

Technical Manual

**COGNIMEM**<sup>®</sup>  
Technologies, Inc.

# HARDWARE MANUAL

CogniStix v1.0

Preliminary

CogniMem Technologies Inc

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## Definitions and Terminology

### ApplImage

The machine code that controls the remaining logic for operating CogniStix during “normal” operations. These functions include parsing commands received from the host, interfacing with the CM1K, and returning the results back to the host. The ApplImage is located in Flash Bank A.

### BootImage

The machine code that controls the initial start-up process and controls whether CogniStix is operated in DfuMode or AppMode. The BootImage is located at the base of Flash Bank A.

### CM1K

The neural network ASIC (chip) at the heart of CogniMem Technology.

### DFU

Device field upgradable, supports the ability to perform firmware upgrades by the end-user over USB.

### DfulImage

The machine code that manages the ApplImage update (flashing) process. The DfulImage is located at the base address of Flash Bank B.

### Flash

The act of uploading a new Image file to the micro-controller.

### Image

The compiled binary file (in Thumb format) that contains the machine code instructions.

### Knowledge Base

This is the resulting network content that is generated following a “Training Session”. It can be “exported from” and “imported into” CogniStix to save or restore a previous training session.

### Learn

This is the legacy terminology for introducing a vector to the CM1K and associating it with a CategoryId. This terminology has been replaced by the term “TrainPattern”.

### MatchPattern

The current terminology for introducing a vector to the CM1K for the purpose of finding the closest match; this replaces the term “Recognize”.

### Network

This is a collection of inter-connected neurons on one or more chips operating as a single unit.

### Neuron

This is the smallest autonomous unit of the CM1K network. It contains 256 bytes of volatile SRAM, a distance calculator/accumulator, and RBF influence field.

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## OpenCV

A popular open-source library of programming functions mainly aimed at real-time computer vision.

## Operating Mode

The purpose/operating behavior of the device based on the Image currently executing in the micro-controller

## Platform Object

This is the main object within the CogniSoft API. It is responsible for all communications with CogniMem Technology hardware.

## Recognize

This is the legacy terminology for introducing a vector to the CM1K for the purpose of finding the closest match. This terminology has been replaced by the term “MatchPattern”.

## ROI

Region-of-Interest is the smaller region/area of an image that your application is focused on processing.

## ROS

Region-of-Search is the larger region/area of an image that your application plans to search.

## Step (size)

The step size is the distance between adjacent ROIs within an ROS. The smaller this dimension is, the more ROIs will be generated within the ROS.

## TrainPattern

The current terminology meaning to introduce (broadcast) a series of bytes to the CM1K associated with a CategoryId; this replaces the term “Learn”.

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## Introduction

CogniStix™ is a compact, low cost USB-powered hardware neural network device. It is the ideal module for simplifying the evaluation of the capabilities and performance of the [CM1K](#) for performing machine learning and pattern matching using the non-linear classifiers RBF and KNN.

CogniStix can also be used by system integrators for rapid prototyping. This hardware accelerator can enhance new and/or existing product performance, and/or simplify application development, reducing time-to-market.

Among the many application tasks that can exploit the capabilities of CogniStix include (but are not limited to):

- object detection / tracking
- data clustering / mining
- real-time signal processing
- image processing and recognition
- audio processing and recognition
- supervised and / or unsupervised learning

The module features one CM1K chip interfaced to an ARM microcontroller Cortex-M3 via the parallel bus for accelerated recognition time<sup>1</sup>.

## Features

- USB Plug and Play capability
- USB Powered
- Complete integration of the CM1K with a 32bit Arm Cortex-M3
- Integrated Flash 1MB
- Interface to Windows 7 & Windows 8 Operating Systems<sup>2</sup>
- Reprogrammable thru USB and JTAG<sup>3</sup>
- Demonstrations with Sample Code

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<sup>1</sup> I2C interface will be available in Q1 2015 with the complete reference design.

<sup>2</sup> Support for additional software platforms available. Contact factory at [CogniStix.support@cognimem.com](mailto:CogniStix.support@cognimem.com)

<sup>3</sup> Current device allows local non-volatile storage of neuron contents- later versions will allow user re-programmability of code.

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## Drivers

### Windows 7.0 and Windows 8.x

The device should be recognized automatically by the operating system and no further steps should be necessary.

### Linux

Under development, check the CogniMem web site periodically for details and a release date.

### Mac OS X

Under development, check the CogniMem web site periodically for details and a release date.

### Embedded Devices

Arduino, Raspberry Pi, Beagle Bone, etc...

Under development, check the CogniMem web site periodically for details and a release date.

## Board Specifications

### General

- ARM Cortex-M3 processor, running at CPU frequencies of 180 MHz.
- JTAG and Serial Wire Debug.<sup>4</sup>
- 1 MB on-chip dual bank flash memory with flash accelerator.<sup>5</sup>
- 16 kB on-chip EEPROM data memory.<sup>6</sup>
- 136 kB SRAM<sup>7</sup>
- 64 kB ROM containing boot code and on-chip software drivers.
- High-speed USB 2.0 Host/Device/OTG interface with DMA support and on-chip high-speed PHY
- 1024 silicon neurons working in parallel
- Classify vectors of up to 256 bytes, Up to 32K categories
- Radial Basis Function (Restricted Coulomb Energy machine learning) and K-Nearest Neighbor non-linear classifiers
- Amber/Green LED status and error code indicators

### Power

5.0V DC (USB powered)

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<sup>4</sup> Will be available in Q1 2015 with the complete reference design.

<sup>5</sup> User Flash Code execution for future software release reference design

<sup>6</sup> Available in a future software release

<sup>7</sup> Available in a future software release

Typical: 300 mA

## Temperature

This product is intended to work in a commercial environment 0°C - 80°C. No additional characterization has been performed to determine performance at extreme temperatures.

## USB Interface

USB 2.0 OTG, Type A High Speed.

## RoHS

This product conforms to all RoHS compliance standards.

## System Overview

### Introduction

CogniStix provides the host S/W environment, tools and hardware resources for developing machine learning applications by utilizing a 1024 hardware trainable neural network and an ARM based microcontroller for future preprocessing.

The initial release gives the user access to three demonstrations: 1) CogniCar- where the user can train a “CogniCar” to navigate a randomly drawn track on the screen, 2)CogniCoaster- object recognition from a provided coaster where the user can use their pc camera to recognize an object on the provided coaster and 3) CogniScript<sup>8</sup> - Digit Recognition where the user can draw digits 0-9 on the screen and have them recognized by the CogniStix.

Sample source code and the API are contained in this kit to allow the user to develop further applications.

### Block Diagram

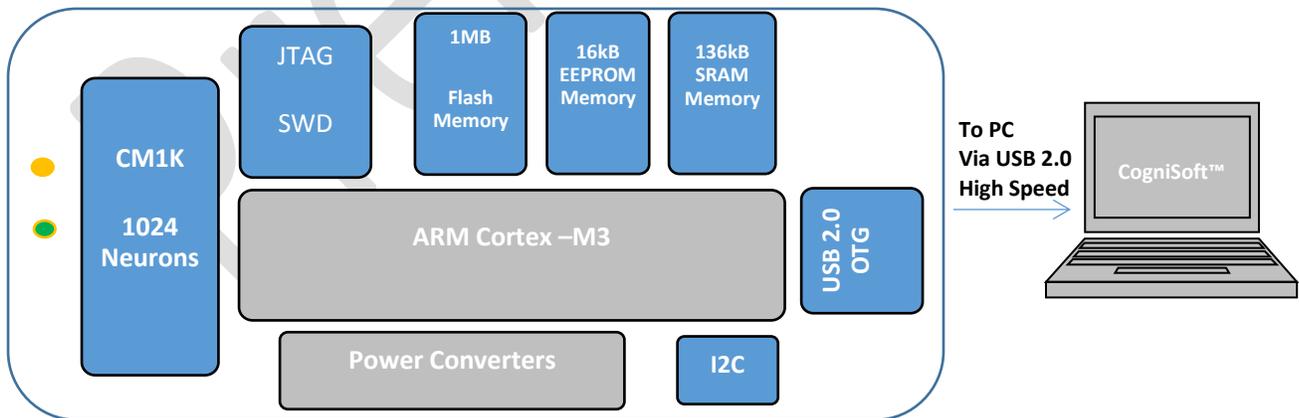


Figure 1

<sup>8</sup> Available in mid September 2014

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## Operating Modes

The operating system of CogniStix is made up of three distinct **Images**, *BootImage*, *DfuImage*, and *AppImage*. Each of these Images is responsible for controlling CogniStix in one of three different modes, *BootMode*, *DfuMode*, *AppMode* respectively.

## Operating Mode Details

### BootMode

This mode is responsible for initializing USB block and accepting commands from the host PC. Once the device has completed the start-up process the host has 3000 milliseconds to send a “dfu” command. If the “dfu” command is received (with the correct passcode) control is then passed to DfuImage, consequently the device will begin operating in DfuMode. If DFU timeout expires, control is then passed to the AppImage and the device will begin operating in AppMode.

### DfuMode

This mode is responsible for controlling the firmware upgrade process. The only Image that can be upgraded is the AppImage, the BootImage and the DfuImage cannot be upgraded; their functionality is frozen at the time the device is first flashed at the factory. The upgrade process (for AppImage) is outlined in diagram 1.

### AppMode

This mode is responsible for controlling the normal operation of the device.

## Interfaces

CogniStix comes equipped with a USB 2.0 Type A connector. It is designed to be operated in slave/device mode and needs to be connected to a USB bus that has a device that is operating in host mode (e.g. PC).

## LED Indicator Details

There are two LED indicators (AMBER and GREEN) on the edge of the board that communicate the health and status of the device. Below is a list of the possible patterns and their meanings.

Green	Amber	Mode	Health	Meaning
Alternating	Alternating	Boot	Good	Normal operation
Heartbeat Indicator	Activity Indicator	App	Good	Normal operation
Activity Indicator	Heartbeat Indicator	Dfu	Good	Normal operation
Off	Off	n/a	Bad	Device failed to start
On	ON	n/a	Bad	Device not responding

Table 1

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## Amber LED

This indicator is known as the “system busy” indicator.

Under normal conditions this LED will blink while the device is processing (reading and/or writing) data, otherwise this LED will not illuminate.

Under failure conditions (hardware or software) this LED will blink rapidly, opposite to the Green LED.

## Green LED

This indicator is known as the “heart beat” indicator during APP mode.

Under normal operating conditions it will maintain a slow, steady blink.

Under failure conditions (hardware or software) this LED will blink rapidly, opposite to the Amber LED.

## Firmware Upgrade Details

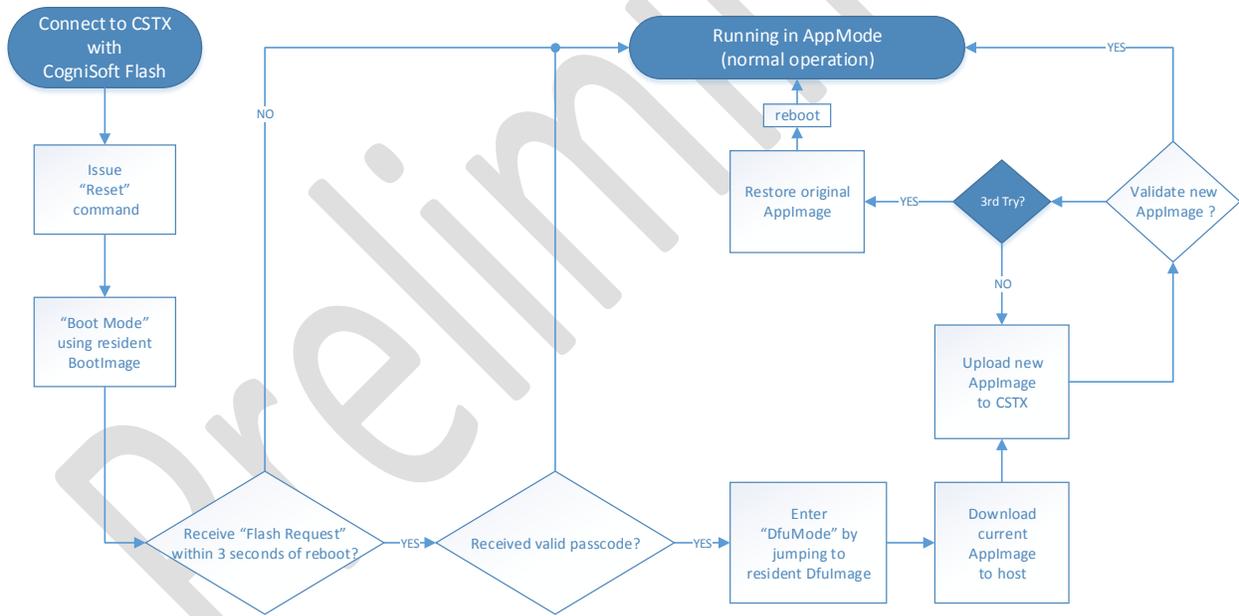


Diagram 1

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## Memory Allocation Details

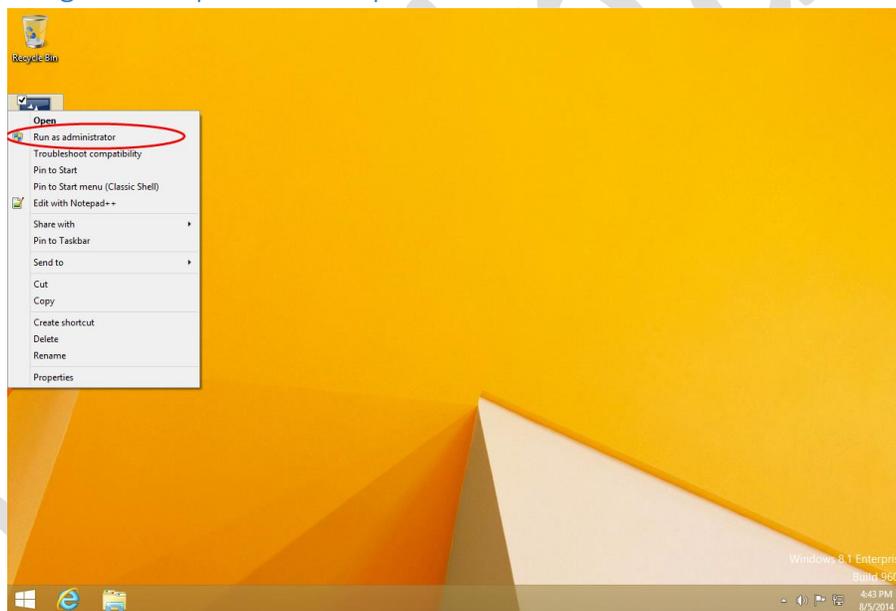
### CogniStix File-system

CogniStix has two banks of Flash (non-volatile) memory. The application developer has the option of storing data on the host PC's file-system or the CogniStix file-system; the decision will basically come down to how "portable" the developer wants the application data/CogniMem knowledgebase files to be.

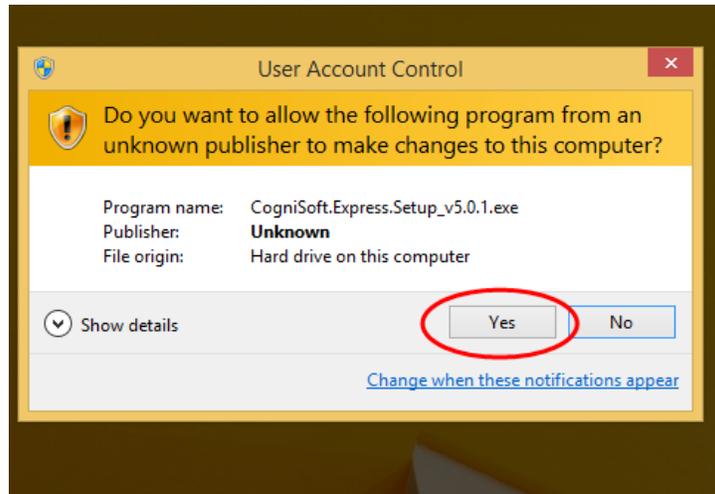
The CogniStix file-system consists of 14 - 64kB files. Each file is then divided into 128 – 512 byte sectors (the smallest unit). Due to the nature of Flash technology the smallest unit that can be written is a page and the smallest unit that can be erased is a sector. Once a page/sector has been written it must first be erased before it can be written or updated.

## Programming and Startup

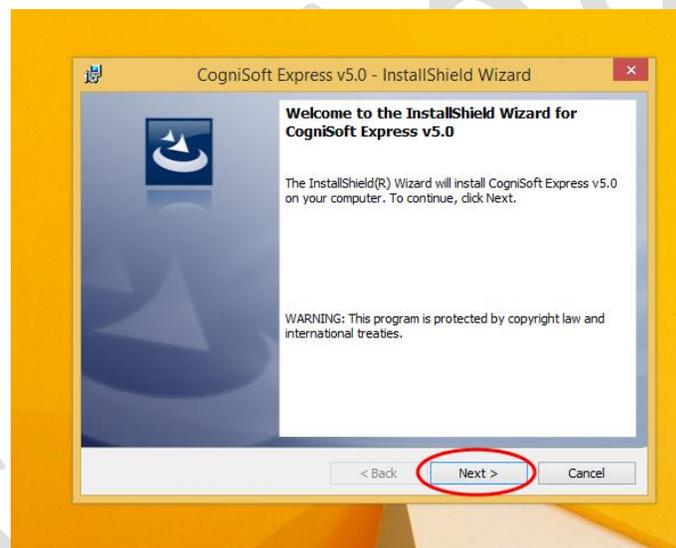
### Installing the CogniSoft Express Development Kit



Upon installing the CogniSoft Express SDK, click run as administrator



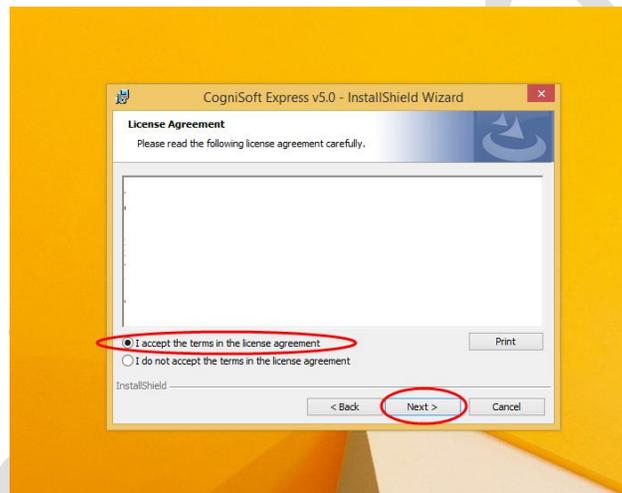
On subsequent screens, click “yes” to allow changes to the computer



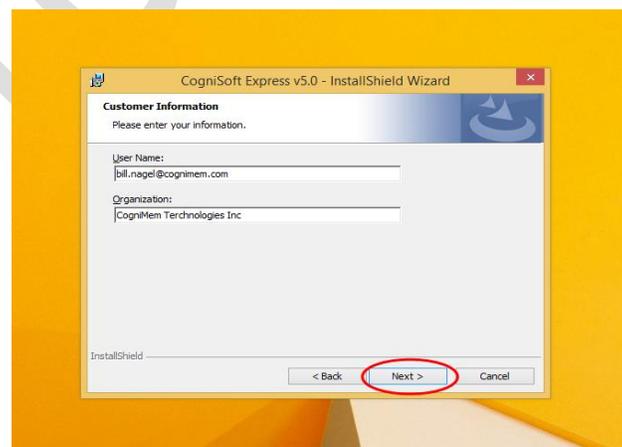
Then “next” to begin installation of wizard



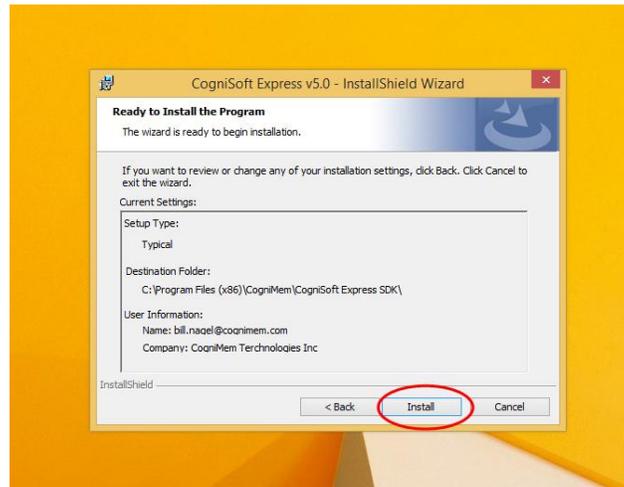
Wait for wizard to finish installing



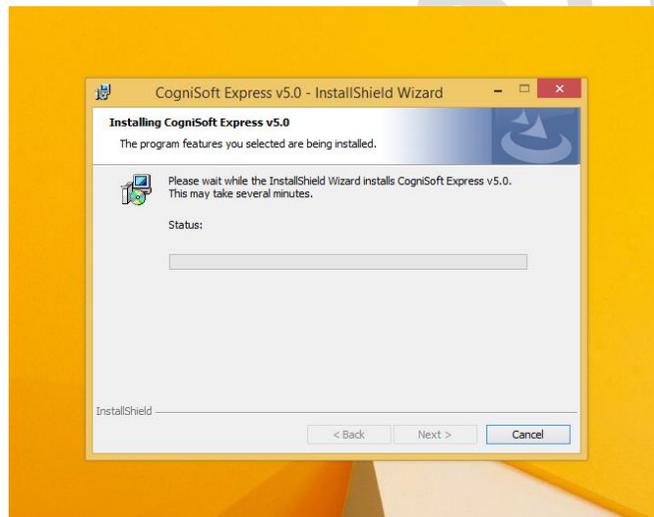
Check acceptance of the license agreement and then click "Next"



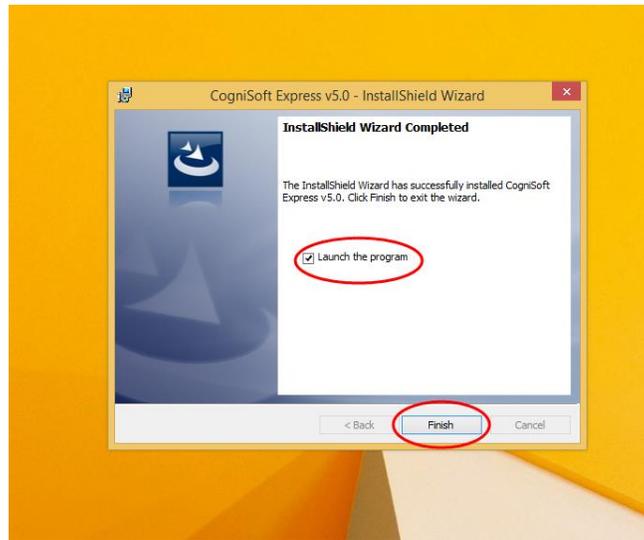
After submitting username and organization, click "Next"



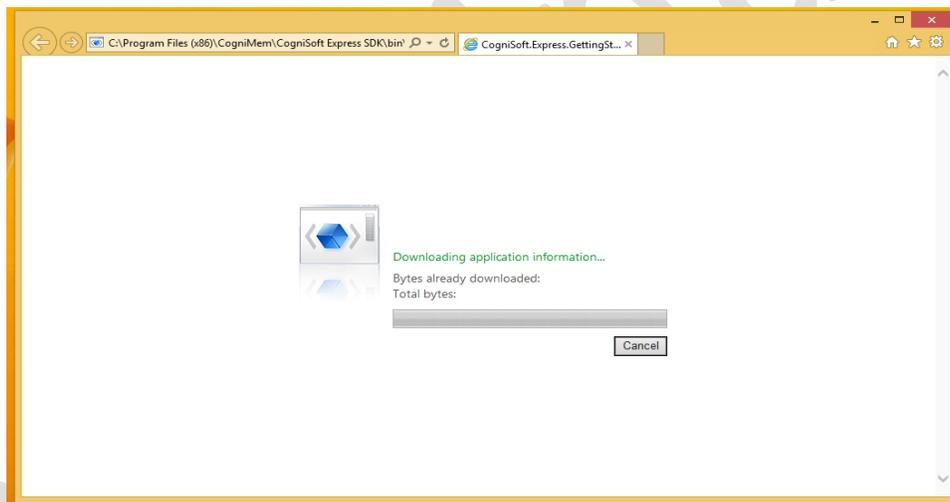
Click “Install” to begin installation



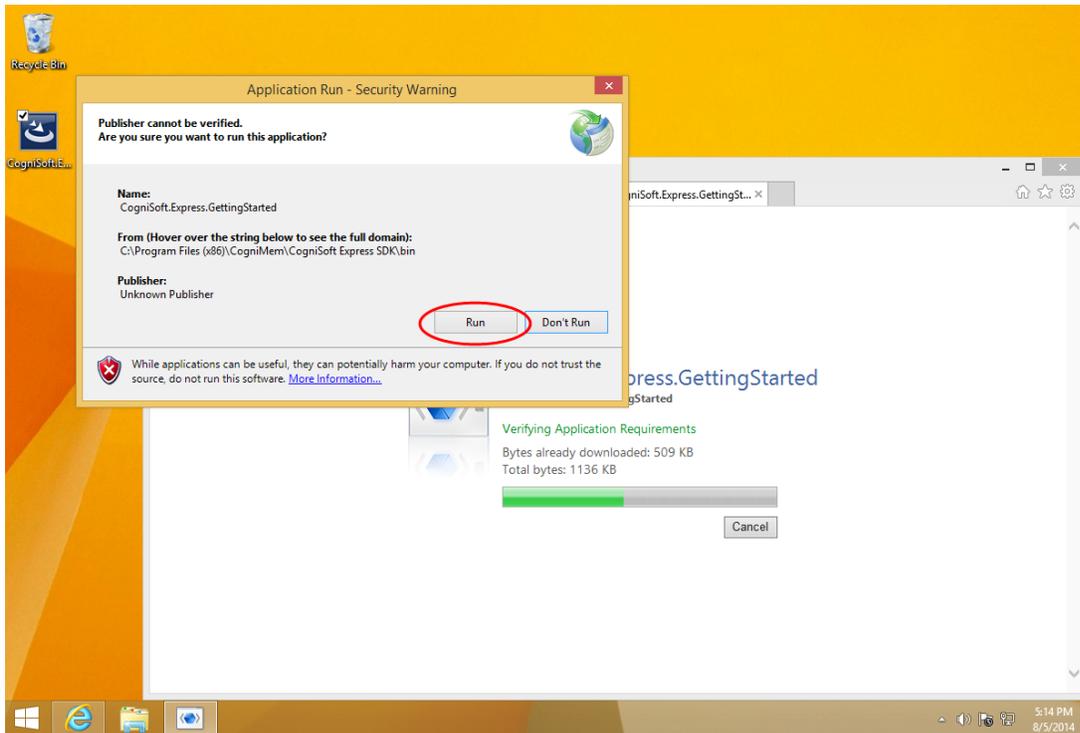
Wait for the installation to complete and click “Next”



Check “Launch the program” and click “Finish”



Wait for application download



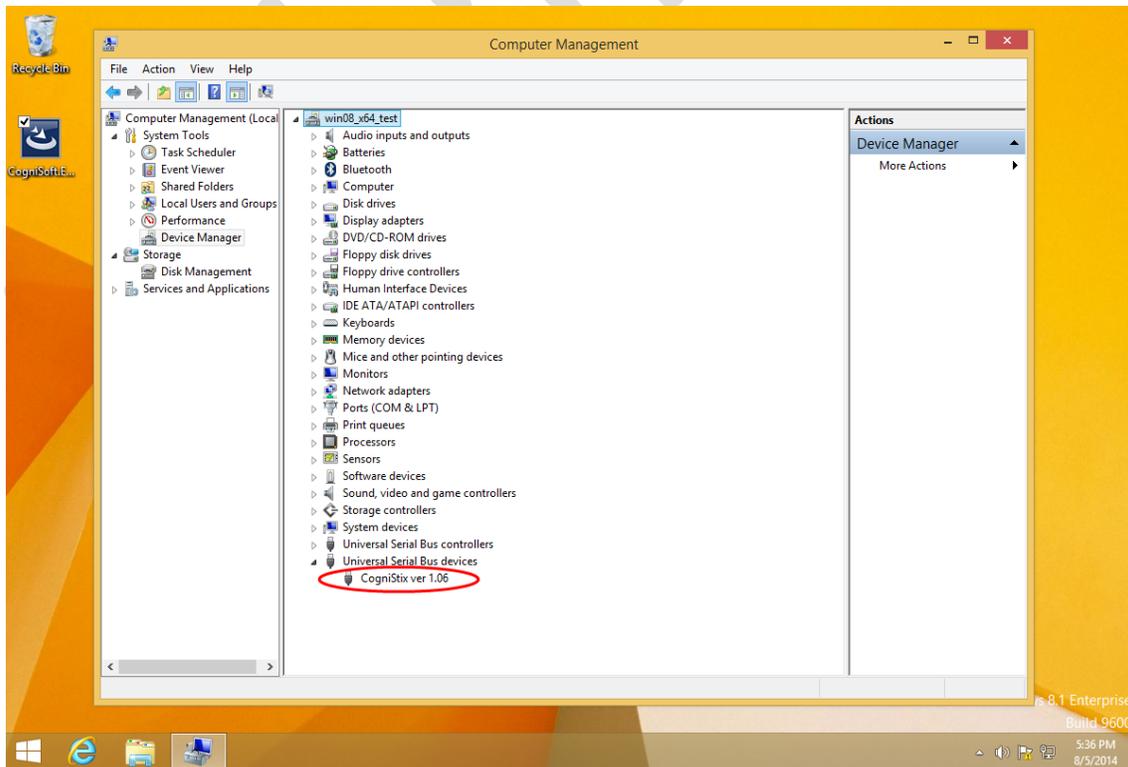
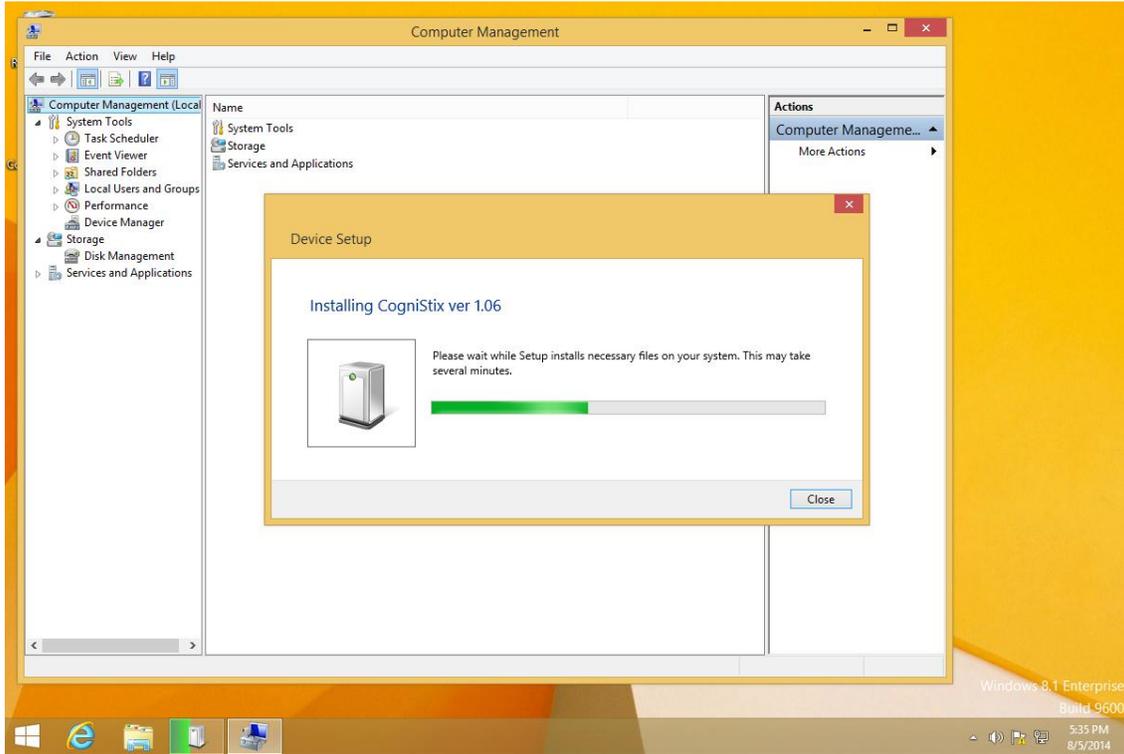
Select run

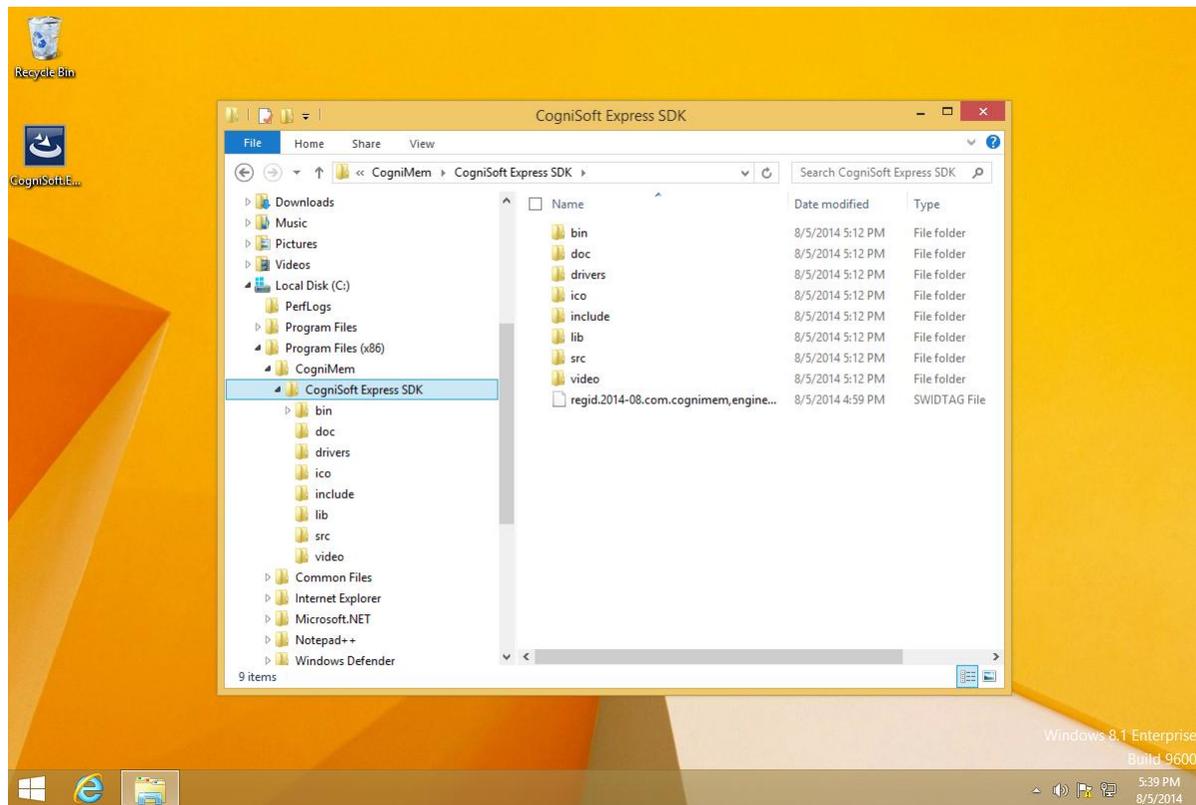


Select from the menu the desired operation

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## CogniSoft Driver Installation Confirmation





## Running the Demonstration Applications

### CogniCar

#### Getting Started

This demo provides a simple introduction to Neural Networks and the training implementation for the network using the CogniMem CM1K and the CogniSoft Libraries.

In addition, the demonstration will use your computer's display, keyboard/mouse and the CogniStix Development USB Stick. The CogniCar will not operate unless the CogniStix is connected to the host PC.

When you launch the demonstration, the CogniCar will appear in the screen on an oval track. The right side of the screen has all of the training tools to teach the CogniCar how to drive around the track. The "RED" box in front of the CogniCar is the area used to capture patterns to train the CogniCar to maneuver around the track.

*Step 1:* Push the "Turn Right" button 2 or 3 times so that the CogniCar has mostly a track view in the RED box, then push train. A neuron is committed, so when the CogniCar sees that pattern it knows to go right to keep on the track. Now press "Start Driving". If the CogniCar stops that means it has never seen that pattern so it doesn't know what to do. It is time to train a neuron; either use the "Turn Right" or

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“Turn Left “ button to put the CogniCar back on the track, then push “Train” and another neuron is committed. Continue the sequence of putting the CogniCar on the track and training neurons until the CogniCar can navigate the track without stopping.

*You are finished when the CogniCar is zooming around the track!*

*Step 2:* You can draw a new track and see if the training you have completed and stored in the neurons is enough to navigate a new track or you may have to add some additional training. Use the pencil and eraser at the top of the page to erase the current track and then use your mouse to draw a new track. Next push the pencil and your CogniCar will reappear. Now you can push the “Start Driving” button and see if additional training is needed (repeat Step 1).

*You are finished when the CogniCar is zooming around the new track!*

*Step 3:* You can view all the knowledge stored in the neurons by pressing the graph icon at the top of the page.

## How It Works

When working with image data, it is important to perform some filtering on the image in order to make it easier to classify correctly.

In this demo, we are performing standard block pattern matching of the image taken from the front of the CogniCar (designated by the red box). The ROI is 32x32 pixels sub sampled to 16 x 16 allowing it to fit into a 256Byte vector. The image in the red box does not have to be an exact match to the stored neuron because the CM1K is capable of performing both exact and fuzzy matching. Therefore it is possible to perform a track navigation in as little as 3 neurons.

## Next Steps

Try the other demonstration assets.

## CogniCoaster

### Getting Started

This demo provides a simple introduction to visual object recognition using the CogniMem CM1K and OpenCV libraries. It uses your computer's webcam, the CogniStix development board, and the shapes on the included coaster as objects to recognize.

When you launch the demo, you should see a window displaying the feed from your computer's webcam. A small red box in the center represents the Region of Interest or "ROI". We'll use this demo to train the CM1K to recognize a shape on the CogniCoaster.

#### *Step 1: Train a shape.*

Choose one of the shapes on the CogniCoaster to train the chip on. Position the shape within the red box, then press the space bar to pause the video feed. If the shape is positioned well within the red box, then press the "1-9" number key to have the chip learn up to 9 different shapes. The webcam feed should resume, and the ROI box should turn green when the learned shape is positioned within it.

#### *Step 2: Train counter-examples.*

You'll notice that the ROI also turns green for other patterns besides the shape it was trained on. We need to train the chip on some counter-examples so that it only recognizes the shape chosen on the CogniCoaster. When the ROI box turns green on a pattern that is not the shape, press space bar to pause the video then press "0" to forget this other pattern (that is, train it as a counter-example). You may have to do this 3 or 4 times before the chip stops recognizing other patterns.

You're finished when the CogniStix recognizes the shape on the coaster without generating false positives on other objects.

### How It Works

When working with image data, it is important to perform some filtering on the image in order to make it easier to classify correctly.

In this demo, we are calculating the gradient vectors for the pixels within the ROI, and using the gradient magnitudes as the features for the chip to learn and recognize. These gradient magnitudes indicate the

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presence of edges in the ROI. Higher contrast edges will produce a larger gradient magnitude. The gradient vectors are calculated from a gray-scale version of the image.

The CM1K operates on input vector lengths of 256-bytes, so we also need to resize the ROI down to 16 x 16 pixels. This is done prior to calculating the gradient vectors.

After converting to grayscale, resizing to 16x16 pixels, and calculating the gradient vectors, the resulting vector of 256 values is shown to the chip for classification.

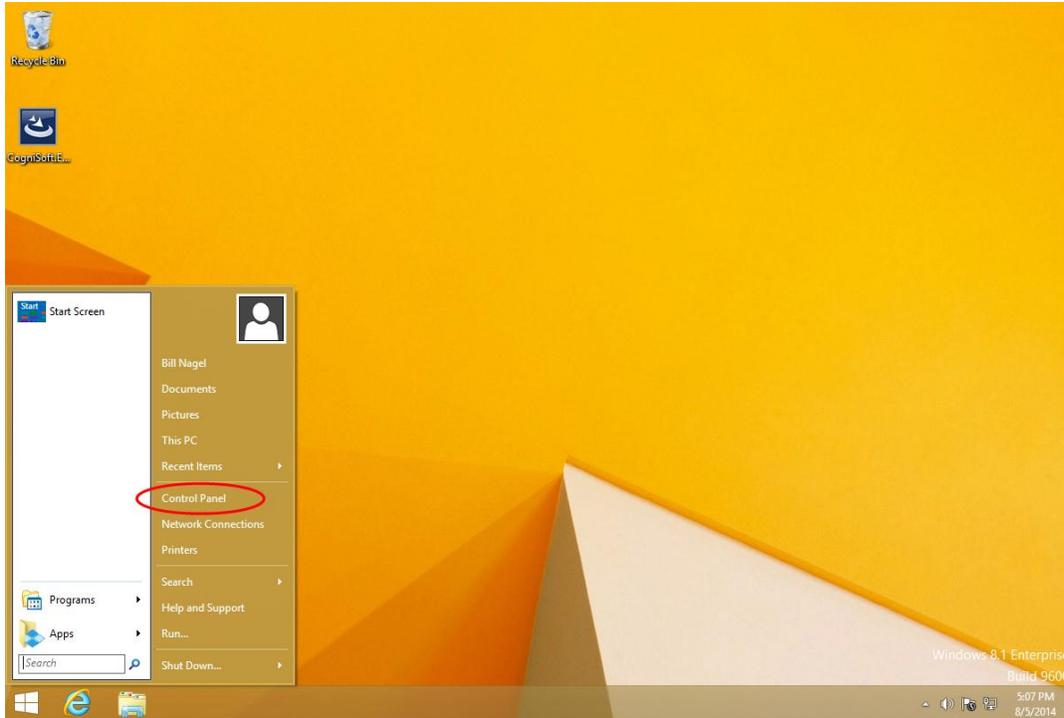
## Next Steps

This demo also includes the C++ source code as a Visual Studio project. You can modify this demo to recognize multiple objects (train them as different categories and use different colors to represent the different categories), or experiment with other filtering techniques.

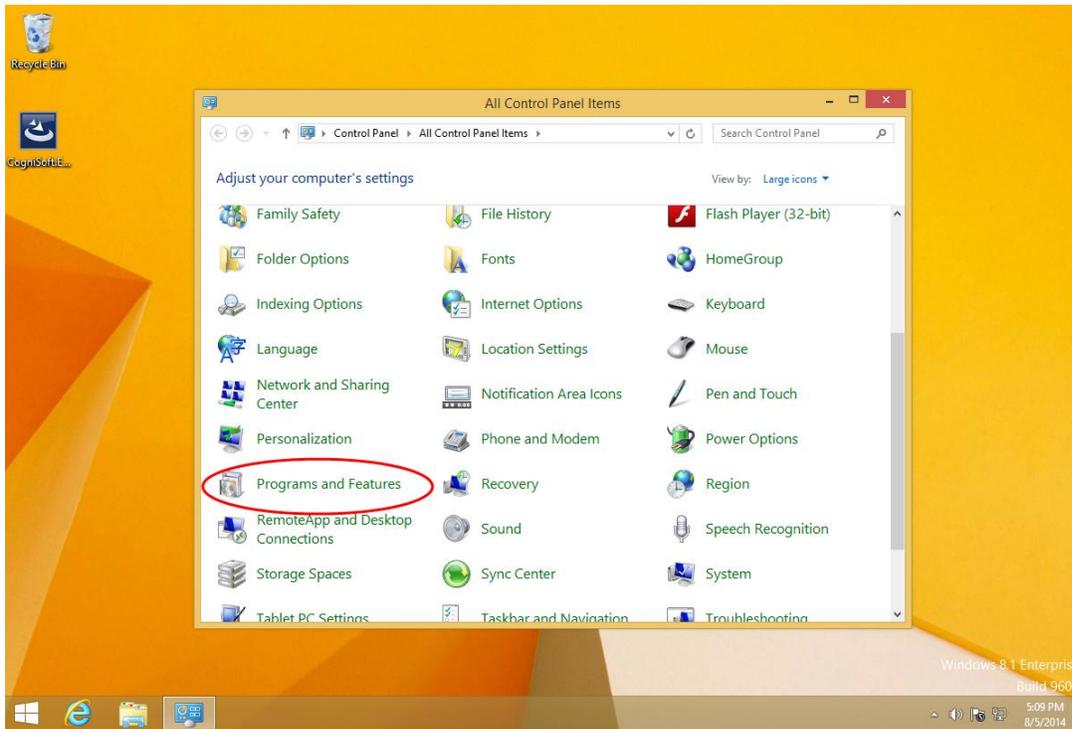
## CogniScript

This demonstration will be available in mid September 2014.

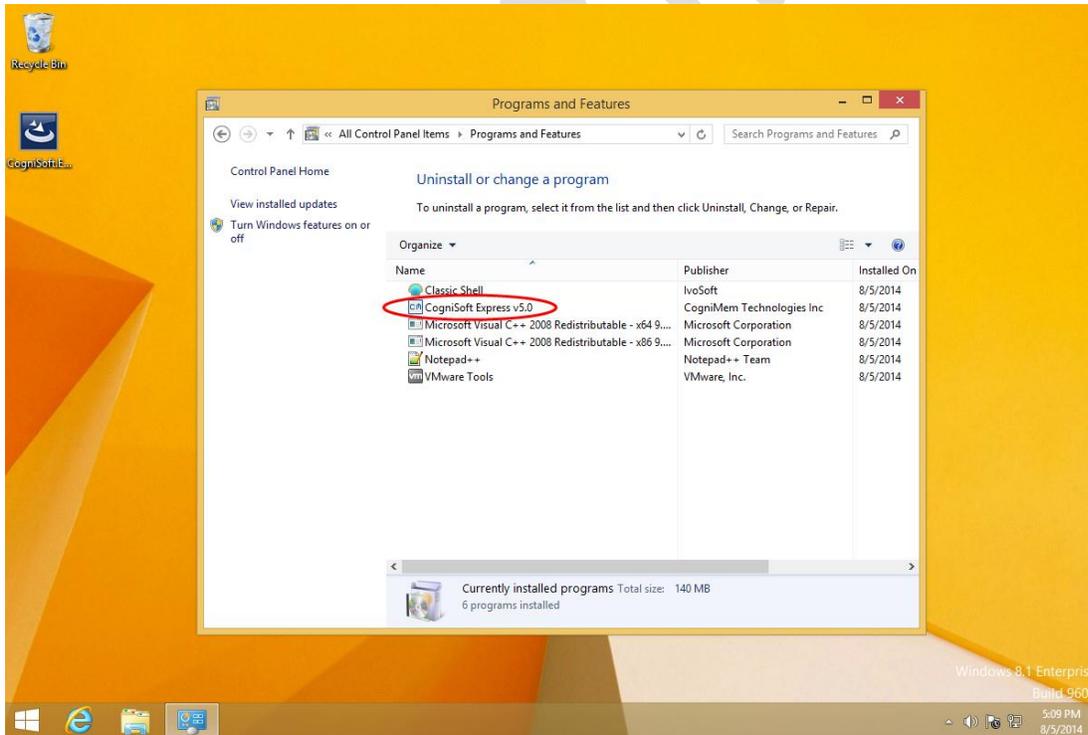
## Uninstalling the CogniSoft Express Development Kit



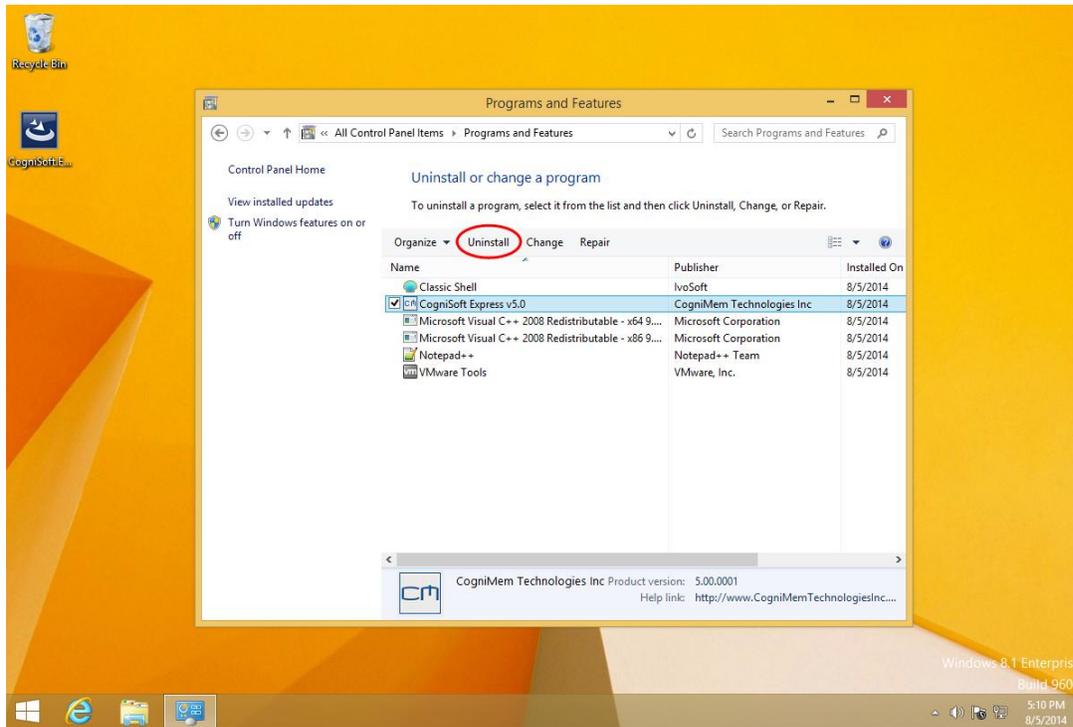
To uninstall the program, go to the control panel tab



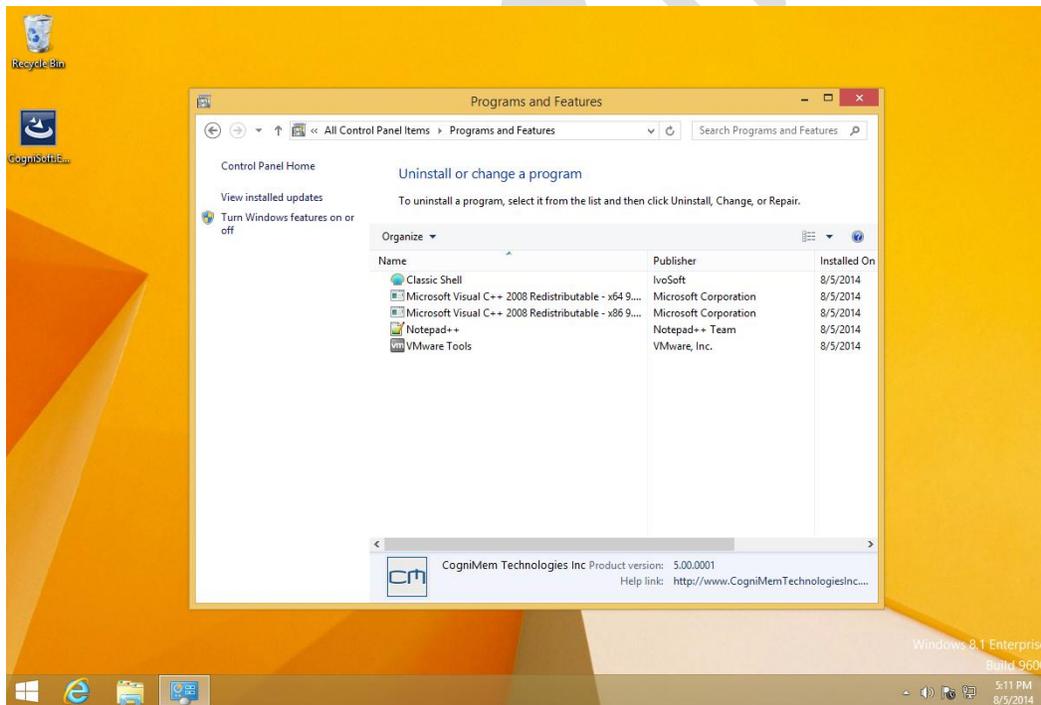
Select Programs and Features in the control panel

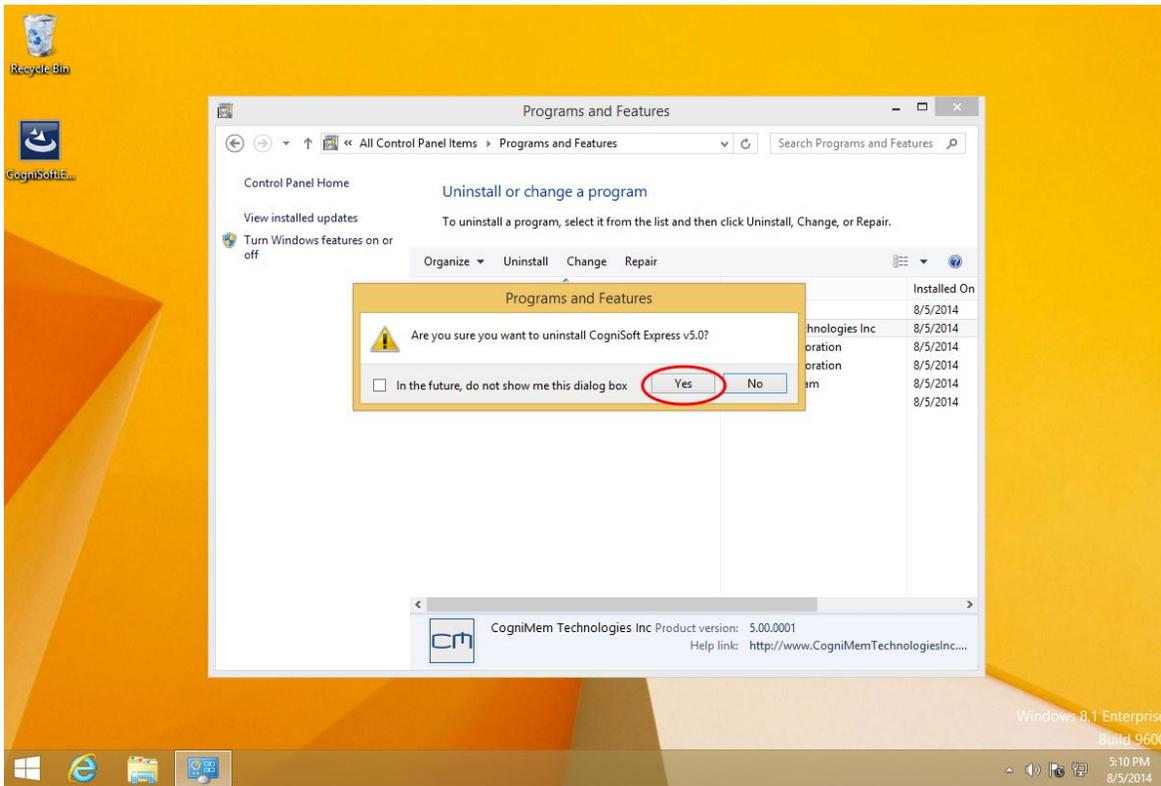


Select the CogniSoft Express V.xx



Click uninstall





Select "Yes" to verify action

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## Schematics

Schematics will be available in the reference design material to be released in 2015.

Please contact [CogniStix.support@cognimem.com](mailto:CogniStix.support@cognimem.com) for additional information.

## Board Layout

Gerber Files for board layout will be available in the reference design material to be released in 2015.

Please contact [CogniStix.support@cognimem.com](mailto:CogniStix.support@cognimem.com) for additional information.

## Bill of Materials

Bill of materials will be available in the reference design material to be released in 2015.

Please contact [CogniStix.support@cognimem.com](mailto:CogniStix.support@cognimem.com) for additional information.

## External References

CogniMem CM1K Hardware User's Manual

[http://www.cognimem.com/docs/Technical-Manuals/TM\\_CM1K\\_Hardware\\_Manual.pdf](http://www.cognimem.com/docs/Technical-Manuals/TM_CM1K_Hardware_Manual.pdf)

CogniStix Datasheet

[http://www.cognimem.com/docs/Datasheet/DS\\_CTX.pdf](http://www.cognimem.com/docs/Datasheet/DS_CTX.pdf)

CogniMem Technologies Fundamentals Guide

[http://www.cognimem.com/docs/Technical-Manuals/TM\\_CogniMem\\_Technologies\\_Fundamentals.pdf](http://www.cognimem.com/docs/Technical-Manuals/TM_CogniMem_Technologies_Fundamentals.pdf)

## Revision History

Version 1.0

Initial Release.

## ESD Caution

Electrostatic discharge (ESD) warning: charged devices and circuit boards can discharge without detection. Permanent damage to this device can be caused by exposing it to high ESDs. Therefore, proper CogniCare should be taken to protect this device from such damage.

## Legal Terms and Conditions

By using this device you agree to the terms set forth below.

The CM1K integrated circuit uses the following Patents: US5717832, US5701397, US5710869, US5740326.

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