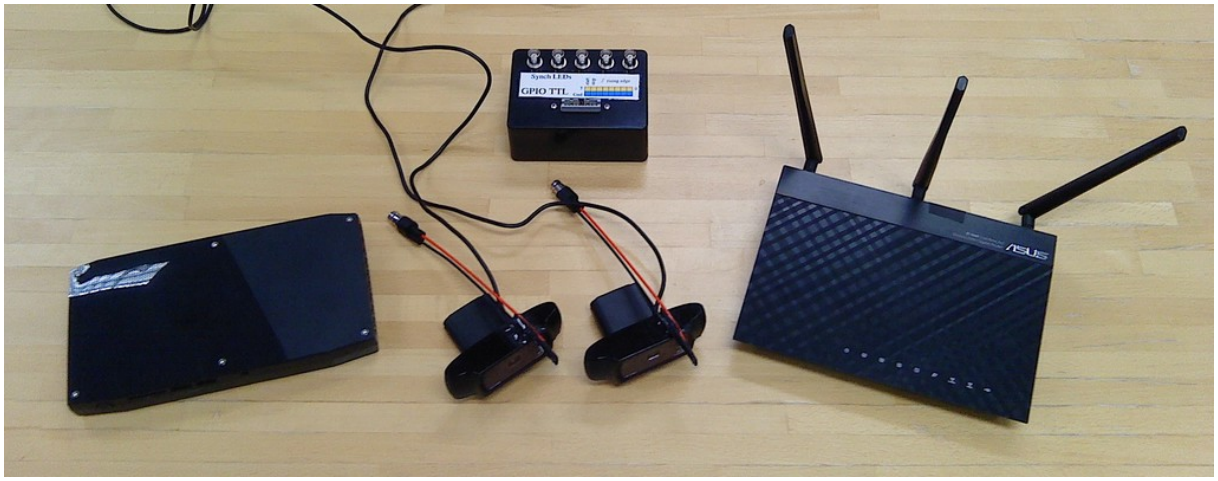
NeuroCam System User Guide

Written by Christopher Thomas – February 9, 2021.



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Chapter 1

Overview

The NeuroCam system is a computer-controlled camera network that collects footage of a subject interacting with a game (or other apparatus). It was commissioned by the Attention Circuits Control Laboratory (`http://accl.psy.vanderbilt.edu/`) to facilitate their experiments.

A system diagram is shown in Figure 1.1, below:

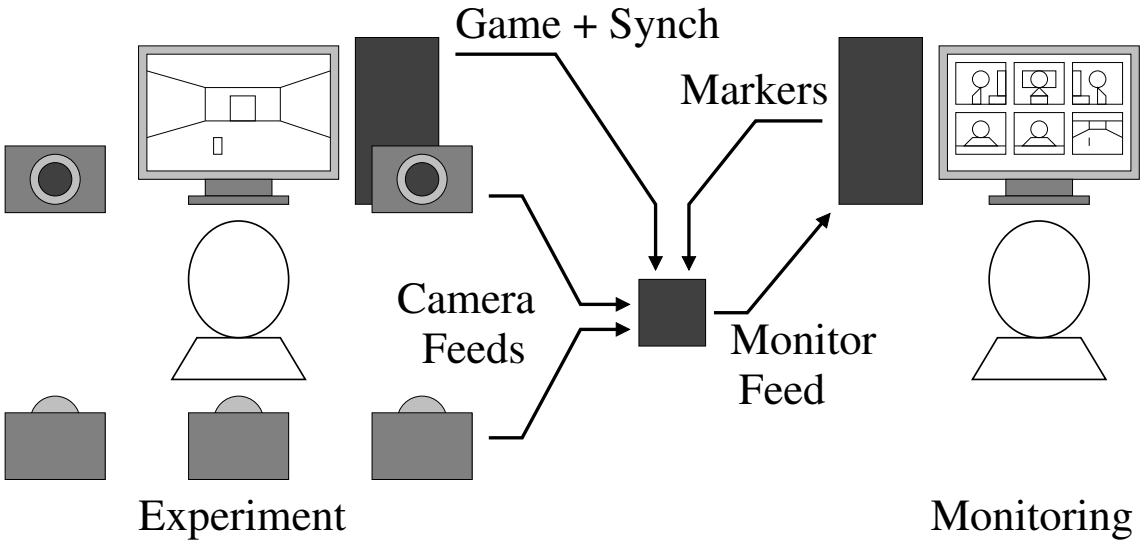


Figure 1.1: System block diagram.

The NeuroCam system processes several types of data and events (described in detail in later sections):

- It collects frame data (with timestamps) from several cameras.
- It collects streamed video data from the game machine.
- It accepts web connections from authorized computers for control and monitoring.
- It provides a "monitoring" feed to the control computer showing all video streams.

- It records "marker" events when interface buttons are clicked on the monitoring web page.
- It records digital (TTL) signals from external equipment.
- It accepts TTL "start" and "stop" signals from external equipment.
- It offers collected data for examination, download, and post-processing via a web interface after experiments have completed.

To get started, connect an authorized machine to the "`neurocam`" network and point it to "`http://192.168.1.`*(value)*" (the IP address given on the sticker on the NeuroCam machine).

Chapter 2

Hardware Setup

The NeuroCam system has several hardware components:

- One "NeuroCam" embedded computer. This performs data collection and storage.
- One wireless router. This is connected to the NeuroCam computer and to the game machine via wired LAN, and accepts wireless connections from user machines. *Do not connect this to the internet.*

  The router used by the prototype system was an Asus RT-N66U.
- One GPIO-and-synchronization box. This is connected to the NeuroCam computer via USB, and provides TTL synchronization outputs over BNC and accepts TTL-level inputs via a ribbon cable.

  Any change in the TTL inputs is reported (and logged). A low-to-high transition on bit 7 will start the NeuroCam recording, and a low-to-high transition on bit 6 will stop recording (with a "dead time" of ten seconds before further commands will be recognized). Input bits 0–5 are logged but do not change NeuroCam behavior, and may be used for any desired purpose.
- Five cameras, connected to the NeuroCam computer via USB.

  The camera model used by the prototype system was the Logitech C920.



There are several tasks of note that have to be performed in order to configure the NeuroCam hardware for use:

- The camera synchronization LEDs must be connected to the GPIO-and-synchronization box via BNC cables.

  Alternatively, a TTL-controlled lamp (visible or IR) may be placed in the scene within view of all cameras and connected to the GPIO-and-synchronization box.

- The administrator password for the wireless router *must* be set to a new, stronger value. The default password ("administrator") is provided strictly for setup purposes.

  The password for the NeuroCam network should also be changed. The default password ("neurocam") is easily guessed from the network name.

- Any machines that are intended to communicate wirelessly with the NeuroCam system must be added to the wireless router's MAC whitelist. Machines that communicate via network cable may also need to be added, depending on the router's configuration.

- The game machine must be configured to stream MJPEG video, and to respond to NeuroCam queries about offered content. The "`VLC`" application was used for MJPEG streaming in the prototype system. Consult VLC's documentation for further information.

  Network handshaking with the game machine is described in Chapter 5.

The wireless router may be reconfigured by connecting to a wired LAN port and accessing the web address printed on the bottom of the device. **Do not** reset the device to factory default settings; this will lose all NeuroCam-related configuration.

See Chapter 6 for details about configuring routers.

Chapter 3

Web Interface

The NeuroCam system has three interface screens: The **configuration** screen, the **monitoring** screen, and the **repository browser**. The monitoring screen is seen when the system is collecting data. When the system is not collecting data, the configuration screen and the repository browser are both available.

Important: Do not use the "back" button of your web browser to switch pages. This will result in stale CGI information being submitted. Use the navigation buttons in the NeuroCam application instead.

3.1 Configuration Screen

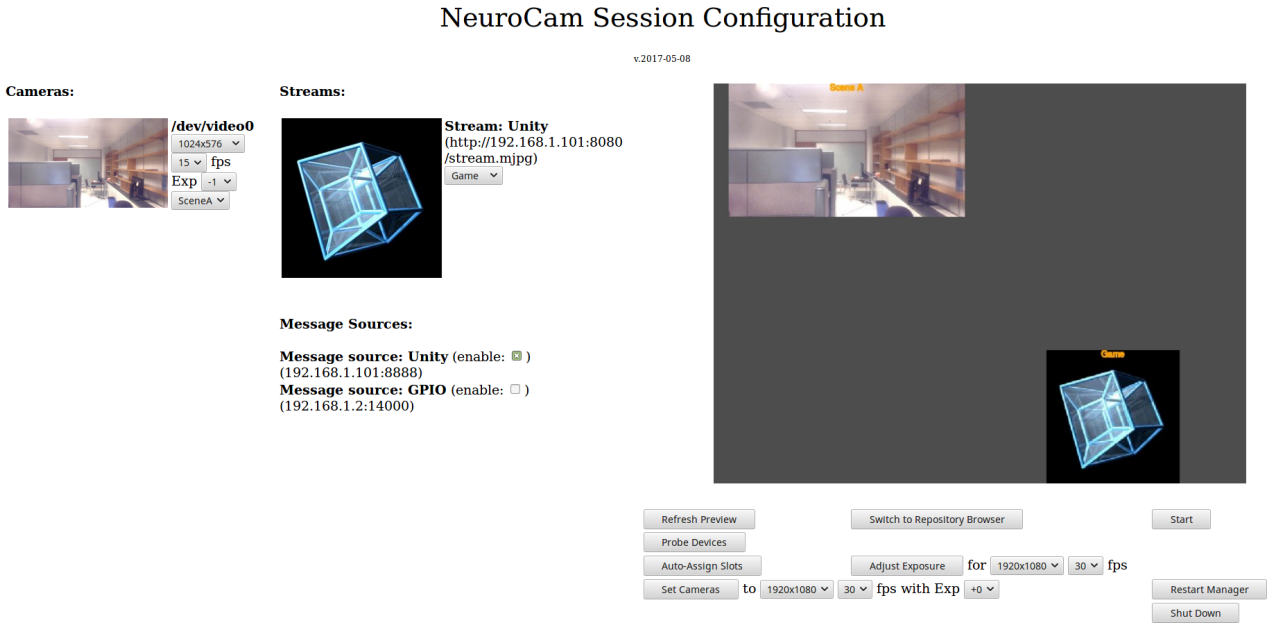


Figure 3.1: Configuration screen.

The configuration screen is used to set up a new video capture session.

Detected cameras are shown in the left column. The middle column shows detected computer video streams and detected event message sources. The right column shows a still-frame preview of the video feeds, with a control panel under the preview.

Each camera has resolution, frame rate, and exposure settings, along with a still-frame preview of its input. Longer (positive) exposures give a brighter image but may reduce frame rate; shorter (negative) exposures give a dimmer image but may increase frame rate. The "slot" to which the camera feed is assigned may also be changed.

Camera settings may be changed all at once using the "Set Cameras to..." control in the control panel.

Camera settings may also be adjusted using the "Adjust Exposure for..." control in the control panel. This reduces exposure and resolution for each camera until the specified frame rate is achieved. **Note:** this adjustment takes several minutes (up to tens of minutes if the system has difficulty finding appropriate settings).

There should always be at least one computer video stream, representing a "screencast" of the game the subject is playing.

There should always be at least two event message sources: one from the game computer (which sends game-time synchronization messages), and one from the GPIO-and-synch box (which sends camera LED synchronization messages and messages indicating changes in its TTL inputs).

The NeuroCam interface tries to enable appropriate message sources, choose acceptable resolutions and frame rates, and assign appropriate feeds to appropriate slots in the composite image, but some manual adjustment is usually necessary. The "Auto-Assign Slots" control in the control panel can be used to reset this assignment to the default.

The "Refresh Preview" button can be used to capture new images from the cameras and computer video sources and to redraw the composite image preview.

NOTE: Some browsers may fail to update the preview images due to cache behavior. Wait a moment and then click the "preview" button again to refresh these images.

The "Probe Devices" button can be used to re-detect cameras, computer video streams, and event/message feeds.

The "Switch to Repository Browser" button changes to the repository browser screen, saving the configuration for later editing.

The "Start" button creates a new session directory, activates video capture, and switches to the monitoring screen. This may alternatively be done by raising the "start capture" TTL line.

The "Restart Manager" button forcibly restarts the NeuroCam software. This allows recovery if any part of the NeuroCam software stops behaving correctly. This is also needed if performing a software update without restarting the NeuroCam machine.

The "Shut Down" button turns off the NeuroCam computer.

3.2 Monitoring Screen

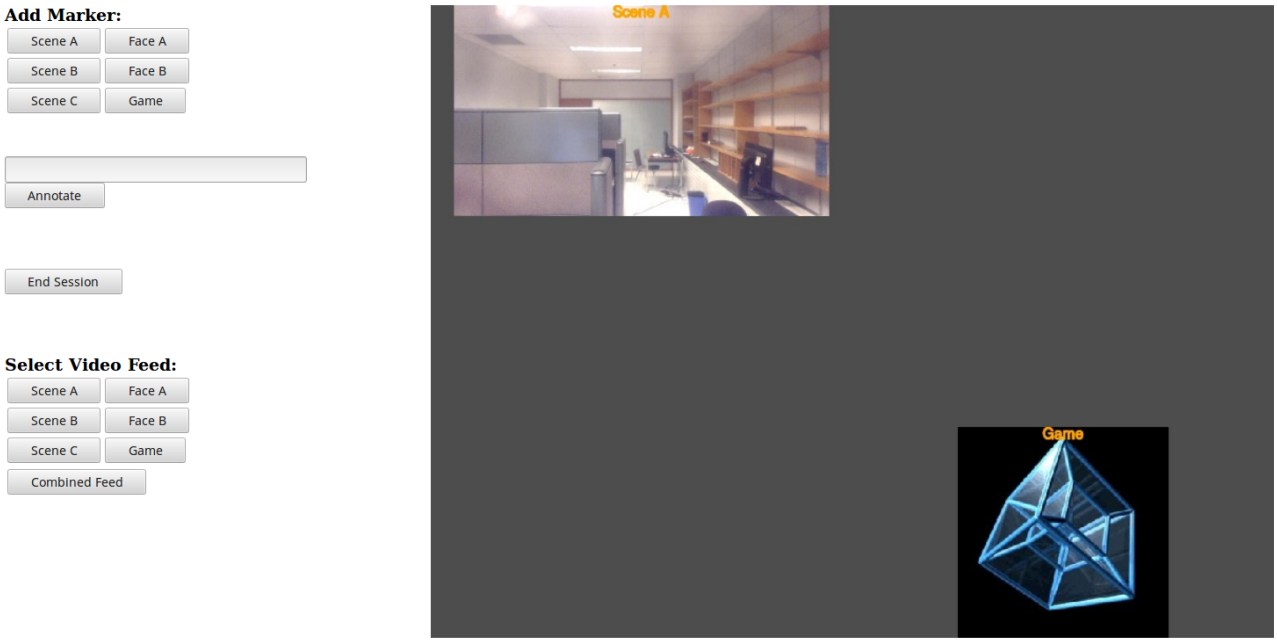


Figure 3.2: Monitoring screen.

The monitoring screen is used to view the progress of a capture session that is underway, and to add event markers to the log file for this session.

The "Add Marker" buttons produce timestamped log entries indicating events of interest in their respective video feeds.

The "Annotate" button produces a timestamped log entry containing user-supplied text.

The "End Session" button stops video capture, closes the log file, and switches to the repository browser screen. This may alternatively be done by raising the "stop capture" TTL line.

The "Select Video Feed" buttons replace the combined image with the raw video frames from the selected feed. This is usually better-quality and faster than the combined feed. The "Combined Feed" button returns to the composite feed.

3.3 Repository Browser

The repository browser is used to inspect the data files produced by past sessions, to perform post-processing of session data, and to download and transfer packaged session data. Old sessions may also be deleted to free up disk space.

The "Session Folder" column lists sessions within the repository. Clicking on a session name opens that session's directory in a new window. Files may be individually inspected and downloaded via that window. See Chapter 4 for a description of the repository folder contents.

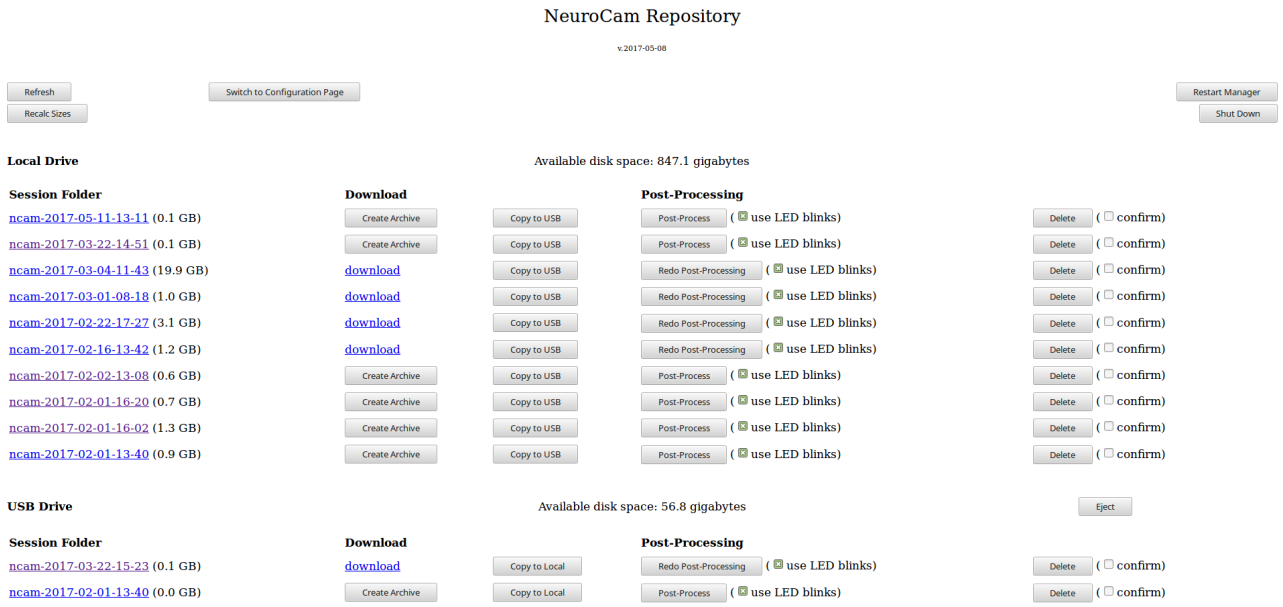


Figure 3.3: Repository browser.

The "Download" column contains a link to a ".tar" archive containing a session's entire directory tree. This is intended to provide an easy way to transfer a session's data over the network. The archive is created using the "Create Archive" button. If post-processing has been performed, the archive includes the post-processed files. **NOTE:** The archive file is large. Check that there is sufficient free space before creating it.

The "Copy to USB" and "Copy to Local" buttons create duplicates of their session folders on a USB-attached drive and on the local drive, respectively. **NOTE:** These may instead be named "Move to USB" and "Move to Local", depending on settings. "Move" deletes the original folder, while "Copy" leaves it in place.

The "Post-Processing" button triggers several operations on a session folder. If the "use LED blinks" checkbox is set, video timestamps are synchronized with each other using flashes of the infrared LEDs. A new log file is saved with these adjusted timestamps. After synchronization, a "Composite" video feed is created, arranged in the same manner as the monitoring feed but at higher resolution and with full frame rate. A new log file is saved with composite feed frame events added. Finally, movie files of all video feeds are created for easy preview/playback. **NOTE:** Post-processing operations take a lot of time on the local drive (a solid-state drive), and even longer on magnetic platter or flash drives.

FIXME: Benchmark post-processing. How long does processing an hour of five-camera-plus-game footage take?

The "Delete" buttons allow individual session folders (and their archives) to be removed. This cannot be undone; to prevent accidental deletion, the corresponding "confirm" checkbox must be checked before pressing the "Delete" button. Deleting old sessions will need to be performed frequently in order to free up disk space.

The "Eject" button unmounts an external drive so that it can be safely removed. **NOTE:** Writing data to an external drive can take a while, so please wait until the NeuroCam indicates that it is safe for

the drive to be removed.

The “Refresh” button re-scans the repository directory for new sessions.

The “Recalc Sizes” button recomputes metadata for all session folders. **NOTE:** This can take a while, as each session may contain millions of files.

The “Switch to Configuration Page” button changes to the configuration screen, so that the next capture session may be set up.

The “Restart Manager” button forcibly restarts the NeuroCam software. This allows recovery if any part of the NeuroCam software stops behaving correctly. This is also needed if performing a software update without restarting the NeuroCam machine.

The “Shut Down” button turns off the NeuroCam computer.

Chapter 4

Repository Data

NeuroCam session data is stored in a "repository". Each session has its own timestamped repository folder, containing some or all of the following:

- Raw video capture frames, stored as JPEG images in the "Scene" and "Face" folders.
- Raw game capture frames, stored as JPEG images in the "Game" folder.
- A "Monitor" folder containing reduced-size composited frames that were sent to the monitoring GUI during the experiment. The composited frames are not necessarily synchronized with each other.
- A "Composite" folder containing larger composited frames produced during post-processing. These composited frames should be synchronized.
- A "`session.cfg`" file containing information about the settings used for the capture session. This file is described in detail in Chapter **??**.
- A "`logfile.txt`" file containing raw event data (frame times, user-supplied markers, and so forth).
- Post-processed log files "`logfile-timed.txt`" and "`logfile-composited.txt`". The "`-timed`" file has properly synchronized timestamps and the "`-composited`" file includes timestamps for the "Composite" video stream (properly synchronized).
- Several "`.mp4`" compressed video files corresponding to the video frame folders described above. These are lower-fidelity copies intended to simplify review of footage.

A typical session folder before post-processing is shown below:

Index of /repositories/ncam-2017-05-11-13-11

Name	Last modified	Size	Description
Parent Directory		-	
FaceA/	2017-05-11 13:11	-	
FaceB/	2017-05-11 13:11	-	
Game/	2017-05-11 13:11	-	
Monitor/	2017-05-11 13:11	-	
SceneA/	2017-05-11 13:11	-	
SceneB/	2017-05-11 13:11	-	
SceneC/	2017-05-11 13:11	-	
logfile.txt	2017-05-11 13:11	123K	
session.config	2017-05-11 13:11	1.2K	

A typical session folder after post-processing is shown below:

Index of /repositories/ncam-2017-03-04-11-43

Name	Last modified	Size	Description
Parent Directory		-	
Composite.mp4	2017-03-10 17:06	301M	
Composite/	2017-03-10 17:06	-	
FaceA/	2017-03-04 11:43	-	
FaceB/	2017-03-04 11:43	-	
Game/	2017-03-04 11:43	-	
Monitor.mp4	2017-03-10 16:58	284M	
Monitor/	2017-03-10 16:58	-	
SceneA.mp4	2017-03-10 16:49	310M	
SceneA/	2017-03-04 12:26	-	
SceneB.mp4	2017-03-10 16:55	301M	
SceneB/	2017-03-04 12:26	-	
SceneC/	2017-03-04 11:43	-	
logfile-composited.txt	2017-03-10 16:47	13M	
logfile-timed.txt	2017-03-10 15:22	8.7M	
logfile.txt	2017-03-04 12:26	8.7M	
session.config	2017-03-04 11:43	1.0K	

4.1 Log File Format

The logfile is a human-readable text file recording one event per line. The following types of event are recorded:

- **Frame events**, indicating that a video frame was recorded. This may be from a camera, from a remote computer video feed, or from a generated feed like the "Monitor" and "Composite" feeds.
- **Network message events**, which are typically sent by the GPIO-and-synch box or by external applications such as the game.
- **Local GUI events**, which are either user annotations, user markers, or instructions to change the monitoring display.

Frame events indicate arrival time, stream "slot" name, sequence number, and the filename (including subfolder) where the frame was saved. Typical frame events are as follows:

```
(1367) [SceneA]  frame 8  SceneA/00000008.jpg
(1374) [SceneB]  frame 16  SceneB/00000016.jpg
(1382) [Monitor]  frame 36  Monitor/00000036.jpg
(1403) [SceneB]  frame 17  SceneB/00000017.jpg
(1417) [Monitor]  frame 37  Monitor/00000037.jpg
(1437) [SceneA]  frame 9  SceneA/00000009.jpg
(1444) [SceneB]  frame 18  SceneB/00000018.jpg
```

Netowrk events indicate arrival time, IP and port of the source, and a message string. Typical network events are as follows:

```
(304) [192.168.1.101:8888]  MSG Unity timestamp 53284 ms
(1303) [192.168.1.101:8888]  MSG Unity timestamp 54283 ms
(2303) [192.168.1.101:8888]  MSG Unity timestamp 55283 ms
(2795) [192.168.1.2:14000]  MSG gpio A0 O: 01
(2815) [192.168.1.2:14000]  MSG gpio A0 O: 00
(3303) [192.168.1.101:8888]  MSG Unity timestamp 56283 ms
(4303) [192.168.1.101:8888]  MSG Unity timestamp 57283 ms
```

Local GUI events indicate event time, the fact that the event was local, and a command, annotation, or marker string. Typical local events are as follows:

```
(23197) [local]  CMD monitor SceneA
(39396) [local]  Marker: Game
(48249) [local]  CMD monitor Game
(76264) [local]  CMD monitor SceneA
(104119) [local]  CMD monitor Monitor
(491174) [local]  User annotation: "task started"
```

Chapter 5

Game Machine Handshaking

The NeuroCam system queries machines on the local network to find content providers. For the prototype system, the only network content provider is the game machine.

The game machine should listen for UDP packets on port 8888. These will be any of the following messages in plain text:

- "`looking for sources reply to port NNNN`"
- "`talk to me on port NNNN`"
- "`stop talking`"

The game machine may send any of the following responses:

- "`stream source at http://URL label XXXX`"
- "`message source at HOST:PORT label XXXX`"
- "`MSG (message text goes here)`"

The game machine will typically offer one video stream (the game video) and one message source (which sends plain text timestamps for synchronization of game events and NeuroCam data).

The video URL will generally be of the form "`http://(host IP):(port)/(file).mjpeg`". Any valid URL should work, as long as the file has the suffix "`mjpeg`" and as long as the host is given by IP address rather than hostname. This video stream will be fetched by the NeuroCam and treated like any other camera feed.

Message sources must use IP addresses (not hostnames) as the host identifier. These will be sent "`talk to me`" and "`stop talking`" messages, and when active are expected to send plain text UDP messages to the NeuroCam machine. Messages are expected to begin with "`MSG `", with message content transcribed to the NeuroCam session log file. Message source and NeuroCam timestamp information are also recorded in the log.

Multiple machines may respond to the broadcast query, and the same machine may respond multiple times to one query. As long as the message and video stream sources indicated by the responses are unique, they will all be available to the NeuroCam system.

Chapter 6

Router

The NeuroCam computer, the game machine, and user machines talk to each other via a wireless router. Any modern router should be suitable.

All routers have different configuration interfaces, so consult the router's manual for information on performing any given step.

The following configuration steps must be performed:

- **Reset to factory defaults if necessary.**

  This can be done by holding down a small button on the rear or underside of the router. **Do not do this after the router is configured** – it will undo all configuration, and it will all have to be done again.

- **Update router firmware if necessary.**

  This is done by downloading the new router firmware to a USB stick and following the directions in the router's manual.

- **Log into the router.**

  This is done by connecting a notebook or desktop computer to one of the router's LAN ports, and pointing a web browser to the IP address written on the bottom of the router. This is usually "`http://192.168.1.1`".

- **Set the administrator password.**

  The default login and password are written on a sticker on the router. These are usually both set to "`admin`". NeuroCam systems are configured to use the login "`admin`" and the password "`administrator`".

  This is easily guessed, and so should be changed when the system is installed per Chapter 2.

- **Set the wireless SSID and password.**

  The SSID is the name of the wireless network provided by the router. For NeuroCam machines, this should have the form "`neurocam-NN`", for some unique number "`NN`". Routers that offer 2.4 GHz and 5 GHz networks separately should use the names "`neurocam-NN-2.4GHz`" and "`neurocam-NN-5GHz`" for those networks.

The wireless password should be set to "`neurocam`" for new NeuroCam systems. **This is easily guessed, and so should be changed when the system is installed per Chapter 2.**

NOTE: Routers that offer 2.4 GHz and 5 GHz networks may need the password to be set for each separately. Make sure both are set!

- **Enable and configure MAC address filtering.**

  To provide additional security, the router should be configured to use whitelist–based MAC address filtering ("default deny" or "default to block" policy). This will only allow machines to connect if their network cards belong to a list supplied during router configuration.

  The MAC address of the machine being used to configure the router should be added to the list before enabling filtering. If known, the MAC addresses for other user machines may be added as well.

  The MAC address of the NeuroCam machine and of the game machine will often also have to be added. This depends on exactly how the router implements filtering (some filter inbound wireless connections, others filter both wireless and LAN connections). When in doubt, add the NeuroCam and game machines to the whitelist.

  To find the MAC address of a Linux machine, type "`ifconfig`" (or "`/sbin/ifconfig`") at a command prompt and look for the "`HWaddr`" field.

  NOTE: Routers that offer 2.4 GHz and 5 GHz networks need MAC address filtering set up separately, and saved, for each. Make sure it's set up for both!

- **Add static IP assignments.**

  The router normally dynamically assigns IP addresses to clients (including the NeuroCam machine and the game machine).

  Known machines can be assigned fixed IP addresses. At minimum the NeuroCam machine should be given a fixed IP address. These usually take the form "`192.168.1.NN`", where NN is the number of the NeuroCam computer.

  NOTE: Some routers use a number other than "`1`" in "`192.168.1.NN`". Where possible, the DHCP configuration should be changed to make this "`1`", for consistency between installations.

  NOTE: The router may have a "device name". This should be set to "`neurocam-NN-gw`" (where "`NN`" is the same number from the SSID, described above). The "`-gw`" suffix guarantees that this will not conflict with any NeuroCam computer name.

- **Cover the WAN port (internet port).**

  The NeuroCam system should never be connected to the internet, as it is not hardened against attack. To avoid confusion between the WAN (internet) port and the LAN (local network) ports, place a sticker or piece of tape over the WAN port.

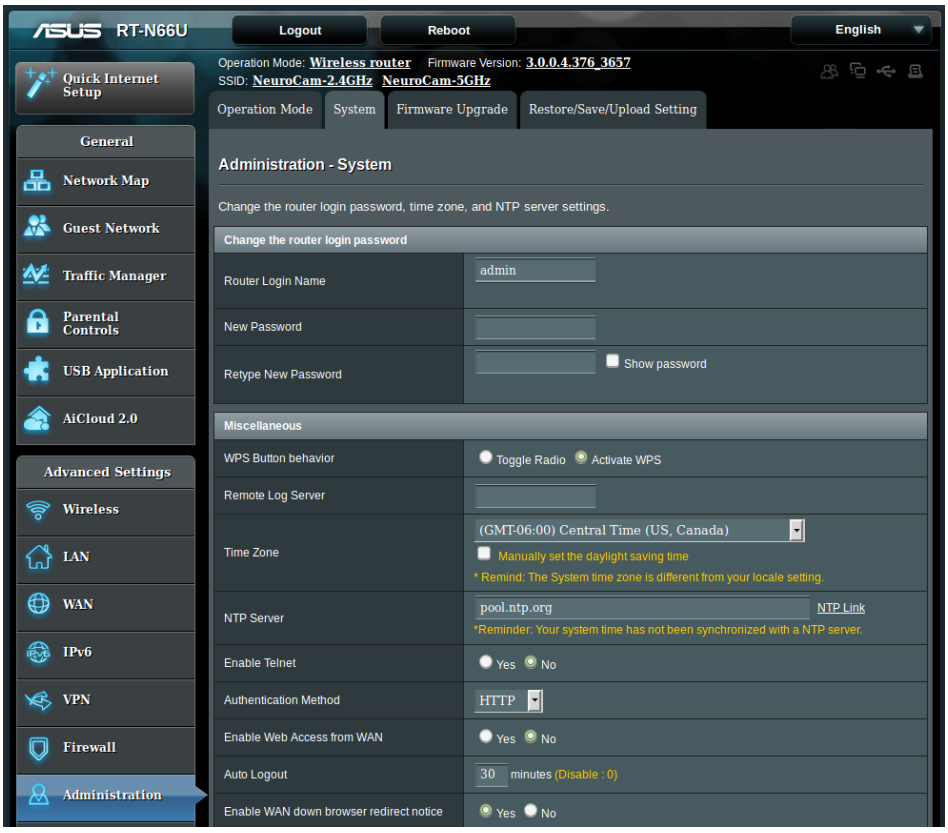
The preferred router for the NeuroCam prototype was as follows:

Qty	Description	Manuf. p/n	NewEgg SKU
1	wireless router (a/b/g/n)	Asus RT-N66U	N82E16833320091

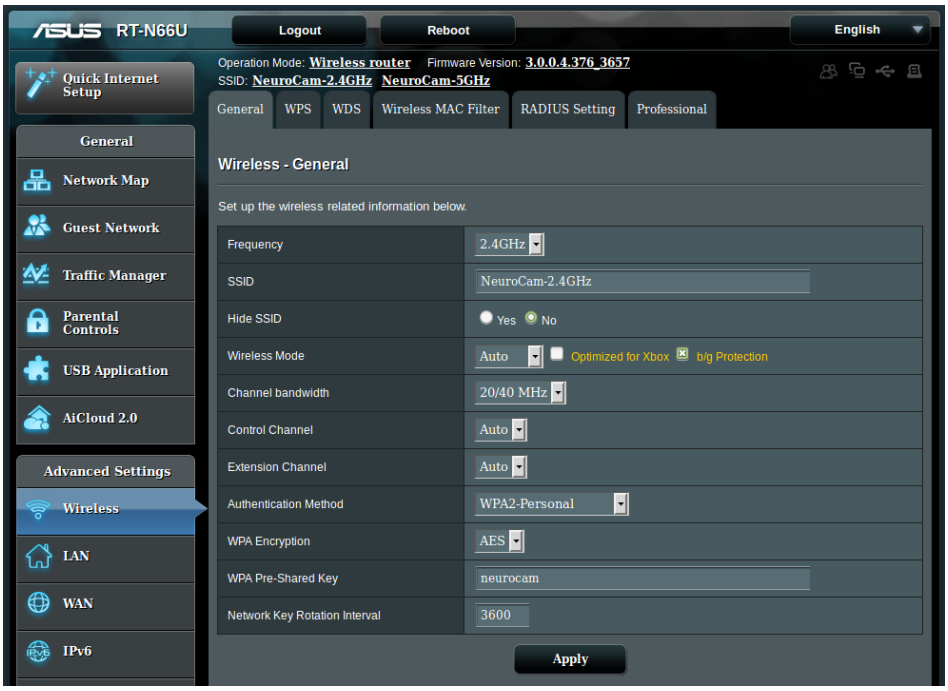
6.1 Asus RT-N66U Screenshots

This is the Asus RT-N66U router (with tape over the WAN port):

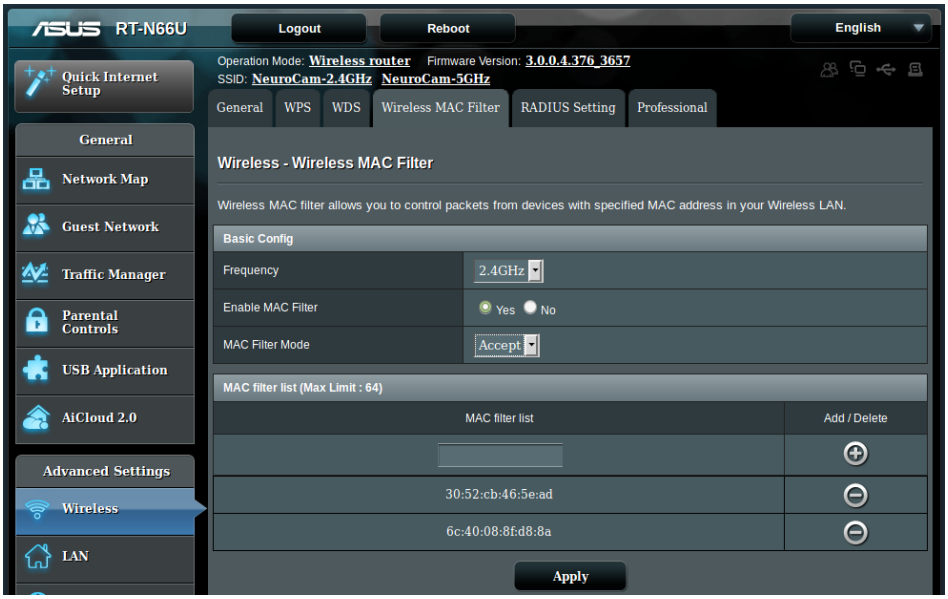
Changing the administrator login/password (top section):



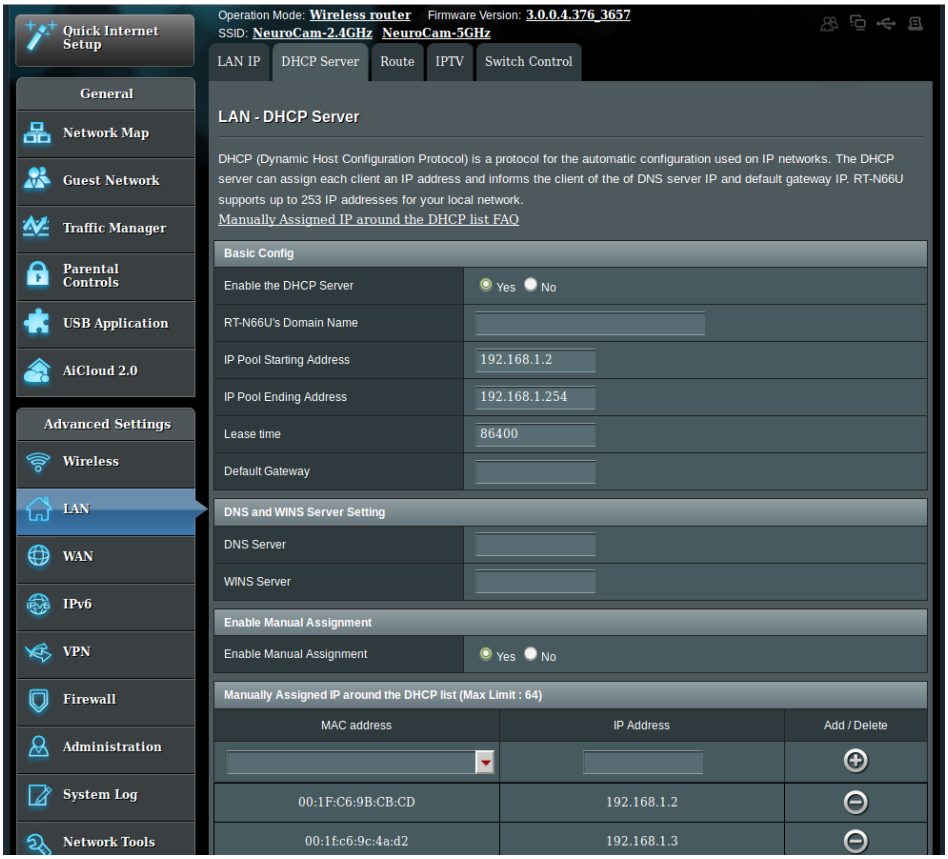
Setting the wireless network name ("SSID") and password ("pre-shared key"):



Changing the MAC filter to whitelist mode ("accept the specified addresses"), and adding addresses:



Assigning static IP addresses to specific machines:



6.2 Installing OpenWrt

FIXME: This hasn't been implemented, so no documentation for it.

The idea is to provide scripts that automatically configure and compile the "`OpenWrt`*" open–source firmware. This lets us lock down any features we don't want active, force an appropriate filtering mode, and disable the web interface (which is one of the main security holes).*

Implementing this is deferred, as it will be time–consuming.