What is NXTCam

NXTCam 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 NXT sensor port. This interface provides high-level, post-processed information of the image NXTCam sees. The processed information contains the bounding box coordinates of the objects of interest in view of NXTCam, in line tracking mode, this information contains coordinates of line segments.

NXTCam does not send the image itself to NXT, however connecting NXTCam to a PC with USB cable, and using a Viewer and Configuration software, you can see the image on the PC.

NXTCam Feature List

The NXTCam provides following capabilities:

- Track up to 8 different colorful objects at 30 frames/second

- Configure the NXTCam using USB interface on Windows XP, Windows Vista.

- Supports two tracking modes: Object tracking and Line tracking.

- Provide real-time tracked object statistics (number of objects, color of objects, bounding box coordinates or line coordinates) through a standard NXT sensor port.

- Tracked image resolution of 88 x 144 pixels at 30 frames/second

- Perform full-resolution (176 x 144) pixels color image dumps to PC via USB port.

- Maximum power consumption (42 mA at 4.7 V)

- Uses NXT compatible I2C protocol for communications.

- Supports Auto Detecting Parallel Architecture (ADPA) for NXT sensor bus. This means that NXTCam can coexist with LEGO or third party digital sensor on the same NXT port. ADPA support enables user to employ several sensors on the same port without the need of external sensor multiplexer, reducing the overall size without compromising the functionality.

What you will need before using NXTCam

Connector Cables

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

For offline operations (for programming and configurations), NXTCam connects to PC using mini-USB cable. (This is in addition to the cable you would use to connect NXT 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 XP (i386 and AMD processors)
- Windows Vista (i386 and AMD processors)
- Mac OS X v10.4.10 (PowerPC G4)

Download the drivers and installation instructions from following location:
http://www.mindsensors.com/NXTCam_Driver_Installation.htm

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 onboard processing, you will need to install and use Viewer and Configuration software on your PC.

For MS-Windows XP/Vista, download Viewer and Configuration software from:
http://nxtcamview.sourceforge.net/

For Macintosh, download Viewer and Configuration software from:

http://www.mindsensors.com/index.php?module=documents&JAS_DocumentManager_op=viewDocument&JAS_Document_id=53

Programming Environments

NXTCam is supported for use in NXT-G using a custom block. Download the block from following URL: http://www.mindsensors.com/NXTCam_NXT-G_Block.htm

Follow the installation instructions provided at this URL to install the block.

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:

http://www.mindsensors.com/index.php?module=documents&JAS_DocumentManager_op=viewDocument&JAS_Document_id=50

NXC/NBC Library functions are available at:

http://www.mindsensors.com/index.php?module=documents&JAS_DocumentManager_op=viewDocument&JAS_Document_id=57

Connecting NXTCam

Wiring for NXTCam

NXTCam may be connected to any of the sensor ports of NXT 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, NXTCam must be connected to PC (using USB cable) as well as NXT (using standard NXT connector cable) while NXT is powered ON.

During runtime (or autonomous) operations on NXT, the USB connection to PC must be removed.

NOTE: While NXTCam is connected to NXT as well as PC, the PC communication takes priority over any other communication.

In other words, while NXTCam is connected to PC as well as NXT, if you run a program on NXT, it will not be able to talk to NXTCam.

Mounting NXTCam on your contraption

The holes on the NXTCam enclosure are designed for tight fit of Technic pins (or axles) with '✚' cross section. The holes however are not designed for repeated insertions/removals of these pins.

To mount NXTCam v2 on your contraption we suggest that you use two dark gray 'Technic Axle 3 with Stud' as shown.

Insert axles from the front (lens side) of the NXTCam and secure with a bushing on the back or mount it on your contraption directly.

Alternately, you may use blue 'Technic Axle Pin with Friction', as shown.

While disassembling contraption, leave the axles and/or pins on NXTCam.

LED on NXTCam

The LED on NXTCam lights up whenever NXTCam is supplied with power. Under normal operations, the power will be supplied by NXT from the sensor port.

Configuring Colormaps in NXTCam

Default Object Colormap

The NXTCam is shipped with a default Colormap to track a light source. Download a test program or write a test programs, and try tracking a light source.

Objects of interest

Below are screen dumps of NXTCamView software, showing objects of interests and their tracking information.

The top left window in the picture below shows the field of view of NXTCam. The objects of interest from this view are the red and blue pens. In the object tracking mode, the bounding box coordinates are returned, as shown:

In line tracking mode, beginning point and end point coordinates of a line representing the object are returned. In the following picture, the bounding boxes are drawn for the line coordinates received from NXTcam:

More about Colormaps

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 NXTCam. These color values are known as Colormaps.

NXTCam can store up to 8 Colormaps and provide processed information of the objects matching those Colormaps.

For more information on how to pick Colormap values of your objects of interest and how to store them on NXTCam using the NXTCamView software, please refer to section 'teaching NXTCam colors' from URL: http://nxtcamview.sourceforge.net/

Also watch a demo video 'Capture and Select' at following URL: http://nxtcamview.sourceforge.net/DemoScreenCam.htm

Tips on using NXTCam in your environment

Object Colors in Line Tracking Vs Object Tracking Modes

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

In line tracking mode, it is recommended to limit the number of colors to one.

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.

For advanced operations it is possible to change color gain, brightness and contrast of NXTCam by manipulating the I2C register values.

Focus

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, capture images and see if the new focus is satisfactory. Do not apply excessive force, as it may damage the lens. For better grip while turning lens, you may wrap a rubber-band around the exposed threads of the lens. To check the focus, you can use Viewer software and perform a 'capture' and see the results.

Programming Techniques

NXT-G:

Download the NXT-G block that's available in the NXT-G Blocks Repository at Mindsensor's website (see the URL above under section 'Programming Environments'.) This block provides functionality for tracking objects based on the Colormaps downloaded on NXTCam.

Note: While using with NXT-G, ensure to use firmware version 1.05.

Changing the I2C Bus 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 carefully for future reference.

Alternately, you can download address scan and change functions written in RobotC from following URL, and change them to suit your needs:
http://www.mindsensors.com/RobotC_Utility_Programs.htm

Troubleshooting NXTCam communication

Troubleshooting NXTCam communication with your PC

To ensure USB drivers are installed properly, follow these steps:

1. Ensure to install the USB drivers as mentioned in this document.
2. Connect the NXTcam using a USB cable to your computer.
3. From Start menu -> Right click on Computer, select 'Properties', select 'Hardware' tab, and select the 'Device Manager'.
4. Expand the 'Universal Serial Bus Controller' entry.
5. You should see 'NXTCam' listed.
6. In the same Device Manager, Expand 'Ports (COM & LPT) entry.
7. You should see a COM port listed for NXTCam (this is the COM port you should use for your viewer software configuration).

To ensure actual USB communication, follow these steps:

1. Connect the NXTcam using a USB cable to your computer.
2. Run Hyperterminal: Start -> All Programs -> Accessories -> Communication -> Hyper Terminal
3. Give a name for the configuration, say 'mynxtcam'.
4. In the next dialog box specify:
   Connect Using: <NXTCam COM Port> (the port you noted from Ports (Com and LPT) entry in Device Manager)
5. Click OK.
6. In next window Specify:
   Bits per second: 115200
   Data bits: 8
   Parity: None
   Stop bits: 1
   Flow Control: None
7. Click OK.
8. In the main terminal window, just press <enter>
   You should get a response from NXTCam as 'NCK'
9. In the same window, type:
   GV<enter>
   You should get a response from NXTCam as 'NXTcam V n.n' (where n.n is your NXTcam version number)

Troubleshooting NXTCam communication with your NXT

Ensure to install NXT-G blocks for NXTCam as mentioned above in the document.

1. Connect your NXT to your PC using it's standard USB cable.

2. Connect your NXTCam to NXT Port 1 using standard NXT sensor cable.

3. Run NXT-G software on your computer.

4. Power on the NXT.

5. Start a New Program (say Untitled-1), and from Advanced Block Palette, drag and drop the NXTCam block in it.

6. Click on the block, and examine the bottom left corner of NXT-G window (where block control panel is located).

7. You should see NXTCam version number shown in the bottom left corner, as shown in the adjacent picture.
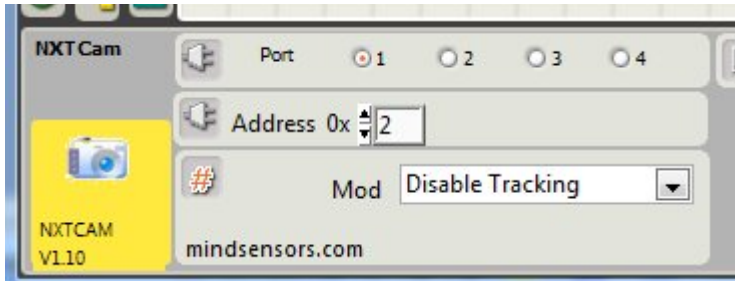
8. If the NXTCam is not connected correctly to your NXT, this status will indicate 'No Device'. If that happens, ensure the port and Address in your program match to what's on NXTCam.

Reference Information

Wiki for NXTCamView, NXTcam and related Projects and findings

Visit following URL for the wiki

http://nxtcamview.wiki.sourceforge.net

Open Source Software and Hardware

NXTCam is based on AVRcam, and is Open Source using GNU license. We encourage you to improve the source code and features and inform us the changes for inclusion in future releases. Visit following URL to download the source code and related docs.

http://www.mindsensors.com/NXTCam_Source_Code.htm

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**	
A	0x41	Sort tracked objects by size
B	0x42	Select Object tracking mode
C	0x43	Write to Camera Registers
		Use extreme CAUTION when using command C since this can stop your camera working properly. In case this happens, please power off your NXTCam

		and power it on again.
D	0x44	Disable Tracking
E	0x45	Enable Tracking
G	0x47	Get the Color map from Camera Engine
H	0x48	Read data from the Camera Registers
I	0x49	Illumination on (Future)
L	0x4C	Select Line tracking mode
N	0x4E	Set ADPA mode O**N** (setting stored in NVRAM)
O	0x4F	Set ADPA mode **O**ff (default) (setting stored in NVRAM)
P	0x50	Ping camera Engine
R	0x52	Reset Camera Engine
S	0x53	Send the color map to camera Engine
T	0x54	Illumination Off
U	0x55	Sort tracked objects by color
V	0x56	Get camera Engine firmware version No
X	0x58	Do not Sort tracked objects

I2C Registers:

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

Register	Read	Write	Comments
0x00-0x07	Software version – *(Vn.nn)*	-	
0x08-0x0f	Vendor Id – *mndsnsrs*	-	
0x10-0x17	Device ID – *NXTCam*	-	
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	1st object color	-	This is the first object color as per the sorting method selected.
0x44[1]	1st object - X upper left		Upper left X coordinate of first object
0x45	1st object - Y upper left		Upper left Y coordinate of first object
0x46	1st object - X lower right		Lower right X coordinate of first object
0x47[2]	1st object - Y lower right		Lower right Y coordinate of first object
0x48	2nd object color		
0x49-0x4C	2nd object co-ordinates		
0x4D	3rd object color		
0x4E-0x51	3rd object co-ordinates		
0x52	4th object color		
0x53-0x56	4th object co-ordinates		
0x57	5th object color		
0x58-0x5B	5th object co-ordinates		
0x5C	6th object color		
0x5D-0x60	6th object co-ordinates		

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[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.

Register	Read	Write	Comments
0x61	7th object color		
0x62-0x65	7th object co-ordinates		
0x66	8th object color		
0x67-0x6A	8th object co-ordinates		
0x6B	No. of registers to Read	No. of registers to Write	This is the number of registers you need to read or write from camera image sensor
0x6C	1st Camera register Address	1st Camera register Address	
0x6D^3	1st Camera register Data	1st Camera register Data	1st register Data read from image sensor or written to image sensor
………………………..	………………………………..	……………………………	
0x7A	8th Camera register Address	8th Camera register Address	
0x7B	8th Camera register Data	8th Camera register Data	
0x80^4	Color map data Red 0	Color map data Red 0	0x80 – 0xAF - These registers are used for Colormap data reading and writing
0x80	Color map data Red 0	Color map data Red 0	
0x81	Color map data Red 1	Color map data Red 1	
0x82	Color map data Red 2	Color map data Red 2	

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[3] If you need to read image sensor register 0x00 (i.e. 1 register) then follow this:

      Write 0x01 to register 0x6B, Write 0x00 to register 0x6C

      Run command 'H'

      Results will be stored in register 0x6D

  If you need to write to image sensor register 0x00 (i.e. 1 register) then follow this:

      Write 0x01 to register 0x6B, Write 0x00 to register 0x6C, Write data to register 0x6D

      Run command 'C'

[4]If you need to read Colormap data from camera engine, then follow this:

      Run command 'G'

      Read registers 0x80 – 0xAF.

  If you need to write Colormap data to camera engine, then follow this:

      Write your color map data in registers 0x80 – 0xAF,

      Run command 'S'

Register	Read	Write	Comments
0x83	Color map data Red 3	Color map data Red 3	
0x84	Color map data Red 4	Color map data Red 4	
0x85	Color map data Red 5	Color map data Red 5	
0x86	Color map data Red 6	Color map data Red 6	
0x87	Color map data Red 7	Color map data Red 7	
....	……………………………….	…………………………………	
0x8F	Color map data Red 15	Color map data Red 15	
0x90	Color map data Green 0	Color map data Green 0	
0x91	Color map data Green 1	Color map data Green 1	
....	……………………………….	…………………………………	
0x9F	Color map data Green 15	Color map data Green 15	
0xA0	Color map data Blue 0	Color map data Blue 0	
0xA1	Color map data Blue 1	Color map data Blue 1	
....	……………………………….	…………………………………	
0xAF	Color map data Blue 15	Color map data Blue 15	