



What is NXTCam5

NXTCam5 is a real-time image processing engine. Think of it as a vision sub-system with on-board processor and a protocol interface that is accessible through a standard LEGO Brick sensor port. This interface provides high-level, post-processed information of the image NXTCam-v5 sees.

In Object tracking mode, the processed information contains the bounding box coordinates of the objects of interest in view of NXTCam5.

In line tracking mode, this information contains coordinates of line segments.

NXTCam5 does not send the image itself to LEGO Brick. However, you can capture image (or Video) to SD card.



Compatibility with NXTCam-v4 and older:

NXTCam5 is compatible with NXTCam-v4 software on NXT, EV3, EVShield and PiStorms. (The NXTCamView5 software is new).

What you will need before using NXTCam5

Connector Cables

For runtime operations (on the robot, in autonomous mode), the NXTCam connects to EV3 (or NXT) on a sensor port using a standard connector cable that comes with EV3 (the one with jacks similar to phone jacks).

For offline operations (for programming and configuration), NXTCam5 connects to PC using mini-USB cable. (This is in addition to the cable you would use to connect your EV3 to your PC). Adjacent picture shows the mini-USB connector you would need on your USB cable, this connector is commonly used for digital cameras. If you need to acquire a cable separately, it should be a '5 wire' cable.



USB Driver installation

In order for NXTCam to work properly, you will need to install USB drivers for your operating system. Currently support exists for:

- Windows Vista (i386 and AMD processors)
- Windows 7 (i386 and AMD processors)
- Windows 8 (i386 and AMD processors)

Download the drivers and installation instructions from following location:
<http://www.mindsensors.com/content/95-usb-driver-installation-instructions-for-nxtcam-v5>

Viewer and Configuration Software

To see the picture that's in the field of view of NXTCam, capture that picture for analysis and configure the Colormaps for on-board processing, you will need to install and use Viewer and Configuration software on your PC.

Download Viewer and Configuration software for your operating system from following location:

For MS-Windows XP/Vista/7/8:

<http://www.mindsensors.com/largefiles/NXTCam5>

For Mac OSX:

David Lechner from ev3dev has published a package, you can download it here:

<https://github.com/dlech/NXTCamView5/releases/tag/mac%2F5.0.1>

Linux:

David Lechner from ev3dev has published an Ubuntu package. Install it with following instructions:

```
sudo add-apt-repository ppa:ev3dev/tools
sudo apt update
sudo apt install nxtcamview5
```

How to view videos captured by NXTCam5

You can use VLC media player by VideoLAN. <http://www.videolan.org/>



You can also upload these files to YouTube directly, (no pre-processing needed).

YouTube



On Mac you can use iMovie to view/edit these files.

Programming Environment(s)

EV3:

To use capabilities of the NXTCam5, please download EV3 blocks available at following URL:



http://www.mindsensors.com/index.php?controller=attachment&id_attachment=335

Installation instructions for EV3 block are available at:

<http://www.mindsensors.com/content/13-how-to-install-blocks-in-ev3>

Download EV3 sample program from following URL and modify it to suit your needs.

http://www.mindsensors.com/index.php?controller=attachment&id_attachment=336

Note: While using with EV3, ensure to use latest firmware version on your EV3.

NXT-G:

NXTCam5 is supported for use in NXT-G using a custom block.

Download the block from following URL:

http://www.mindsensors.com/index.php?controller=attachment&id_attachment=23



This block provides functionality for tracking objects based on the Colormaps downloaded on NXTCam5.

Installation instructions for NXT block are available at:

<http://www.mindsensors.com/content/21-nxt-g-blocks-how-to-install-blocks>

Note: While using with NXT-G, ensure to use latest firmware version on your NXT (1.31 as of this writing).

LeJOS API's are available at:

http://lejos.sourceforge.net/p_technologies/nxt/nxj/api/lejos/nxt/NXTCam.html

RobotC API's are available at:

<https://github.com/botbench/robotcdriversuite>

NXC/NBC Library functions are available at:

http://www.mindsensors.com/index.php?controller=attachment&id_attachment=94

Other (MATLAB/Simulink, Microsoft Robotics Developer Studio, etc.):

Above are the list of officially supported programming environments. However, you may be able to use others. In theory, if your programming environment has generic I2C methods, you should be able to. See [Appendix A](#) for more information.

Connecting NXTCam

Wiring for NXTCam

NXTCam may be connected to any of the sensor ports of EV3 Brick using standard NXT connector cable. In your program, select the appropriate port number to which NXTCam is connected.



WARNING

Do not connect the NXTCam to any motor port, as the voltage applied by the motor port may damage the electronics of NXTCam.

During offline operations, such as programming and configuration, connect your NXTCam to PC using USB cable.

During run-time (or autonomous) operations on EV3 Brick, the USB connection to PC should be removed.

NOTE: If NXTCam is connected to EV3 as well as PC, and if both hosts are sending commands, the latest command will be in effect.

NXTCam5 Features

Object Tracking Mode

In this mode the NXTCam5 will return color number and coordinates of 8 objects of matching colors. This is the default mode, as soon as the NXTCam5 is powered on, it will start in this mode using the colormaps stored on it. The returned data format is explained below in this document (in Advanced Reference Information Section).

Face/Eye Tracking Mode

In this mode the NXCam5 will return coordinates of matching faces (or eyes) it sees in front of it. The returned data format is same as Object Tracking mode, however the color number returned will have no meaningful data.

Line Tracking Mode

In this mode, the NXTCam5 will return up to 8 bounding boxes of the line segmented. The returned data format is same as Object Tracking mode, however the color number returned will have no meaningful data.

Capturing Still Pictures

In this mode, the NXTCam5 will capture an image and save it to micro-SD card. The image captured is in JPEG format with 320x240 resolution. After the image is captured, the NXTCam5 goes back to previous mode it was operating in. To view/copy the images, you can connect the NXTCam5 to PC using USB cable and open its drive in File Explorer to see files. The file has extension JPG.

The file name will be as: **M12345_00.jpg**

12345 is session ID, and 00 is capture ID, the session id is constant during each run, where as capture id increments for each clip or image captured to SD card.

Capturing Short Video Clips

In this mode, the NXTCam5 will capture a short clip of about 10 seconds to micro-SD card. When video recording finishes, the NXTCam5 resumes previous mode it was running.

The video format is MJPEG. You can open these files using [VLC media player from VideoLAN](#).

The filename is similar to still image, with extension MJPEG.

Capturing Continuous Video

In this mode, the NXTCam5 will begin capture of video and does not stop until next command is received. The recordings are stored as 10 second clips each, the file names are similar to still image names (capture ids are chronological sequence numbers).

Configuring Colormaps

What's a Colormap?

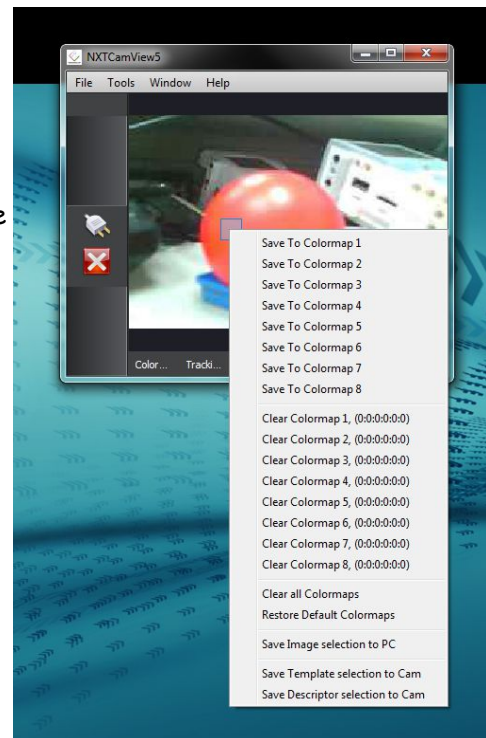
The objects of interest are recognized by NXTCam by matching the stored color values with the captured image. To do that, color values of the objects of interest need to be stored on NXTCam5. These color values are known as Colormaps.

A Colormap consists of various color values derived from a picture of your object. NXTCam can store up to 8 Colormaps and provide processed information of the objects matching those Colormaps.

Note: The more the number of Colormaps, slower is tracking. So, try to limit your Colormaps to minimum, and clear other Colormaps.

How to change Colormaps

1. Connect your NXTCam5 to your PC using USB cable
2. Start the NXTCamView5 program, and click on the 'Connect' icon.
3. You can then click on the arrow below the connect icon to begin tracking.
4. That should show an image from the NXTCam5 on your screen.
5. Click and Drag Left mouse button to select a region of your desired sample on the image and then right click to access the menu.
6. Now you can add the selected sample to your desired Colormap.

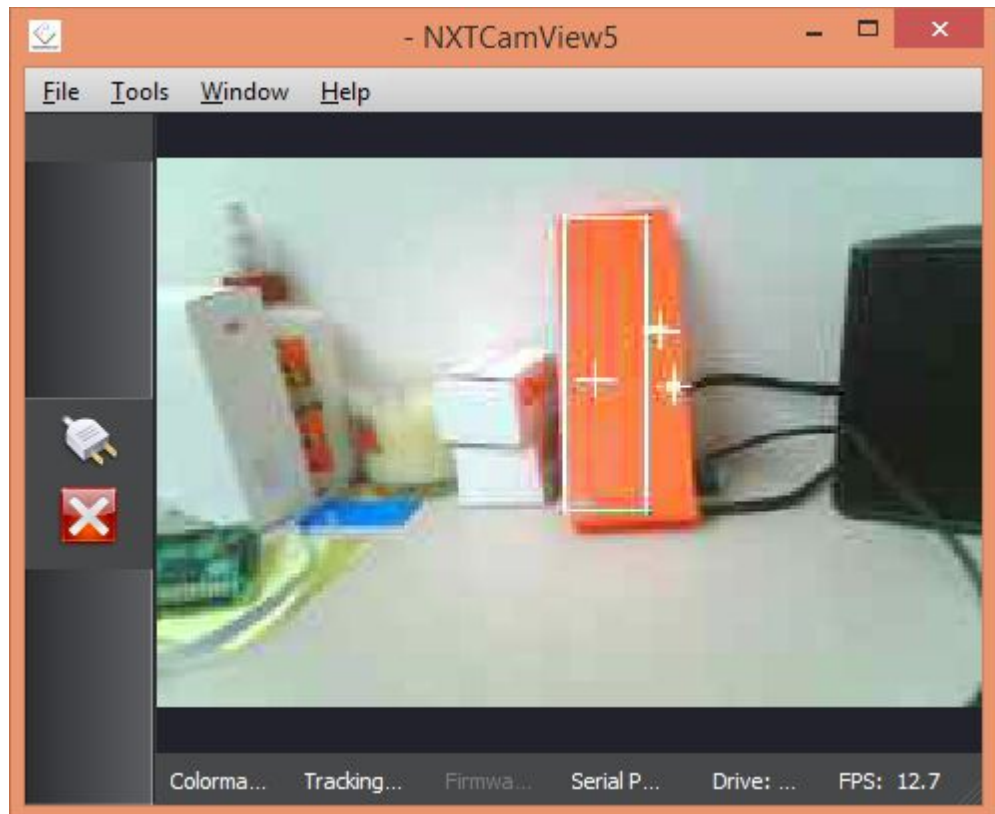


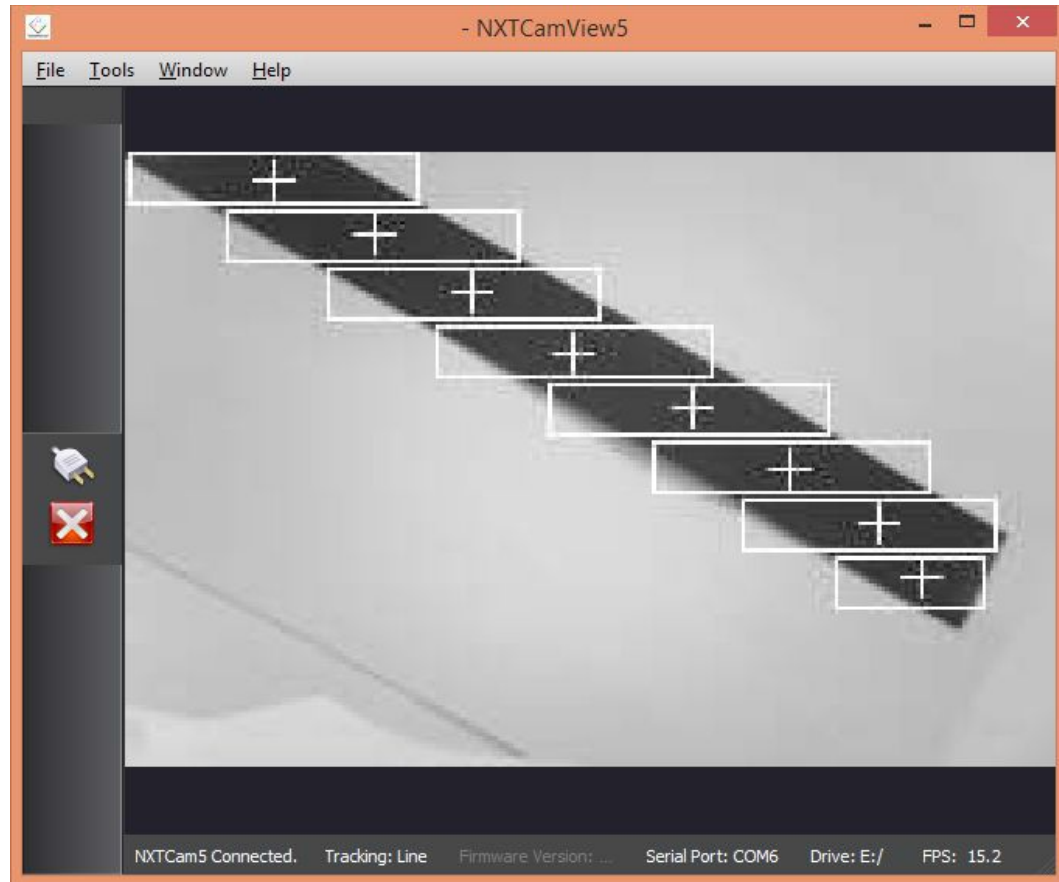
Default Object Colormaps

The menu which pops up upon right click has an option 'Restore Default Colormaps' to revert to factory defaults.

Objects of interest

Below are screen dumps of NXTCamView5 software, showing object of interest and their tracking.





Update your Colormap if lighting changes

Human eyes (and brain) are conditioned to adapt to ambient light conditions and see. Whereas based on ambient light, the colors of objects appear different to a camera CCD. In other words, a blue ball in your laboratory lighting conditions will appear to be a different shade of blue in Gymnasium lighting. Considering this aspect, ensure to update your NXTCam Colormap based on your final lighting conditions.

Tips on using NXTCam in your environment

Log File

The NXTCam5 operations are logged to a file on the micro-SD card, **NXTCam5_log.txt**.

This file can be used for debugging purposes.

LED on NXTCam5

The LED on NXTCam5 is a multi color LED with following indicators.

LED Color	Reason
Rapid Multi color blinking	There are no valid Python programs (generally this happens when SD card is missing)
Blue blinking at about 1 second interval	Normal operation in Tracking mode.
LED is on with Solid Green color	NXTCam5 is capturing a Video or a picture.

Object Colors in Line Tracking Vs Object Tracking Modes

In the object tracking mode, you can track objects of 8 distinct colors. While selecting colors, avoid any overlap between colors of different objects.

In line tracking mode, Colormaps are ignored and lines with contrast are used for detection.

Lighting conditions

The NXTCam is designed to operate under **white fluorescent light**. If you notice reddish image color, which tends to happen when your environment has lot of ambient Infrared light, try to find the source of Infrared light and reduce it by replacing it with fluorescent light.

Removing NXTCam5 from your computer

NXTCam5 connects to your computer as a USB drive, (as well as a serial device).



Your computer will be accessing and updating files on the NXTCam5. **So, while removing the USB connection from computer be sure to 'Eject' it first.**

Focus

For model equipped with fixed lens: the focus can not be changed.

For model equipped with changeable lens: As a factory default, NXTCam lens is set for optimal focus between 2 and 4 feet. The lens is screwed in it's holder and it is designed to be tight to prevent accidental rotation and loss of focus. To refocus the lens, gently turn the lens from the holder, If the lens is too tight, loosen the set screw on the lens mount and then try changing focus. Do not apply excessive force, as it may damage the lens. To check the focus, you can use Viewer software to see the new focus results.



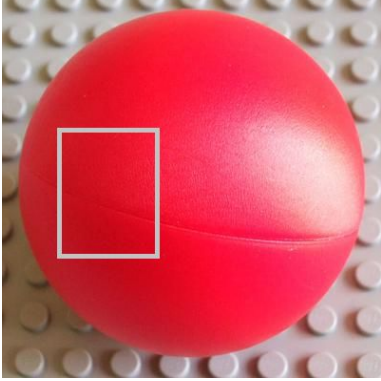

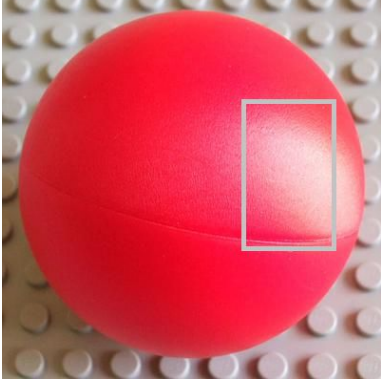

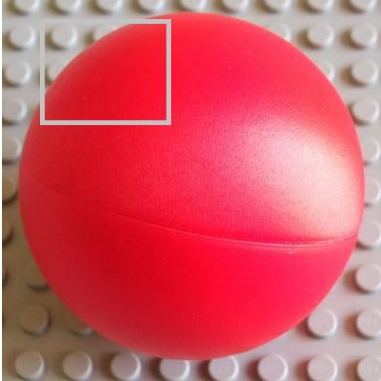

WARNING

While focusing, do not apply excessive force, as it may damage the lens.

Color Selection for Colormap

Due to angle of light and shadows cast on the object, to NXTCam, the object appears to be a mix of dark and light shades.

In choosing color for your Colormap, select only the sample of colors you want to track, and avoid any unrelated colors. e.g. in adjacent ball, avoid sample of the glare on the ball on the right side, also avoid the gray background or deep shadows on left.

	 <p>Keep the selection within the representative colors of the object.</p>
	 <p>Do not include extreme colors such as surface reflection in this case.</p>
	 <p>Do not include selection outside the target object (such as gray background in this case).</p>

Advanced Reference Information:

Appendix A: I2C

Open Source Software and Hardware

NXTCam5 is based on OpenMV Cam and is Open Source using MIT license. We encourage you to improve the source code and features and inform us the changes for inclusion in future releases.

I2C Operations

Pins used: SDA(1), GND(2), SCL(3), +5V(4)

Following table lists the register definitions and setup commands:

Commands		Action
ASCII	Hex	
B	0x42	Select Object tracking mode
F	0x46	Select Face Tracking Mode
R	0x52	Begin Capturing Continuous Movie (end by any other command)
M	0x4D	Capture Short Movie Clip
P	0x50	Capture Still Picture
e	0x65	Select Eye Tracking Mode
Q	0x51	Select QR Code Tracking Mode (future)
L	0x4C	Select Line tracking mode
J	0x4A	Lock tracking buffer Tracking is going on continuously, and while you read, buffer may be updated by the tracking engine. You can issue this command to Lock the buffer updates. After issuing this command allow 25 milliseconds for any updates in progress to finish. Then read the tracking information.
K	0x4B	Unlock tracking buffer. If you had locked the buffer before reading, ensure to unlock it after you are done reading.

While programming in NXC, you can use the API function `NXTCam_SendCommand ()` to send the command to NXTCam5. While using EV3G block, most of the essential commands are enumerated in it Menu.

I2C Registers:

The NXTCam5 appears as a set of few registers as follows.

Register	Read	Write	Comments
0x00-0x07	Software version - (Vn.nn)	-	

Register	Read	Write	Comments
0x08-0x0f	Vendor Id - <i>mndsnsrs</i>	-	
0x10-0x17	Device ID - <i>NXTCam5</i>	-	
0x41	-	Command	This register is command register. A command written here will be executed.
0x42	Number of objects detected	-	Shows how many objects are being tracked. Zero indicates that there are no objects being tracked.
0x43	1 st object color	-	This is the first object color as per the sorting method selected.
0x44 ¹	1 st object - X upper left		Upper left X coordinate of first object
0x45	1 st object - Y upper left		Upper left Y coordinate of first object
0x46	1 st object - X lower right		Lower right X coordinate of first object
0x47 ²	1 st object - Y lower right		Lower right Y coordinate of first object
0x48	2 nd object color		
0x49-0x4C	2 nd object co-ordinates		
0x4D	3 rd object color		
0x4E-0x51	3 rd object co-ordinates		
0x52	4 th object color		
0x53-0x56	4 th object co-ordinates		
0x57	5 th object color		
0x58-0x5B	5 th object co-ordinates		
0x5C	6 th object color		
0x5D-0x60	6 th object co-ordinates		
0x61	7 th object color		
0x62-0x65	7 th object co-ordinates		
0x66	8 th object color		
0x67-0x6A	8 th object co-ordinates		

¹ In case of line tracking mode, these are coordinates of beginning and end points of the line.

² This repeats for all 8 objects. Please note that object position and coordinate are overwritten if new object is detected, otherwise previous value is retained.

Changing the I2C Address

The factory default I2C address of NXTCam is 0x02.

This address can be changed. To set an address different from default address, send sequence of following commands on the command register:

0xA0, 0xAA, 0xA5, <new I2C address>

Note: Send these commands with no break/read operation in between. This new address is effective immediately. Please note down your new address for future reference.

Alternately, you can download device scan and address change programs from following URLs, and change them to suit your needs:

EV3/NXT:

<http://www.mindsensors.com/blog/how-to/change-i2c-device-address>

PiStorms:

<http://www.mindsensors.com/blog/how-to/change-i2c-device-address-with-pistorms>

Processing Resolutions and Speeds

- CCD resolution: VGA (640x480)
- Images or Video are captured in QVGA resolution (that is: 320x240)
- Tracking resolution: QVGA or HQVGA (this is internal to camera for the tracking algorithm).
- Video capture is 10 second clips, (you can multi trigger to capture multiple clips and later join them in video editing software) - this limitation is due to buffer size to flush SD card with video data.
- Tracking speed at HQVGA: 10 fps
- Tracking speed at QVGA: 7 fps