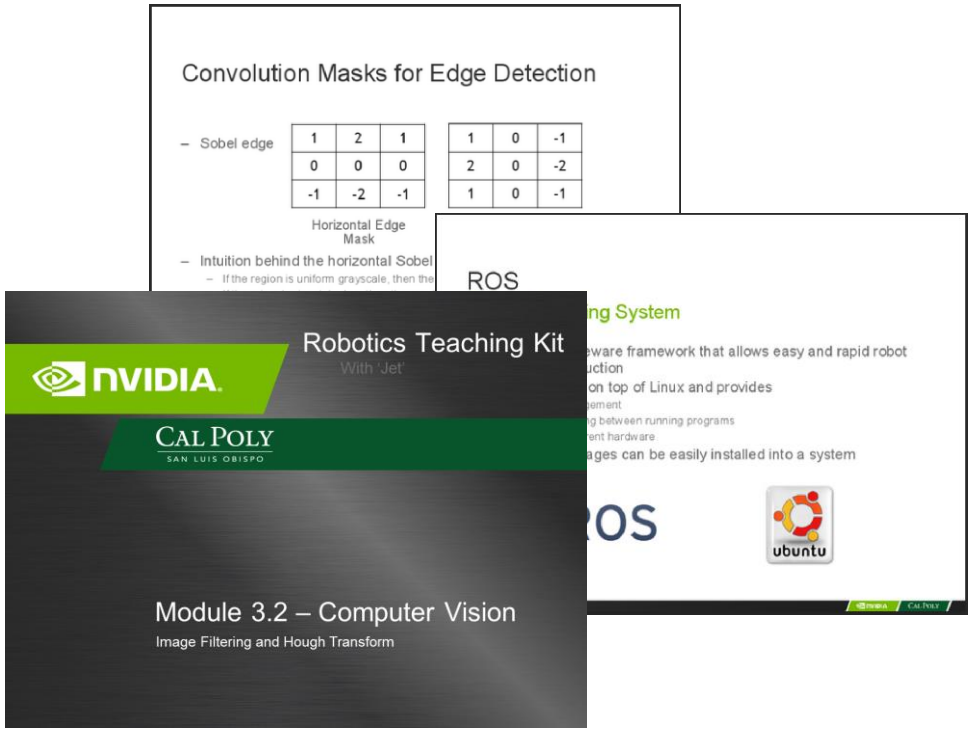
TEACHING KIT CONTENTS

Lecture Slides

Current Release: **14** total slide decks from **4** modules

Later Release: **~30** total slide decks from **10** modules + Embedded audio narrations

.pptx format



TEACHING KIT CONTENTS

Hands-on labs/solutions

1-2 week assignments

Includes description, objectives, prerequisites and open-ended questions

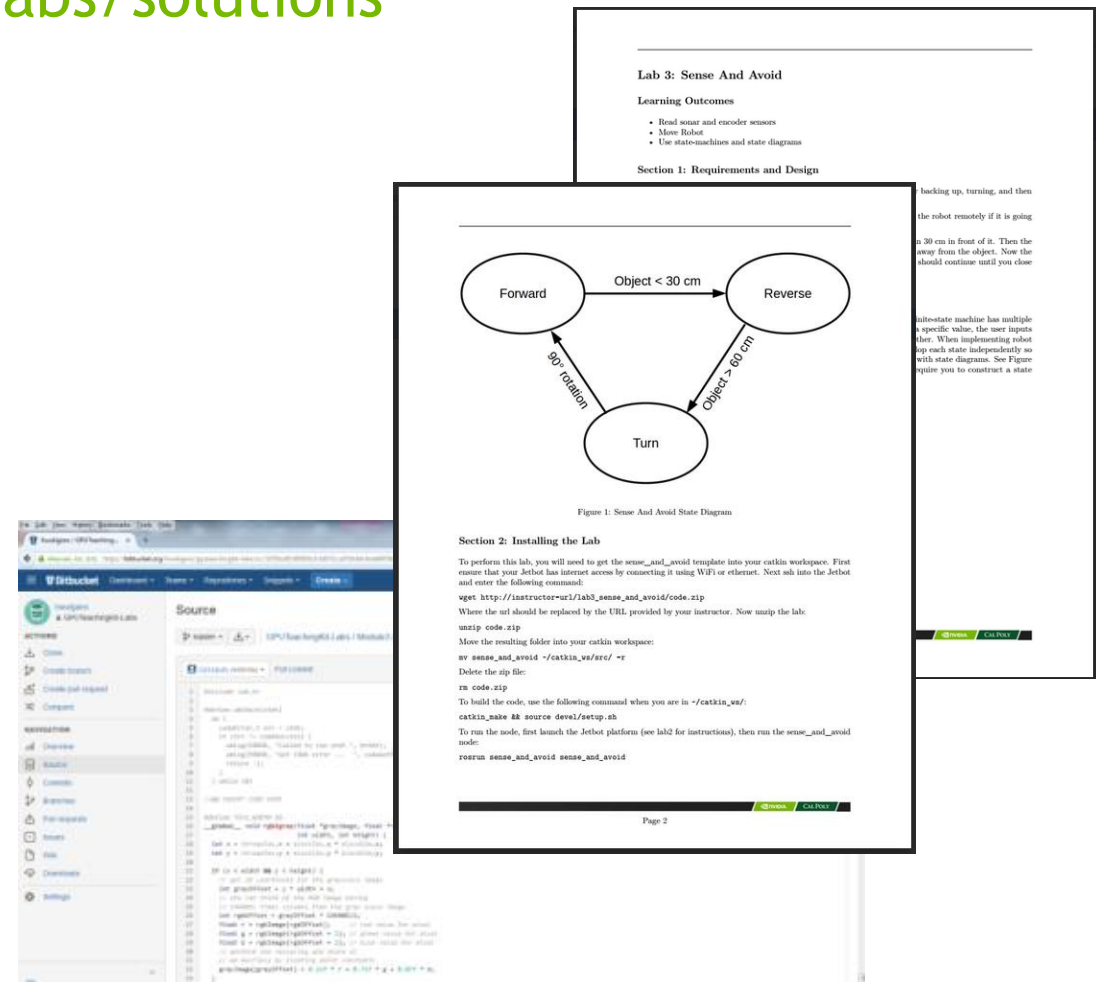
Includes Pseudo-code and solution code templates

Latest source code and instructions always on BitBucket

Current Release: **5** total labs from **4** modules

Later Release: ~**12** total labs from **10** modules

.docx and .pdf formats



TEACHING KIT CONTENTS

Quiz questions/answers

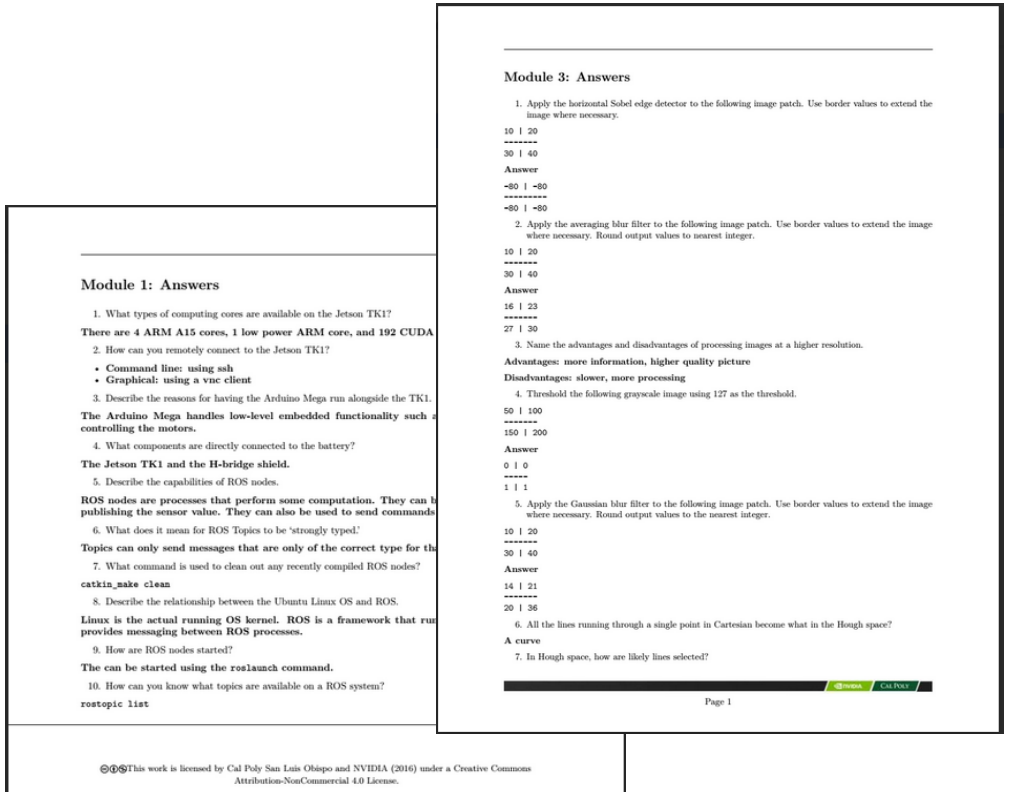
Multiple choice, including rationale for answers

Students should be able to answer from lecture content

Current Release: **3** total quiz questions/answers from **4** modules

Later Release: **9** total quiz questions/answers from **10** modules

.docx and .pdf formats



Module 1: Answers

1. What types of computing cores are available on the Jetson TK1?

There are 4 ARM A15 cores, 1 low power ARM core, and 192 CUDA

2. How can you remotely connect to the Jetson TK1?

- **Command line: using ssh**
- **Graphical: using a vnc client**

3. Describe the reasons for having the Arduino Mega run alongside the TK1.

The Arduino Mega handles low-level embedded functionality such a controlling the motors.

4. What components are directly connected to the battery?

The Jetson TK1 and the H-bridge shield.

5. Describe the capabilities of ROS nodes.

ROS nodes are processes that perform some computation. They can b publishing the sensor value. They can also be used to send commands

6. What does it mean for ROS Topics to be 'strongly typed.'

Topics can only send messages that are only of the correct type for th

7. What command is used to clean out any recently compiled ROS nodes?

`catkin_make clean`

8. Describe the relationship between the Ubuntu Linux OS and ROS.

Linux is the actual running OS kernel. ROS is a framework that run provides messaging between ROS processes.

9. How are ROS nodes started?

The can be started using the `roslaunch` command.

10. How can you know what topics are available on a ROS system?

`rostopic list`

Module 3: Answers

1. Apply the horizontal Sobel edge detector to the following image patch. Use border values to extend the image where necessary.

```
10 | 20
-------
30 | 40
```

Answer

```
-80 | -80
---------
-80 | -80
```

2. Apply the averaging blur filter to the following image patch. Use border values to extend the image where necessary. Round output values to nearest integer.

```
10 | 20
-------
30 | 40
```

Answer

```
16 | 23
-------
27 | 30
```

3. Name the advantages and disadvantages of processing images at a higher resolution.

Advantages: more information, higher quality picture

Disadvantages: slower, more processing

4. Threshold the following grayscale image using 127 as the threshold.

```
50 | 100
-------
150 | 200
```

Answer

```
0 | 0
-----
1 | 1
```

5. Apply the Gaussian blur filter to the following image patch. Use border values to extend the image where necessary. Round output values to the nearest integer.

```
10 | 20
-------
30 | 40
```

Answer

```
14 | 21
-------
20 | 36
```

6. All the lines running through a single point in Cartesian become what in the Hough space?

A curve

7. In Hough space, how are likely lines selected?

Page 1

TEACHING KIT CONTENTS

Larger coding projects/solutions

3-4 week, open-ended, multidisciplinary, final semester projects

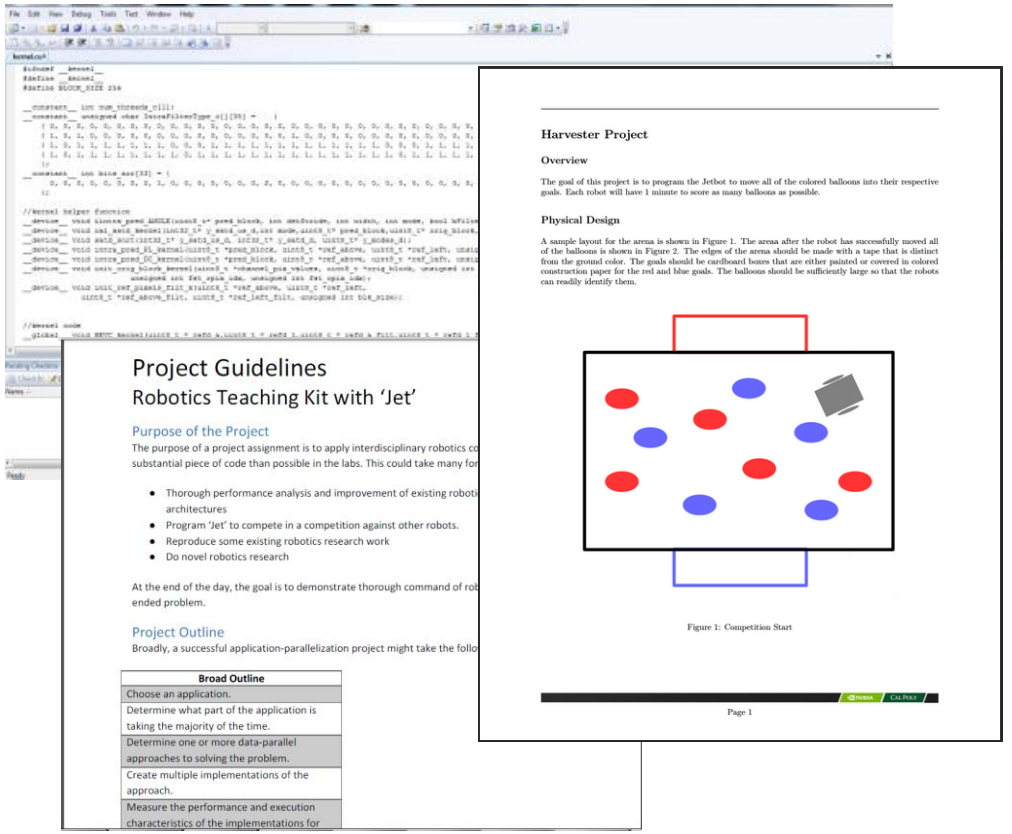
Not tied to specific modules

Current Release: **1** total project/solution/report

Later Release: ~**3** total projects/solutions/reports

.docx and .pdf formats

Solutions in source code



OTHER RESOURCES

qwikLABs

Live, hands-on, self-paced learning environment to reinforce the concepts contained in the Teaching Kit

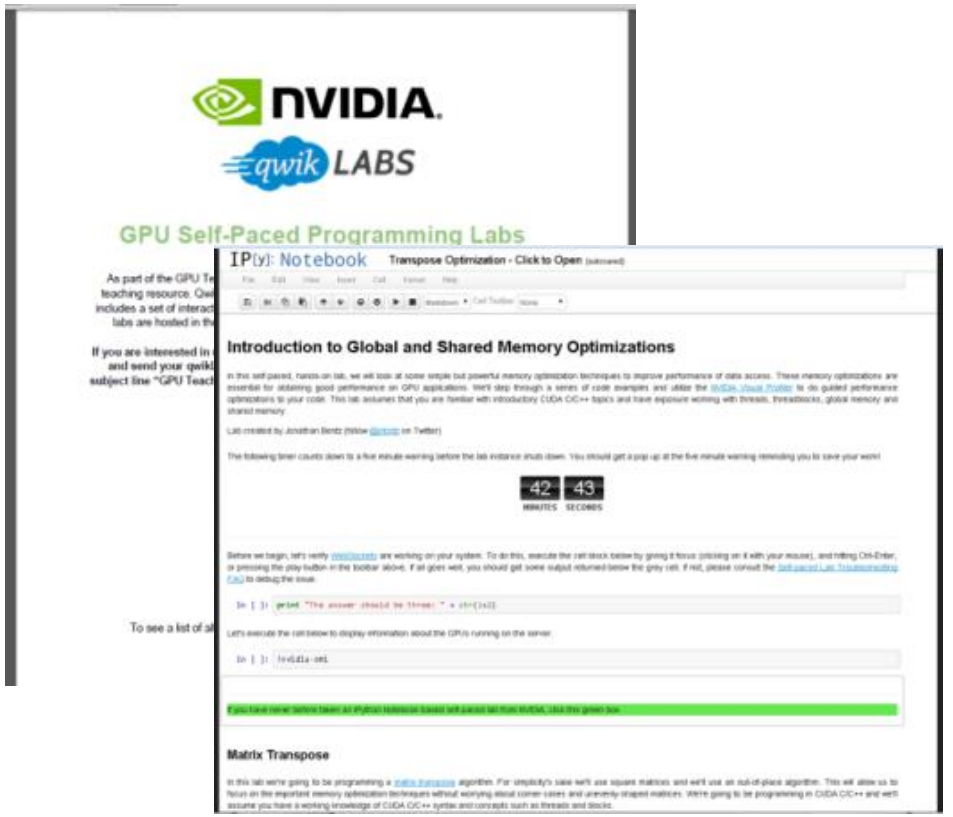
Labs includes interactive instructions, coding and Q/A

Hosted in the cloud

Students only needs a web-browser and internet access

Labs are timed

Free tokens with Teaching Kit



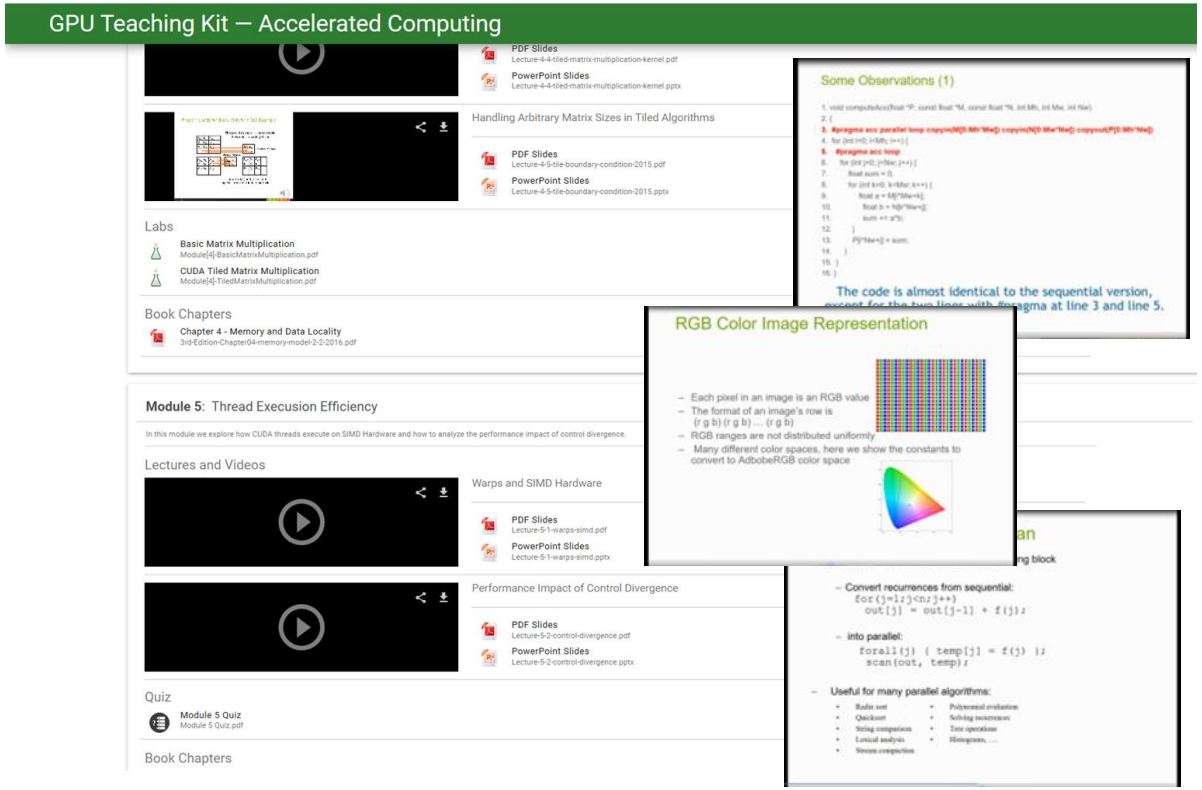
TEACHING KIT CONTENTS

Lecture Videos

Useful for “flipped” course and self-paced learning

Stream individually or download as .mp4 from

Coming in a future release!

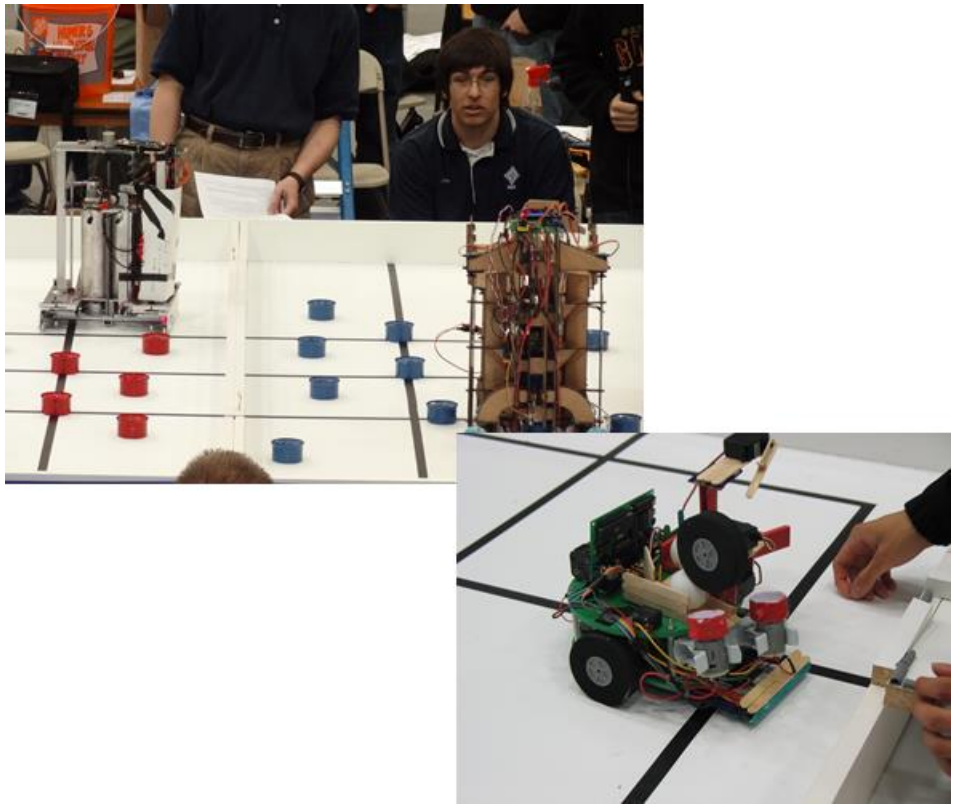


RELATED CAL POLY ACTIVITIES

Robotics at Cal Poly is a multi-disciplinary area

Encourage students to learn by actively engaging in projects

Students learn best by applying theory to real robot designs



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Q&A

Available to Instructors Now!

developer.nvidia.com/educators