Developer's Guide

Tobii EyeX SDK for .NET

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Tobii Tech

The Tobii EyeX Software Development Kit (SDK) for .NET contains everything you need for building games and applications using the Tobii EyeX Engine API and the .NET Framework.

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Introduction

The Tobii EyeX Software Development Kit (SDK) for .NET contains everything you need for building games and applications using the Tobii EyeX Engine API and the Microsoft .NET Framework.

The SDK includes framework components, supporting both WPF and Windows Forms, which simplify the development of user interfaces using the EyeX interaction concepts. The framework components are provided in the form of open source code with a permissive license.

Building on the EyeX Engine lets you create an eye-gaze enabled user interface with a minimum of effort, because the EyeX Engine takes care of the groundwork: you don't have to worry about hardware configuration, calibration, or data processing. The interaction concepts provided by the Tobii EyeX Engine give you the benefit of Tobii's extensive experience with eye-gaze interaction, and let you avoid common design pitfalls. The EyeX Engine provides a faster way to create a consistent user experience across the entire operating system.

The EyeX SDK is available on the same platforms as the EyeX Engine: currently Windows 10, Windows 8.1, and Windows 7.

The EyeX SDK is available in two other variants, one for C/C++ and one for the Unity game engine. EyeX is also available as a plugin for the Unreal Engine. More will follow and they are all available for download from the Tobii Developer Zone.

Getting started

Install and make sure Tobii EyeX is running

As the EyeX SDK builds on the interaction concepts and the API provided by the EyeX Engine, the first thing that you need to do is to install the Tobii EyeX software, and ensure that it works with your Tobii EyeX Controller or other Tobii eye tracker.

Now, does it track your eyes properly? Good, then you're ready for the next step.

Building and running the code samples and framework components

This guide assumes that you have installed Microsoft Visual Studio 2012 or later on your development machine. It should be possible to use the SDK with alternative build tools such as MonoDevelop or XamarinStudio as well, except for the WPF parts which are not supported by these products, but it will take some extra effort.

The EyeX SDK for .NET is distributed as a plain zip file. Extract it to, for example, c:\EyeXSDK. Then browse to the new SDK directory and locate the subdirectory called "source". There you will find a Visual Studio solution file that includes all the code samples as well as the framework components. It is arranged in a folder structure that matches the contents of the zip file:

- The **EyeXFramework** project, containing all framework components. Includes Windows Forms-specific and WPF-specific parts as well as GUI independent utility classes.

In the *Windows Forms Samples* directory you'll find the following samples, written in C# and Windows Forms:

- The **ActivatableButtonsForms** sample demonstrates the *activatable behavior*, also known as *direct click* (just look and click). The application displays a color sample and lets you change the hue and brightness of the color by clicking some buttons.
- The **ActivatableNotesForms** sample is another example of how to use the activatable behavior, here with custom User Controls that are overlapping and have different z-order.
- The **GazeAwareForms** project demonstrates how the gaze-aware behavior can be used and how to specify parent-child relationships between gaze-aware interactors.
- The **UserPresenceForms** project demonstrates how to subscribe for changes in the User Presence state to change the appearance of an animated character.
- The **PannableForms** project demonstrates how the pannable behavior can be used to scroll contents.

In the *Minimal Samples* directory you'll find the following C# console applications:

- The **MinimalEngineStates** sample demonstrates how to read state values from the EyeX Engine, such as eye tracking status and size of tracked screen. In addition, the sample demonstrates how to set up handlers for changes in the engine states.
- The **MinimalEyePositionDataStream** sample demonstrates how to subscribe to the eye position data stream and print out real-time coordinates for the left and right eye position in relation to the center of the screen in millimeters. In addition, eye position coordinates in relation to the track box are also displayed.
- The **MinimalGazeDataStream** sample demonstrates how to subscribe to the gaze data stream and print out real-time eye-gaze coordinates.

- The **MinimalProfile** sample demonstrate how to list calibration profiles and how to change the current profile.

And, finally, in the *WPF Samples* directory you'll find samples written in C# and WPF:

- The **ActivatableElements** sample, which demonstrates how to attach the activatable behavior to FrameworkElement objects.
- The **GazeAwareElements** sample, which demonstrates how to attach the gaze-aware behavior to FrameworkElement objects.
- The **PannableElements** sample, which demonstrates how to attach the pannable behavior to FrameworkElement objects.

The sample applications are plain Visual Studio projects, which can be built and run from within Visual Studio. So give them a try!

Where to go from here

We strongly recommend browsing through the rest of this Developer's Guide, because it will give you a big picture view of the EyeX Engine and its API. Knowing what the engine can do for you, and how the pieces fit together, will surely be helpful as you move on to create your game or application.

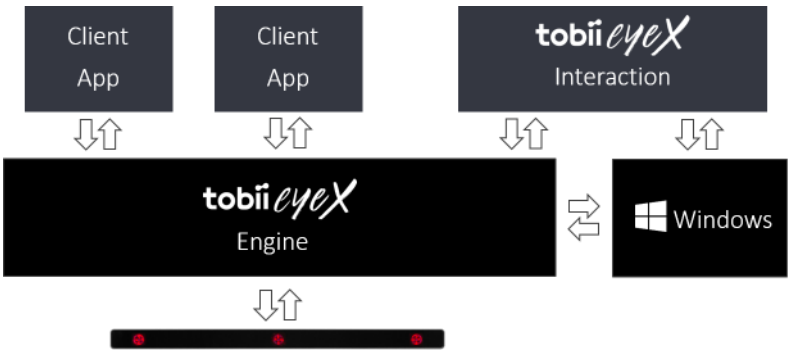
Apart from that, it depends on what you want to do—or how you wish to use the Tobii EyeX interaction concepts in your game or application. Remember that the Tobii Developer Zone is there for you if you need inspiration or if you get stuck.

Introduction to Tobii EyeX

Tobii EyeX is a software package that is used together with compatible eye trackers, such as the Tobii EyeX Controller, to enable new ways to use your eyes for interacting with computers.

The package contains drivers and services for connecting and communicating with the eye tracker as well as the Tobii EyeX Engine and Tobii EyeX Interaction software.

Tobii EyeX Engine is the core software that works like an OS extension for eye tracking. It knows how to configure and talk to the eye tracker, react to system changes, combine the user's eye-gaze and other input and interpret them as user interactions, and it mediates between multiple applications that are using eye tracking simultaneously.



The EyeX Engine also contains a whole lot of eye tracking smartness harnessed over the 10+ years of eye tracking experience at Tobii. This is offered as filtered data streams and built-in heuristics that are specialized in figuring out what the user is actually looking at. Since the EyeX Engine handles all

the groundwork with hardware configuration, screen setup, user calibration and so on, you as a game or app developer can focus on creating a great eye-gaze based experience for your players/users.

Tobii EyeX Interaction is a piece of software built on top of the EyeX Engine, and offers a set of basic eye-gaze interactions available out-of-the-box in the Windows environment. The concepts used in EyeX Interaction have matured through beta-testing programs and many iterations of improvements.

The EyeX SDK provides you with access to the EyeX Engine API. It includes code samples, demo scenes, dlls, documentation and code for integration into a selected set of game engines and GUI frameworks

Overview of the Tobii EyeX Engine API

Figure 1 presents an overview of what the EyeX Engine API offers.

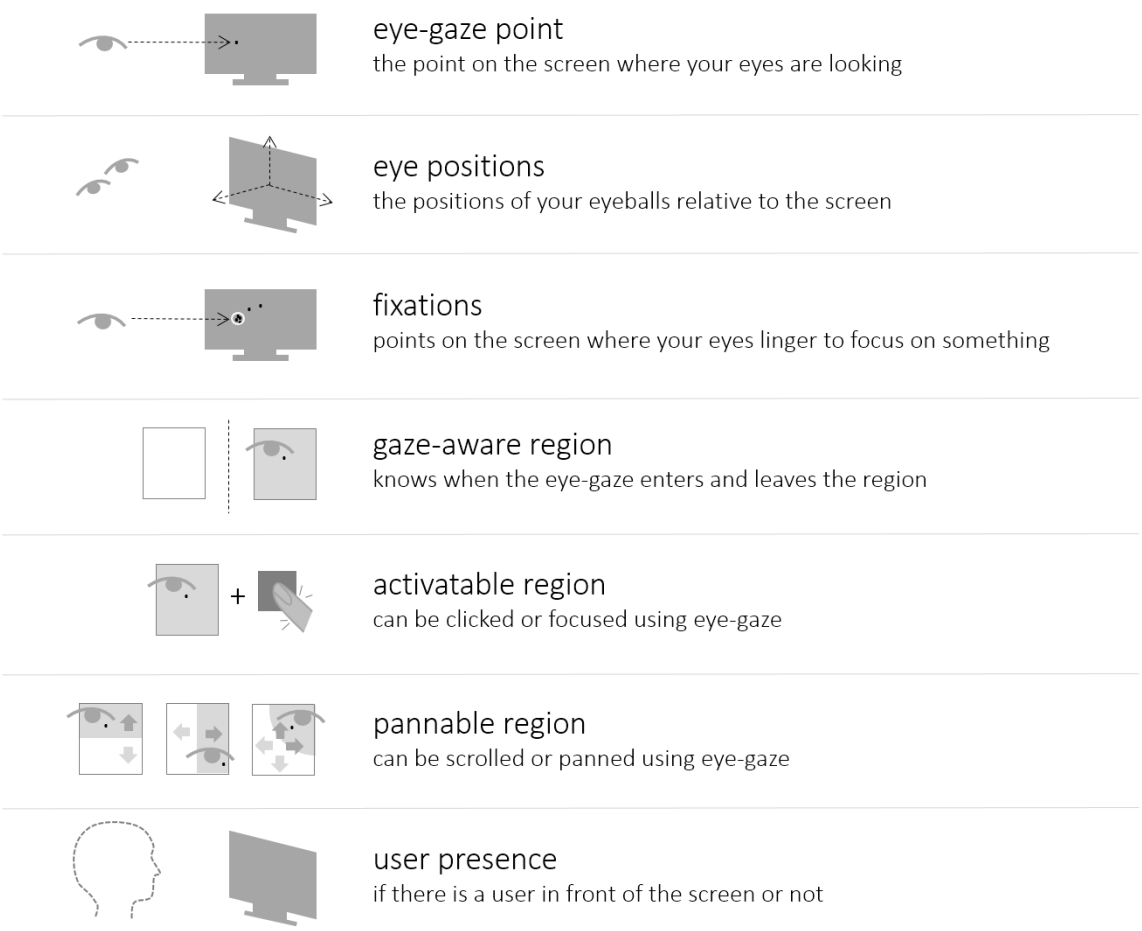


Figure 1 A somewhat simplified view of what the EyeX Engine API can do for you.

The functionality in the EyeX Engine API basically can be grouped in three categories: data streams, states and behaviors. Functionality that falls outside of these categories is there to support and make these three categories possible.

Data Streams

The data streams provide nicely filtered eye-gaze data from the eye tracker transformed to a convenient coordinate system. The point on the screen where your eyes are looking (gaze point), and the points on the screen where your eyes linger to focus on something (fixations) are given as pixel coordinates on the screen. The positions of your eyeballs (eye positions) are given in space coordinates in millimeters relative to the center of the screen.

States

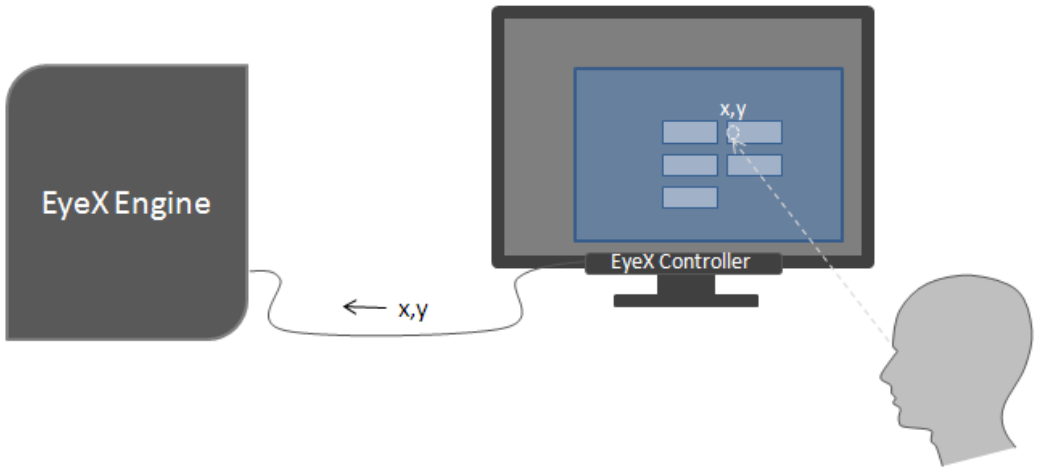
The states provide information about the current state of the EyeX system. There are a couple of more dynamic states related to the user: the user presence state (if there is a user in front of the screen or not) and the gaze tracking state (if the eye tracker is currently able to track the user's eye-gaze or not). There are also states that are related to the system setup, such as the size in millimeters of the display the eye tracker is currently setup for, the currently selected user calibration profile, or if the eye tracker is currently available.

Behaviors

The behaviors are higher level interaction concepts. You can compare them with familiar mouse interactions like click and scroll. The interaction behaviors are related to regions on the screen rather than single points. The regions typically correspond to GUI components like clickable buttons or scrollable panels. The concept of a gaze-aware region is a region that knows if a user is looking at it or not. An activatable region can be clicked by looking at it and simultaneously giving it an activation trigger – such as a tap on a touch pad or click of a keyboard key. The click is direct in the sense that you can click directly on whatever you are looking. The pannable behavior offers a number of different flavors of scrolling and panning a region in different directions. The EyeX Engine uses advanced heuristics and filtering to decide which object a user is trying to interact with and how. This gives a much more stable and precise interaction than one that simply uses the coordinate of the latest gaze point.

How the engine knows what you are looking at

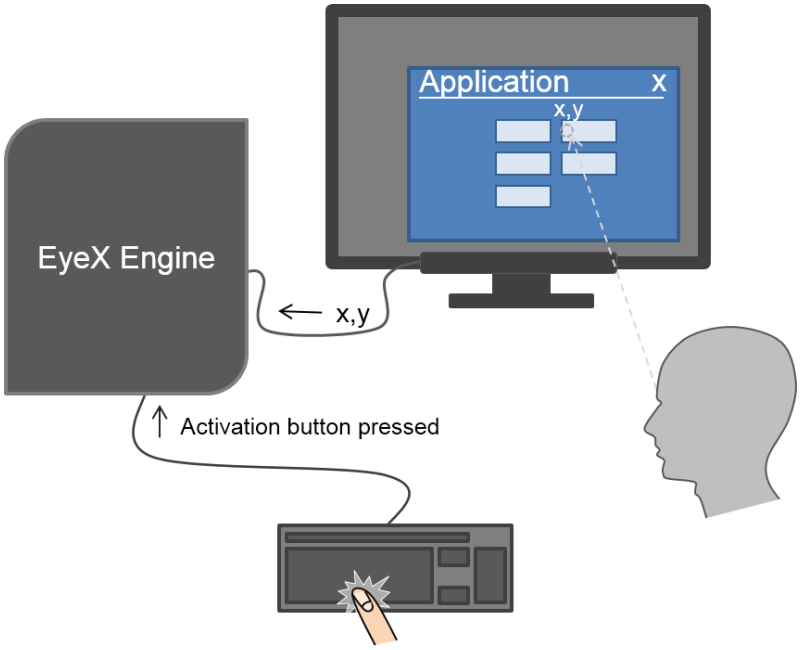
1. The user looks at the screen. The EyeX Controller calculates the coordinates of the user's gaze point. The EyeX Engine receives the normalized screen coordinates and transforms them to pixel coordinates on the screen.



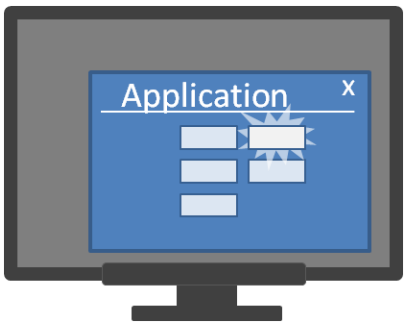
2. The EyeX Engine uses information from the client application to understand what kind of visual object the user is looking at and might want to interact with. Let's say the rectangles on

the screen are buttons with the 'Activatable' behavior. That means that they can be clicked using eye gaze. The EyeX Engine now decides which button the user is looking at and then expects the user to indicate that he or she wants to click the button.

3. The client application might offer the user some different ways of actually clicking the button using eye-gaze, but it will always be some combination of looking at the thing you want to click, and then giving some secondary input to trigger the click. Let's say that in this example client application the user can trigger a click on the object they are looking at by pressing the space bar on the keyboard when the client application has input focus.



4. The user presses the space bar while looking at the button he or she wants to click. The client application informs the EyeX Engine that the user has requested to 'Activate' the activatable button currently looked at.
5. The EyeX Engine generates an event that informs the client application which button the user wants to activate.
6. The client application responds to the event and for example gives the user a visual feedback that the button on the screen is clicked, and then performs the action associated with clicking that button.



The Windows Presentation Foundation (WPF) and WinForms integrations included in the EyeX SDK for .Net makes a lot of the steps above seamless. The app developer specifies the desired EyeX behavior for a certain GUI element, and write the click handling code. The rest is taken care of by client side code included in the SDK.

The EyeX Framework for .NET

The EyeX Engine API is an API with concepts that are language, platform and GUI framework agnostic. To make the EyeX Engine API more straightforward to use for .NET developers, the EyeX SDK for .NET includes the **EyeX Framework for .NET**, which is a layer of utility classes built on top of the API exposed by the EyeX Engine client library.

The EyeX Framework provides code that integrates EyeX with two commonly used GUI frameworks in the .NET community: Windows Forms and the Windows Presentation Foundation (WPF). Using the EyeX Framework, EyeX behaviors can be easily attached to visual objects in these GUI frameworks.

In this section, the adapted and integrated usage of EyeX through the EyeX Framework for .NET is described. For a full description of the concepts in the EyeX Engine API, see the section *EyeX Engine API reference*. To fully understand the EyeX functionality that are used in the .NET code samples, it is recommended that you read through the sections about *Behaviors for region-bound interactors* and *Data streams*.

Adding the EyeX Framework to your Visual Studio solution

The EyeX Framework is included as a separate project in the EyeXDotNet solution included in the source folder of the SDK package.

In order to use the EyeX Framework, it needs to be added to your Visual Studio solution. The easiest way to do this is to copy the whole EyeXFramework project folder to a suitable location in your solution folder, and then right-click the solution and choose “Add”, and “Existing project…”

Since the complete source code is included in the SDK package with a permissive license, you can change the implementation of the EyeX Framework according to your needs.

Including the client libraries

In addition to a reference to EyeXFramework and/or Tobii.EyeX.Client.Net20.dll, you also need to include the Tobii.EyeX.Client dll in your project. Make sure to use “Build Action: Content” and to copy the file to the output directory. The client dll is a native dll, which is why it has to be added as an item to the project and copied this way. (Only managed dll’s can be added as references.)

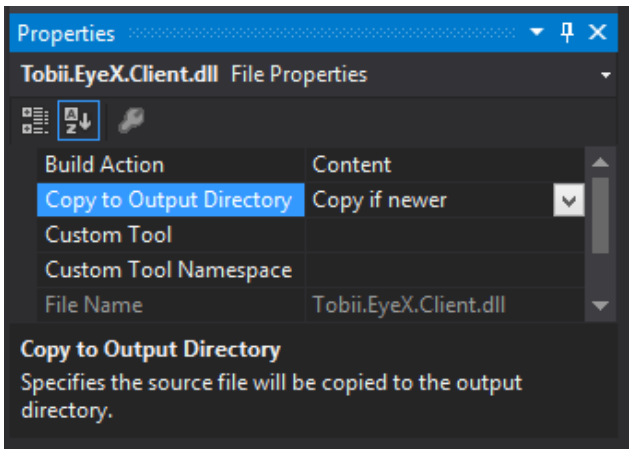


Figure 2 Make sure to copy the Tobii.EyeX.Client.dll file to output directory

Also make sure to build your assembly for either the x86 or the x64 platform and select the client dll's accordingly. The default target platform, "Any CPU", will resolve to either x86 or x64 at run time and at that time it can be difficult to ensure that the proper client dll's are available.

The EyeXHost base class

All classes in the base directory of the EyeXFramework project are GUI independent and can be used from pretty much any application supporting .NET Framework 4.5. The EyeXHost class is where most of the magic happens, you use it to connect to the EyeX Engine and subscribe to data. Below are two examples that use the EyeXHost class to subscribe to data streams and read engine states.

Example: A gaze data stream

```
private EyeXHost _eyeXHost;
...

// Initialize the EyeX Host
_eyeXHost = new EyeXHost();
_eyeXHost.Start();

// Create a data stream object and listen to events.
var stream = _eyeXHost.CreateGazePointDataStream(
                  GazePointDataMode.LightlyFiltered));
stream.Next += MyEventHandler;

...

// Dispose when done
stream.Dispose();
_eyeXHost.Dispose();
```

Note that this data stream will always give you the gaze data in physical pixels, so if you use it from a WPF application, then you might need to convert the coordinates to device independent units (DIU).

Example: Engine states

```
// Print value of user presence state if it is valid
var userPresence = _eyeXHost.UserPresence;
if (userPresence.IsValid)
{
    Console.WriteLine("User presence: {0}", userPresence.Value);
}

// Subscribe to changes in the user presence state.
eyeXHost.UserPresenceChanged += MyEventHandler;
```

If the EyeX Engine is not connected, user presence and all other states will be set to invalid.

Remember to dispose your EyeXHost object when you are done with it.

Windows Presentation Foundation (WPF)

The EyeX Framework for WPF allows you to tie EyeX behaviors to any visual element deriving from the FrameworkElement class, the base class of WPF visual elements. The EyeX functionality can be used directly from XAML using the attached dependency properties and routed events provided by the Behavior class, provided that a WpfEyeXHost has been set up.

Setting up the WpfEyeXHost in the App.xaml.cs

The WpfEyeXHost needs to be created and initialized at the startup of the application, and disposed on exit. In a standard WPF project, just put the following code in the App code-behind:

```
// App.xaml.cs
namespace MyApplication
{
    using System.Windows;
    using EyeXFramework.Wpf;

    public partial class App : Application
    {
        // Keep a reference to the host so it is not garbage
        // collected.
        private WpfEyeXHost _eyeXHost;

        public App()
        {
            _eyeXHost = new WpfEyeXHost();
            _eyeXHost.Start();
        }

        protected override void OnExit(ExitEventArgs e)
        {
            base.OnExit(e);
            _eyeXHost.Dispose(); // always dispose on exit
        }
    }
}
```

Example: Making a WPF button clickable with direct click

Suppose you have set up your solution with the EyeXFramework and a WpfEyeXHost as described above, and now you have a MainWindow with a single button in your WPF application. To make that button eye-gaze clickable with Direct Click, you only have to do the following in the MainWindow.xaml: Add an xml namespace declaration for the EyeXFramework to the Window element, set a default activatable behavior on the button, and declare a handler for activate events.

```
<!-- MainWindow.xaml -->
<Window ...
        xmlns:eyeX="clr-namespace:EyeXFramework.Wpf;assembly=EyeXFramework"
        ... >
    <Grid>
        <Button ...
                eyeX:Behavior.Activatable="Default"
                eyeX:Behavior.Activate="Button_OnEyeXActivate">
            Click me!
        </Button>
    </Grid>
</Window>
```

In the ActivatableElements sample code, there are more examples how visual elements can be given the activatable behavior (using a Style or an ItemsControl), and some different ways of EyeX event handling (raising a Button.ClickEvent, or using a Command).

EyeX Behaviors and RoutedEvents

For more examples of how to use the available EyeX behaviors and RoutedEvents for WPF, please check out the code samples in the WpfSamples folder. For an overview of all currently available EyeX behaviors in WPF, please check out the EyeXFramework.Wpf folder. Here all the available EyeX Behaviors for WPF have been implemented as partial class implementations of the class Behavior. For example, Behavior.Activatable.cs contains the implementation of all attached properties and events related to the activatable behavior.

The currently available EyeX Behaviors are also further described in section *Behaviors for region-bound interactors*.

Windows Forms

The EyeX Framework for Windows Forms makes it easy to tie EyeX behaviors to the Control objects which form the base of all visual elements in Windows Forms. There are two classes you need to use in your Form to get going. A **BehaviorMap**, which keeps track of the EyeX behaviors of the Controls that are interactors in your Form, and the **FormsEyeXHost** (singleton), which handles the connection to the engine and subscriptions to events.

The BehaviorMap is typically added to the Form or UserControl using the designer in Visual Studio. It should appear as a component in the designer toolbox when you add a reference to the EyeX Framework assembly to your project.

Finally, add your Control objects to the BehaviorMap and assign a suitable behavior to create a corresponding FormsInteractor instance and start receiving events from the EyeX Engine. The BehaviorMap will automatically connect to the singleton FormsEyeXHost object when initialized.

Example: Make a Windows Forms button clickable with direct click

```
// Set up a FormsEyeXHost in the Program class.
static class Program
{
    private static FormsEyeXHost _eyeXHost = new FormsEyeXHost();

    /// <summary>
    /// Gets the singleton EyeX host instance.
    /// </summary>
    public static FormsEyeXHost EyeXHost
    {
        get { return _eyeXHost; }
    }

    [STAThread]
    static void Main()
    {
        _eyeXHost.Start();

        Application.EnableVisualStyles();
        Application.SetCompatibleTextRenderingDefault(false);
        Application.Run(new Form1());
```

```
        _eyeXHost.Dispose(); // always dispose on exit
    }
}
```

```
// these lines will be added in the Form1.Designer.cs file when you
// add a Button and a BehaviorMap component:
private System.Windows.Forms.Button _button1;
private EyeXFramework.Forms.BehaviorMap _behaviorMap1;

private void InitializeComponent()
{
...
this.behaviorMap1 = new EyeXFramework.Forms.BehaviorMap(this.components);
}
```

```
// In the form constructor, connect the behavior map to the FormsEyeXHost
// and add an ActivatableBehavior for the button.
Program.EyeXHost.Connect(_behaviorMap1);
behaviorMap1.Add(_button1, new ActivatableBehavior(OnButton1Activated));

// Handle the activated event from the EyeX Engine to trigger a click
private void OnButton1Activated(object sender, EventArgs e)
{
    _button1.PerformClick();
}
```

Note that the ActivatableBehavior constructor can also be called with a second parameter to define a handler for activation focus events. Read more about the activatable behavior in section *Activatable behavior*.

Another useful function in the Windows Forms framework is the static method DpiAwarenessUtilities.SetProcessDpiAware(), which makes the process DPI aware so that changes of screen scale will keep working with eye tracking. The FormsEyeXHost is already calling this function, but if you are creating your own equivalent to FormsEyeXHost in your Windows Forms application it is recommended to use this function.

Redistributing an EyeX client application

The installer for your application must include the client library dll file and install it along with your executable file. Note that you may *not* install the dll in a system directory, because that could potentially cause version incompatibilities with other EyeX client applications.

The Tobii EyeX SDK license agreement gives you the permission to redistribute the client library dll with your game or application, free of charge, in most cases. The exceptions include high risk use applications, applications that might inflict on a person's privacy, and certain other niche applications. Please see the license agreement for more details; it is available in the SDK package and it can also be downloaded from the Tobii Developer Zone.

The client library depends on the Microsoft Visual C run-time libraries, version 110, and will not work unless these libraries are installed on the computer. The run-time libraries can be downloaded free of charge from Microsoft. You can also include them as a merge module in your installer.

EyeX Engine API reference

The EyeX Engine API reference explains all the concepts in the API and how the EyeX Engine and a client application will work together to create an Eye Experience. The Data Streams, States, and Behaviors for region-bound interactors are described at the end of the API reference. The reference has been written so that it can be read through top-down with later sections referring to previous sections.

The Client application

Whenever you find the term **client application**, or just application, in this document, it refers to *your* application. Or to one of the sample applications, or any other application that makes use of the services provided by the EyeX Engine—which plays the part of the server in this instantiation of the classic Client/Server architecture.

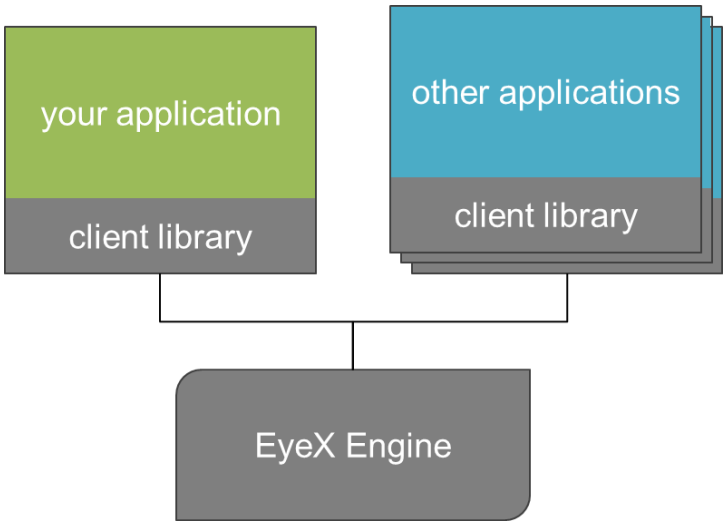


Figure 3 Your application and its relationship to the EyeX Engine.

Something that all client applications have in common is that they use a client library provided with the SDK to connect to the engine.

Interactors

Anything that the user can interact with using eye-gaze is called an **interactor** in the language of the EyeX Engine. For example, an interactor can be an activatable (clickable) button, or a widget that is expanded when the user's gaze falls within its bounds. An interactor can also be a stream of filtered data where the user interacts by moving the head or by appearing in front of the screen after being away from it.

Some modes of eye-gaze interaction take place within a particular region on the screen, as in the case of the button and widget examples above. Other eye-gaze interaction modes are not tied to any particular region of the screen, as in the case of a stream of eye-gaze data. For example, an information kiosk application or ATM could use an eye-gaze data stream to sense that a user has appeared in front of it, and switch its user interface into a different mode at that point.

The EyeX Engine treats the interactors which are used for eye-gaze interaction within a particular screen region quite differently from those interactors that are not. To clearly distinguish the one kind from the other, we will refer to the former kind as **region-bound interactors**, and the latter kind as **global interactors**. Both will be described in more detail below.

Region-bound interactors

Region-bound interactors usually map one-to-one with the visual elements/components in the GUI framework used to create the application. This is by convenience and not a requirement: it makes sense, because it is it easier to maintain the relations between the interactors, and because end users expect objects to respect visual hierarchies and window bounds.

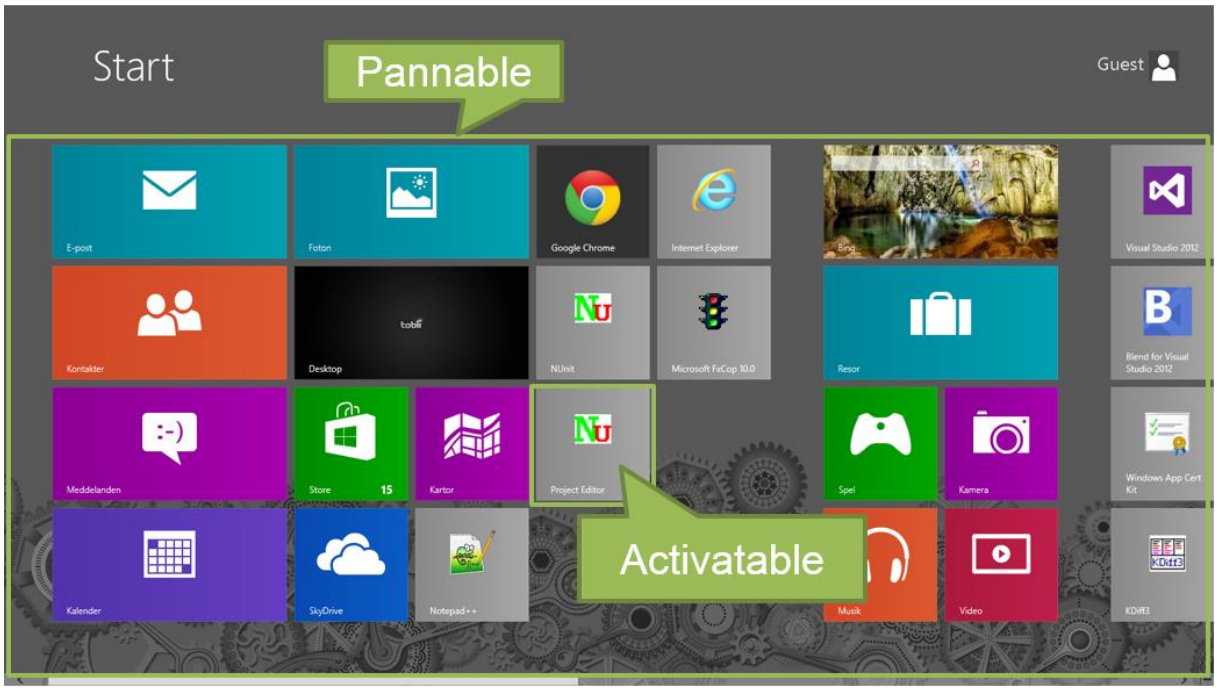


Figure 4 Examples of region-bound interactors

The EyeX Engine considers all region-bound interactors to be transient. The engine will continuously query the application for region-bound interactors based on the user's gaze point. It will remember the interactors long enough to decide what interaction is currently going on, but then it will discard the information. As the user's gaze point moves to a new region of interest, new queries are sent to the application and a new batch of interactors are sent back to the engine. And so on.

Non-rectangular interactors

By default, a region-bound interactor has a rectangular shape. To define non-rectangular shapes, you need to define a **weighted stencil mask** (or just **mask**) on the interactor. A weighted stencil mask is a bitmap that spans the area of the interactor. The interactable parts of the area are represented by non-zero values in the bitmap. The rest of the area is considered transparent, and cannot be interacted with. The resolution of the bitmap does not need to be as high as the screen resolution. Usually, a low-resolution bitmap works just as well and is better from a performance point of view.

Global interactors

Global interactors are used for subscribing to **data streams** that aren't associated with any specific part of the screen.

Once you have told the EyeX Engine about a global interactor, the engine will remember it as long as the connection with your application remains, or until you explicitly tell the engine to remove the interactor. So, while region-bound interactors are committed continuously in response to queries from the engine, a global interactor is usually only committed once per established connection.

A common usage pattern is to set up a global interactor when the application starts, and to send it to the engine as soon as the connection is established, or re-established—for example, due to a switch of users. (The EyeX Engine restarts automatically every time Windows switches users.)

Interactor ID's

The one thing that makes the EyeX Engine recognize an interactor, regardless of how it moves around and how its behaviors change, is the interactor's ID. It is your responsibility, as a developer, to ensure that all interactor IDs are indeed unique—at least within their respective contexts, as described below.

The interactor IDs can be any string values, and since almost anything can be converted to a string, that leaves you with plenty of options. So, what does a good interactor ID look like?

In the rather common case when an interactor maps directly to a user interface component, and that component already carries a sufficiently unique ID, it's good practice to let the interactor ID match the component ID. Not only will that give you reliable, unique, constant ID's; it will also simplify the mapping between interactors and components.

In other cases there are no clear-cut guidelines. Just try to choose ID's that make sense in your domain.

Interaction Behaviors

An interaction behavior, or **behavior** for short, is a particular mode of eye-gaze interaction that an interactor may provide. The catalog of behaviors is by far the most important part of the EyeX Engine API, because each behavior represents a piece of functionality that your application can use. The available behaviors are described in more detail later in this document.

Some behaviors are intrinsically region-bound, and some are not. It is really the behaviors that determine whether an interactor should be region-bound or global.

So, how much use would an interactor be if it didn't have any behaviors? Actually, there is a case where behavior-less interactors are indeed quite useful. A region-bound interactor without behaviors is effectively just preventing eye-gaze interaction on the part of the screen that it covers, and is commonly called an **occluder**.

The EyeX Engine adds occluders representing all top-level windows[1] automatically, in order to prevent any parts of a window which are covered by other windows to take part in eye-gaze interaction. The interactors defined by your application will be considered as children of the top-level window interactors.

[1] "Top-level window" is a Windows term for a window that doesn't belong to another window. Top-level windows are typically displayed on the taskbar. Applications typically display one top-level window for the application itself, or one top-level window for each document opened in the application.

The Query-Snapshot cycle

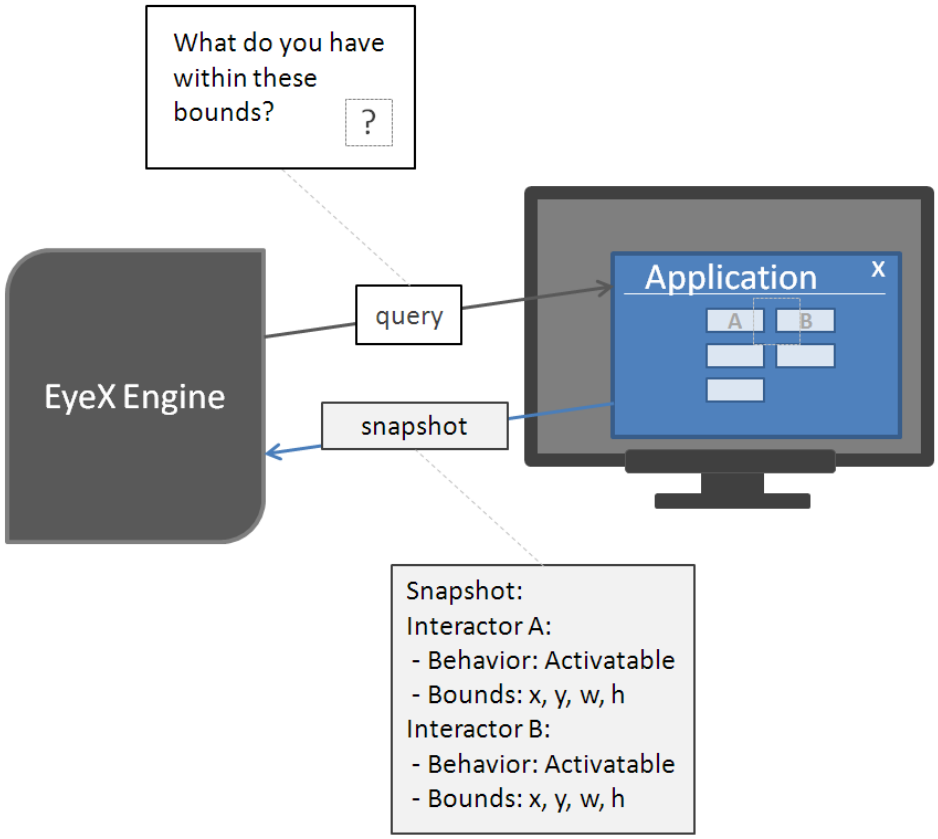


Figure 5 The Query-Snapshot cycle.

A key design principle of the EyeX Engine is that it senses what is on the screen one piece at a time, by making **queries** to the client applications. That is, it does *not* expect the applications to declare their entire gaze enabled user interface up front, but rather to feed the engine with information continuously, on request.

Note that this design principle doesn't prevent an application from keeping a repository, or cache, of its region-bound interactors, and respond to the engine's queries with cached information. Whether or not to use a repository is a design decision left to the application developer.

The queries roughly follow the user's gaze point. Queries are always specified with bounds, that is, a rectangular region on the screen, and with one or more window IDs. In areas on the screen where windows from different client applications are close, the query is sent to all applications, and each is responsible for keeping the engine updated on the region-bound interactors within its window(s). The window IDs in the queries identify the top-level window(s) that the engine wishes to receive interactor information for.

The packet of data that the client sends in response to a query is called an interaction snapshot, or **snapshot** for short. It contains the set of region-bound interactors that are at least partially within the query bounds, a timestamp, and the ID of the window that the snapshot concerns.

There is no one-to-one correspondence between queries and snapshots. If an application doesn't respond in a timely fashion, then the engine will simply assume that it didn't have any region-bound interactors to report—which may or may not be what the application intended.

An application may also act proactively and send the engine snapshots that it didn't ask for. This is how applications usually inform the engine of its global interactors. Animated interactors whose screen bounds change over time is another case where application-initiated updates can be useful.

The information in a snapshot should be considered as the *complete* description of all region-bound interactors within the snapshot bounds. If two snapshots with the same bounds are committed after another, and the first committed snapshot contains an interactor that is not included in the second snapshot, the engine will interpret this as if that interactor has been removed. As a consequence: don't stop responding to queries when your last interactor has gone off-stage—instead, keep sending empty snapshots so that the engine will know that they are gone.

The exception to this guideline is an application that doesn't use any region-bound interactors at all. Such an application doesn't even have to handle queries, because the global interactors are handled separately, as described in the section on global interactors above.

Events

As soon as the EyeX Engine has found out that a particular kind of gaze interaction is taking place between the user and an interactor, it notifies the application that owns the interactor by sending it an **event**.

Events are used for both region-bound and global interactors, so an application should always be set up to receive and handle events from the engine.

Events are tagged with the ID of the interactor and the behavior(s) that triggered the event. Some events also include additional, behavior-specific parameters related to the interaction.

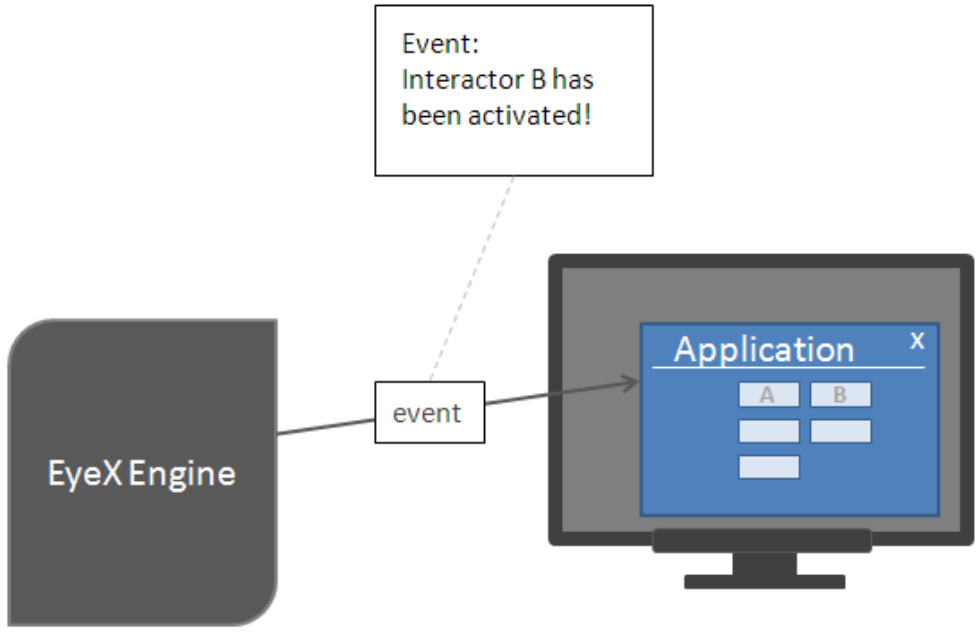


Figure 6 Event notification on a region-bound interactor

Interactor bounds and nested interactors

A region-bound interactor is always associated with a region, as the name implies. This region is called the interactor's **bounds**, and is currently defined as an axis-aligned rectangle on the screen. (If a weighted stencil mask is applied on the interactor, non-rectangular shapes can also be defined).

A region-bound interactor is also associated with a top-level window, and its bounds cannot extend outside the window—or, rather, its bounds will be clipped to the bounds of the window. This might seem like a severe restriction at first, but do remember that it applies to region-bound interactors only—the global interactors by definition do not have this restriction.

User interfaces are typically built as tree structures: starting from the window, there are layout containers, scroll containers, etc, until we finally arrive at the actual content that is visible on the screen. The contents are often only visible in part, such as in the case of a long, scrollable list where only a few items can be seen at any time, or when another window is covering part of the view. Users typically expect the invisible parts to be excluded from interaction.

Using only the bounds information, all region-bound interactors would appear to lay flat next to each other. Suppose two of them were overlapping, which one should the engine pick as the candidate for eye-gaze interaction? Instead of forcing the application developer to avoid overlaps by adjusting the interactor bounds, the API provides **nested interactors** to help out. The engine will consider child interactors to be in front of all its ancestor interactors.

Region-bound interactors can be organized in a tree structure just like the user interface components. Each interactor provides the ID of its parent if it has one, or otherwise a special ID representing the top-level window. Interactors that are children of the same parent interactor should specify a Z order (highest on top) if they overlap. Specifying parent-child relationships like this can be thought of as nesting interactors inside each other.

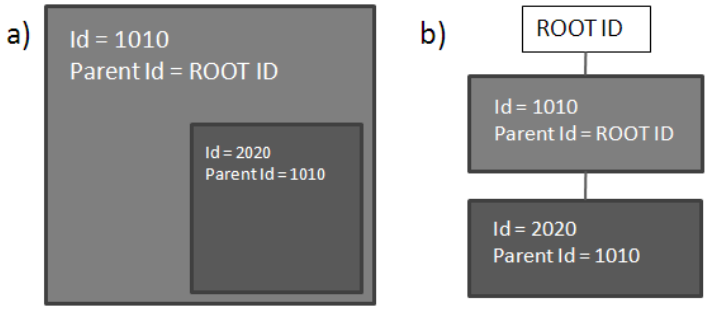


Figure 7 a) Nestled interactors, where the child interactor is overlapping its parent interactor. b) The corresponding interactor tree-structure.

The bounds of a child interactor may extend outside the bounds of its parent. Windows makes a distinction between *child windows* and *owned windows*, and a child interactor is more like an owned window than a child window in this sense.

When the EyeX Engine scans the area around the user's gaze point for interactors, it starts by determining which top-level windows there are in the region. Then it proceeds to search through the interactors attached to those windows, looking for interactors whose bounds contain or are close to the gaze point. During this process the engine makes use of both the parent-child relationships and the Z order information to decide what is on top of what.

The Z order is only compared between sibling interactors, and a sibling with a higher Z order will be considered to be in front of not only its sibling with lower Z order, but also to all children interactors of these siblings. Because of this, one has to be careful when constructing an interactor tree-structure so that the interactors overlap as intended. This is illustrated in Figure 8 and Figure 9.

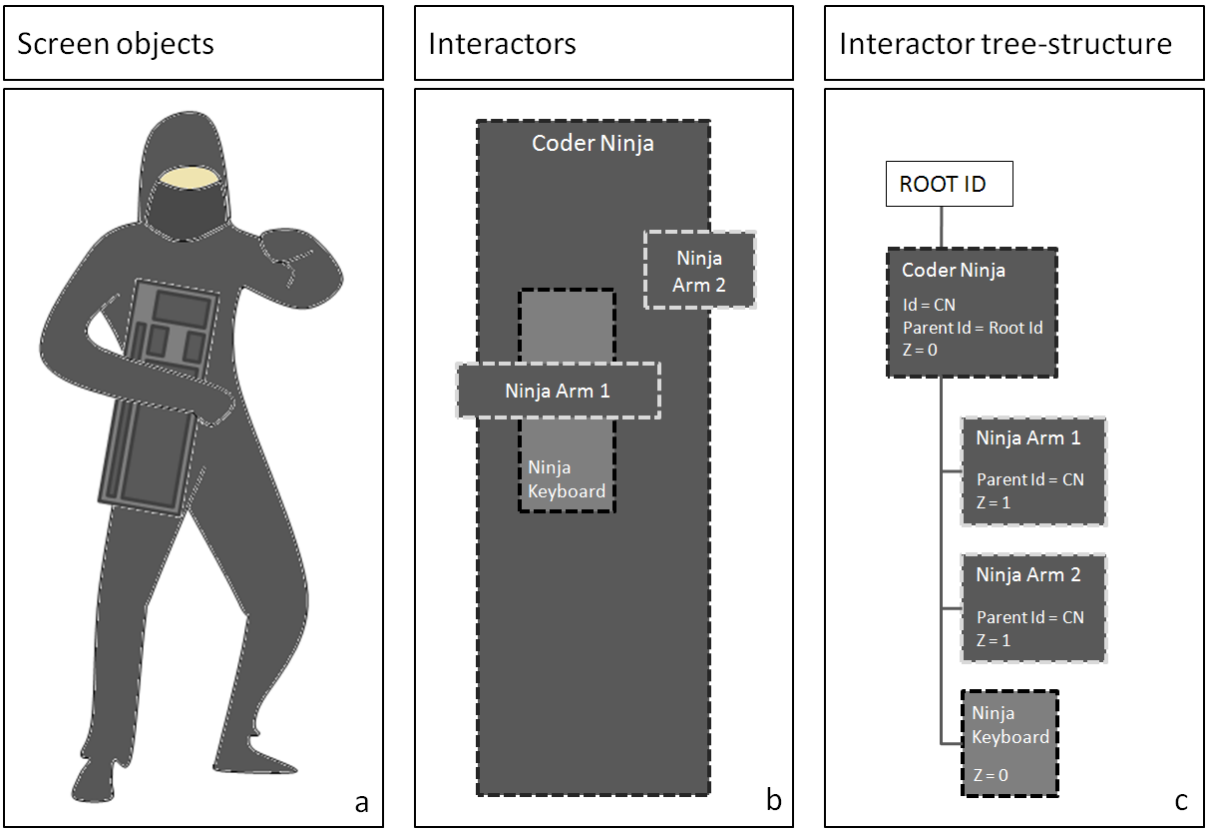


Figure 8 a) Coder Ninja with Ninja Keyboard b) Corresponding overlapping interactors. c) By making the Ninja Arm 1 and the Ninja Keyboard children of the Coder Ninja, but with different Z order, the EyeX Engine is told that they are both in front of the Coder Ninja, but that the arm is in front of the keyboard. The Z order of the other arm does not matter, since it does not overlap any of its siblings.

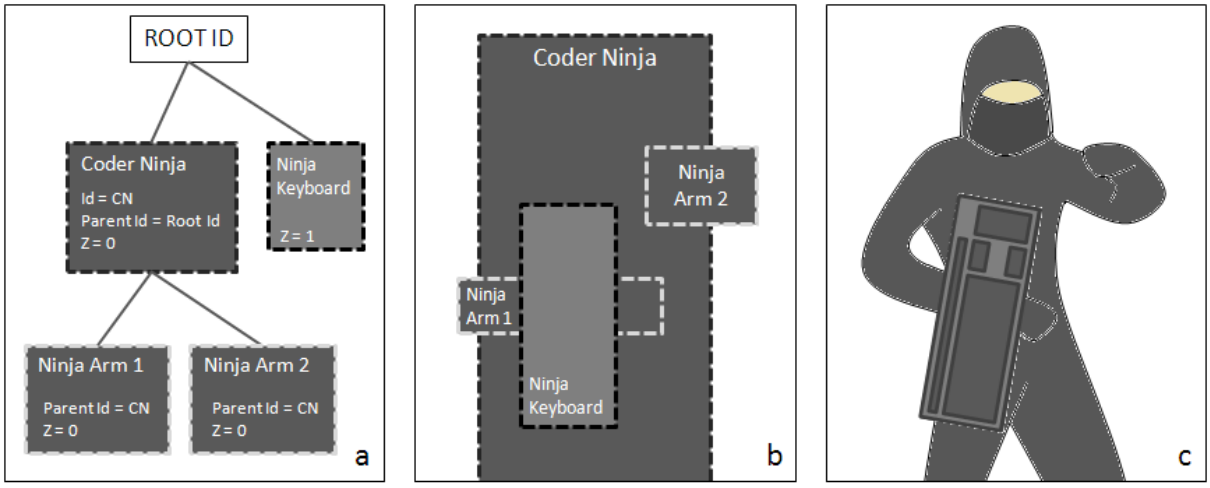


Figure 9 Making the Ninja Keyboard a higher Z order sibling of the Coder Ninja (a), would not only put it in front of the Coder Ninja but also all of Coder Ninja's child interactors, including the Ninja Arm 1 (b and c).

When the engine has identified the topmost interactor that is closest to the gaze point (if any) it looks at the interactor's behaviors to see what kind of user input it should expect and how to react on it.

The existence of nested interactors has some consequences for the application developer when preparing a snapshot:

- If an interactor in a snapshot references another interactor as its parent, then the parent interactor must also be included in the snapshot, even if it isn't within the snapshot (or query) bounds.
- If two interactors with overlapping bounds have the same parent interactor and the same Z order, then the EyeX Engine cannot decide which one is on top. The outcome will be random and the user experience inconsistent. So, do be careful when defining the bounds and relationships of your interactors.

Contexts

A **context** represents a connection between an EyeX client application and the EyeX Engine. Applications typically create a context during startup and delete it on shutdown.

The application uses the context to register query and event handlers, and to create **interaction objects** such as snapshots. Queries and events are also interaction objects, but they are normally not created by the application. An interaction object always belongs to a certain context, and interaction objects cannot be shared between contexts.

3D Coordinate systems

The coordinate system used for 3D points in the EyeX Engine, for example for the Eye position data stream, is relative to the screen where the eye tracker is mounted. The origin is at the center of the screen. The x axis extends to the right (as seen by the user) and the y axis upwards, both in the same plane as the display screen. The z axis extends towards the user, orthogonal to the screen plane. The units are millimeters.

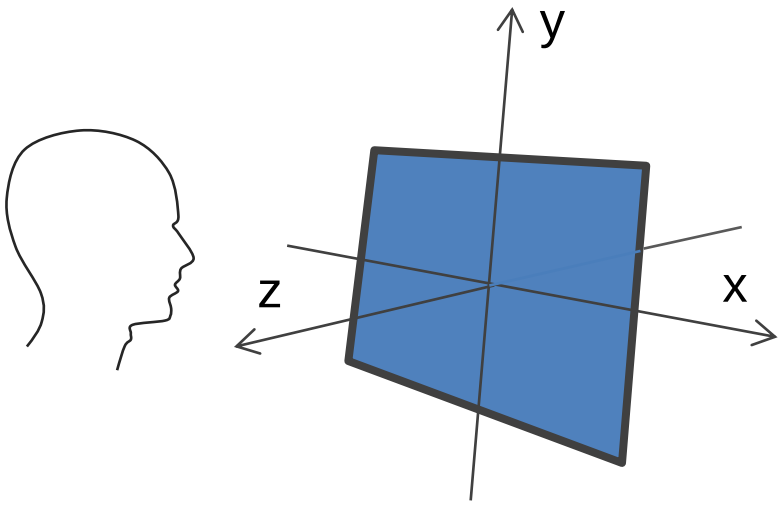


Figure 10 The 3D coordinate system used by the EyeX Engine.

Note that the y axes in the 3D coordinate system and the 2D coordinate system are different. The y axis in the 2D coordinate system crosses zero at the top of the screen and extends downwards; the y axis in the 3D coordinate system crosses zero at the middle of the screen and extends upwards.

The 3D coordinates can also be expressed relative to the *track box*, i.e. the volume in which the eye tracker is theoretically able to track the user's eyes. The track box coordinate system (TBCS) has its origin in the top, right corner located closest to the eye tracker. The TBCS is a normalized coordinate system: the location of the (1, 1, 1) point is the lower, left corner furthest away from the eye tracker.

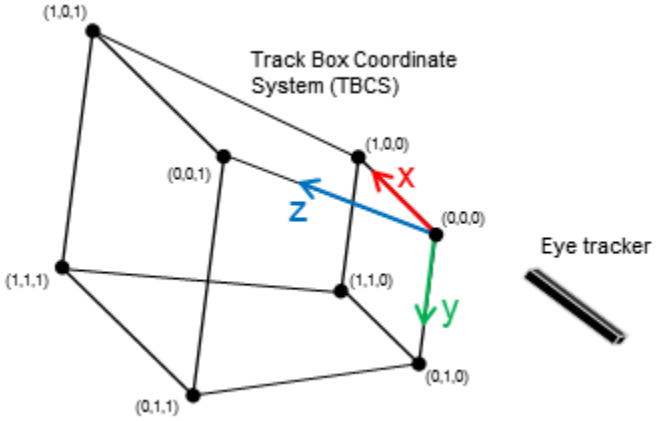


Figure 11 The track box coordinate system.

Client and Screen coordinates

Points on the screen are always given in **physical pixels** in the EyeX Engine API. Unfortunately, this isn't as simple as it sounds. But in order to explain why, we need some background on how Windows handles multiple display monitors, and why a pixel in your application isn't always the same as a pixel on the screen.

The coordinate system most commonly used by developers is the *client coordinate system*, which is relative to the top left corner of a window or the top left corner of a specific GUI component. Each window and GUI component has its own client coordinate system, which is used when laying out its contents.

There is also a coordinate system that relates to the pixels on the screen. That is, a system that is fixed relative to the screen and doesn't move around with a window. This coordinate system is called *screen coordinates* in Windows.

Mapping between screen coordinates and client coordinates is performed using methods that are specific to the GUI framework used by the client application. In WPF and WinForms the methods are called `PointToScreen` and `PointFromScreen` and found on the `Visual` and `Control` classes respectively.

This means that—

- If you received, for example, the user's gaze point from the EyeX Engine, and you want to get its position relative to your application's top level window, then you should use the corresponding `PointFromScreen` method to map the coordinates to the client coordinate system of your window.

- When preparing a snapshot for the EyeX Engine that includes region-bound interactors corresponding to user interface elements, the EyeXFramework uses the `Visual.PointToScreen` method in WPF and the `Control.PointToScreen` in WinForms to map from element and control coordinates to screen coordinates.

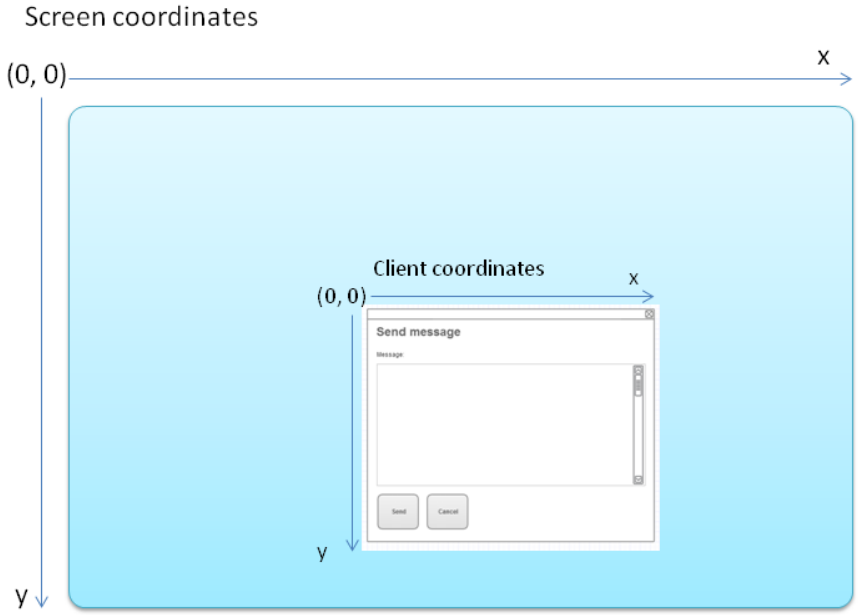


Figure 12 Screen vs client coordinates of a client application window

In a system with multiple display monitors there is still a single screen coordinate system that spans all of the monitors. This is referred to as the *virtual screen*. Pixel coordinates on the virtual screen can be negative because the origin (0, 0) is always on the primary monitor. So if you place another monitor to the left of the primary, then it will have negative x coordinates.

If you are using multiple screens, you can place the eye tracker on any screen you want. Once you have set up the EyeX Engine to use a particular screen, it will make sure that the eye tracker coordinates are mapped properly.

DPI scaling and DPI awareness

Since the advent of Windows Vista, it is possible to set monitor DPI (Dots Per Inch) to higher than 100%, making everything appear larger on screen. This can be useful with very large monitors, with high-DPI monitors, or for users who have impaired eyesight.

Much of this process is hidden from client applications, as Windows will take care of the scaling behind the scenes. Unfortunately, this hidden scaling break the transformation between client coordinates and screen coordinates, so that the coordinates reported by the application to the EyeX Engine will be wrong. **The solution is for all EyeX client applications to register as DPI aware** so that Windows will not do any behind-the-scenes-scaling.

Note that some GUI frameworks, such as the Windows Presentation Foundation, **WPF always declare DPI awareness**, so you might not have to do it yourself. If you are uncertain if this is the case, it is easily tested: set your monitor DPI setting to “Larger” and run your application full-screen. Any offsets should be easily noticed.

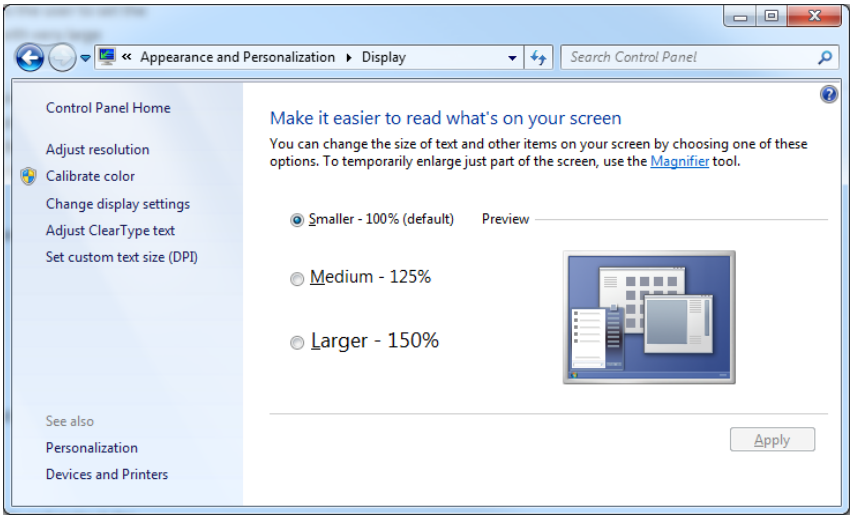


Figure 13 The Display settings page in the Control Panel, where the user can change the DPI setting.

Since Windows 8.1, per-monitor DPI awareness is available, where different scaling happens on different monitors in a multi-monitor setup. Client applications may register as per-monitor DPI aware and take care of scaling themselves. **Unfortunately, EyeX Engine does not currently fully support per-monitor DPI aware applications**.

For more information about screen coordinates, multi-monitor setups and DPI awareness, see

- Multiple Display Monitors on MSDN
- Writing DPI-Aware Desktop and Win32 Applications on MSDN

Data streams

From an EyeX Engine API point of view, data streams are just kinds of behaviors assigned to interactors. The typical way to setup a data stream is to create a global interactor, assign to it one of the data stream behaviors and then subscribe to the events raised for the interactor. Since the interactor is global, the engine will send data events no matter where the user is looking, as long as there is valid data to be sent.

The EyeX Engine also allows for assigning data stream behaviors to a region-bound interactor. In this case, data events will only be sent when the user is looking at the interactor. This could be used on a window level so that a client application only receives data if the user is looking at the client application's window.

Region-bound interactors with a data stream behavior need to be continuously sent to the EyeX Engine using the Query-Snapshot cycle (see *The Query-Snapshot cycle*). This means that these types of data streams tend to be more performance heavy than the straight forward global interactor data streams which only have to be sent once per established connection between the client application and the EyeX Engine. (Read more about the life cycle of global interactors in the section *Global interactors* above.)

Each data stream delivers one kind of data, for example the user's gaze point, and often comes in variants that differ for example in the choice of filtering.

Note: the EyeX Framework for .NET currently only have utility methods for creating data streams with the global interactor mechanism.

Gaze point data

The Gaze point data behavior provides the user's gaze point on the screen as a data stream. The unfiltered data stream produces a new data point whenever the engine receives a valid eye-gaze data point from the eye tracker. No statements are made regarding the frame rate; you get what you get.

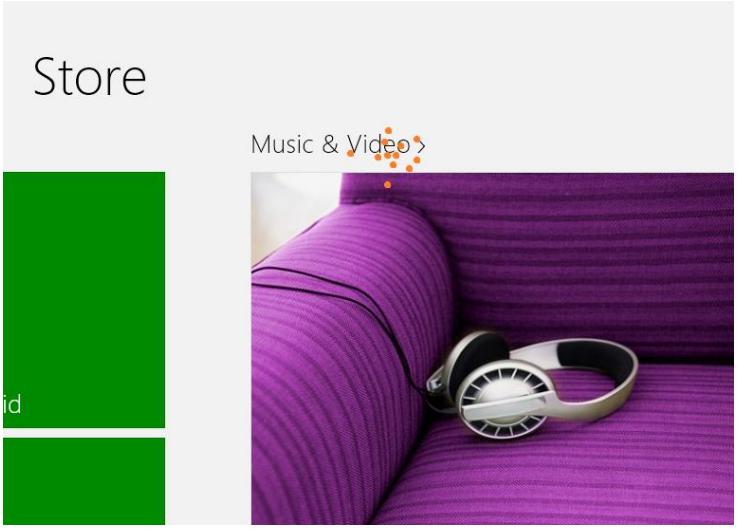


Figure 14 The gaze point is an inherently noisy signal. The orange dots on this screenshot represent the user's gaze point during a fraction of a second. Filtering makes the point cloud shrink towards its center, but also respond slower to rapid eye movements.

The gaze point is given as a single point. If the user has chosen to track a specific eye, then it's the gaze point from that eye. Otherwise the point is taken to be the average from both eyes.

Because the gaze point is an intrinsically noisy signal, the Gaze point data behavior provides a selection of filters that can be used to stabilize the signal. As usual when it comes to filtering, there is a trade-off between stability and responsiveness, so there cannot be a single filter that is the best choice for all applications. The choice of filters are:

- Unfiltered: no filtering performed by the engine. (Except for the removal of invalid data points and the averaging of the gaze points from both eyes.)
- Lightly filtered: an adaptive filter which is weighted based on both the age of the data points and the velocity of the eye movements. This filter is designed to remove noise while at the same time being responsive to quick eye movements.

Note: We expect that more filters will be added in later releases of the engine.

The gaze point is given in physical pixels. See the section *Client and Screen coordinates above*.

Eye position data

The Eye position data behavior provides the user's eye positions in three-dimensional space as a data stream. This data stream can be used, for example, to control the camera perspective in a 3D game.

This data stream produces a new value whenever the engine receives a valid sample from the eye tracker, and no statements are made about the frame rate, just as for the Gaze point data behavior. The eye positions are given for the left and right eyes individually, both in relation to the screen and normalized to the track box. See the section *3D Coordinate system* for a description of the coordinate systems used.

The Eye position data behavior does not offer any filtering options at this time.

Fixation data

The Fixation data behavior provides information about when the user is fixating her eyes at a single location. This data stream can be used to get an understanding of where the user's attention is. In most cases, when a person is fixating at something for a long time, this means that the person's brain is processing the information at the point of fixation. If you want to know more about fixations, the Internet is your friend.

To get information about the length of each fixation, the Fixation data behavior provides **start time** and **end time** for each fixation, in addition to the **x and y point** of each individual gaze point within the fixations. Each fixation correspond to a series of fixation events: Begin, Data, Data, … , End.

When setting up the fixation data behavior, these fixation data modes are available:

- **Sensitive**, will result in many fixations, sometimes very close and in quick succession.
- **Slow**, will result in fairly stable fixations but may leave somewhat late.

States

The EyeX Engine keeps track on a number of **states** that are related to the current status of the eye tracking system, like configuration and user profiles, or to the user in relation to the eye tracking system, like user presence. Below is a list of the common states with a short description what status it tracks. Each state has a unique path that a client application can use to retrieve the information if needed. It is also possible to setup state changed handlers to get notified when a state changes.

User Presence
If a user is present before the eye tracker or not.

Gaze Tracking
If the user's eye-gaze is currently tracked or not. If none of the user's eyes can be tracked, there will be no events sent in the gaze point data stream.

User Profile Name
The name of the currently selected user calibration profile.

User Profiles
A list of names of all the available user calibration profiles.

Screen Bounds
The screen currently set up for eye tracking defined as an area on the virtual screen. Given as x,y coordinates of the upper left corner and the width and height, in pixels on the virtual screen.

Display Size
The physical size of the screen currently set up for eye tracking. Given as the width and height in millimeters.

Eye Tracking Device Status
Current status of the eye tracking device. This state will indicate if the EyeX system is ready to track your eyes (the “Tracking” state), or if there is something stopping it from doing that, for example: a missing user profile or screen setup, that the user has disabled eye tracking in the settings (“TrackingPaused”), or that no eye tracker device seem to be connected to the computer.

Behaviors for region-bound interactors

Behaviors for region-bound interactors are naturally associated with a region or an object on the screen. Or, to be more precise, with a region or object *in a window* on a screen, because region-bound interactors must always be associated with a window.

The behaviors for region-bound interactors either let the user perform an action on the object/region, such as activation (direct click or action), or provide some sort of monitoring of the user’s eye-gaze on the object or region.

Gaze-aware behavior

An interactor with the gaze-aware behavior represents a region or object on the screen that is sensitive to the user’s eye-gaze. Possible uses of the behavior include widgets that expand on gaze, game characters that act differently when being watched, and other usages where the user interface adapts to what the user is looking at, or implicitly, is paying attention to.

The EyeX Engine raises one event when the user’s gaze point enters the bounds of the interactor, and another event when it leaves. The event parameter “HasGaze” will be set to true or false according to if the engine considers the user looking or not looking at the region.

Add inertia by setting delay time
Note that the fact that the user is looking at something doesn’t necessarily mean that she is paying attention to it, and also that this behavior is quite sensitive and can easily be triggered by noise and/or rapid eye movements. A common way of dealing with this uncertainty is to add some inertia to the interaction: make sure that the gaze point stays on the interactor for a while until the response is triggered, and don’t release the trigger until the gaze point has been off for a while.

For a simple way to add inertia, there is a built-in delay parameter that can be set on a gaze-aware interactor to specify a delay between when the user’s gaze point enters the interactor bounds and when the event is raised.

Nested Gaze-aware interactors
If the gaze-aware interactor has child interactors (see *Interactor bounds and nested interactors*) that also have the gaze-aware behavior, the gaze point will be considered to be within the parent interactor as long as it is within an unbroken hierarchy of gaze-aware child interactors. This applies even if the gaze point isn’t within the bounds of the parent.

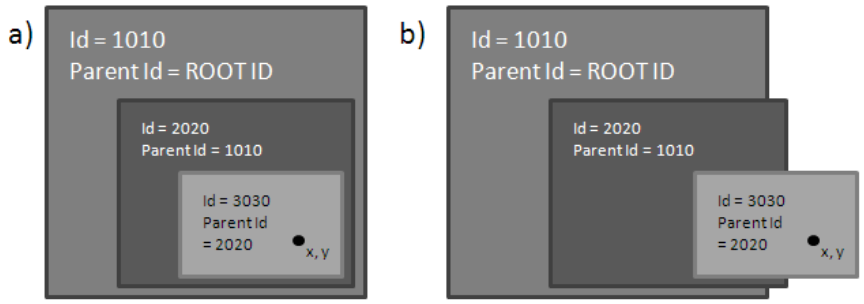


Figure 15 Nested Gaze-aware interactors: The gaze point at (x, y) is considered to be within the bounds of the parent interactors, no matter if it is a) geometrically within or b) geometrically outside the parent interactors' bounds. Moving the gaze point between child interactors does not trigger any additional events for the parent interactor.

Activatable behavior

An interactor which has the activatable behavior represents an action that the user can select and trigger using her eye-gaze. The actual triggering is usually performed using another input modality—because triggering actions entirely using eye-gaze isn't comfortable to most people.

The activation can be thought of as a mouse click, a touch tap, or the pressing of a button. It is up to the application developer to decide what happens on activation. Common usages include selecting an item from a menu, executing a command (for example, launching an application), navigating to a web page, flipping pages, firing the lasers, and so on.

To implement the activatable behavior for an interactor, the client application sends a number of *action commands* to the EyeX Engine and reacts to the *events* the EyeX Engine sends in return. In short: the client application informs the engine of the steps of the interaction the user is doing, the engine informs the client application which interactor the user is trying to interact with.

Activation event 'Activated'

There are two kinds of events associated with the activatable behavior. The most central event for the behavior is the *activated* event. This event is sent for the interactor that the user has looked at while triggering an activate command, for example by pressing a specific key on the keyboard. The *activated* event is the event the application should respond to by performing the action associated with the activatable interactor.

Activation event 'Activation Focus Changed'

To be able to correctly and quickly decide which activatable interactor the user is trying to activate, the EyeX Engine continuously keeps track of which interactor is in focus. Only one interactor can be in focus at a given time. There are two levels of focus: *tentative activation focus* and *activation focus*. The current state of these focuses are set as two separate parameters in the *activation focus changed event*.

While the user is just looking around, not pressing any activation keys or anything, the activatable interactor the user is looking at will have the so called *tentative activation focus*. If the user is not looking at any activatable interactor, then no interactor will have the tentative activation focus at that time. By default, the EyeX Engine will not send any events related to this kind of focus, but it is possible to set a parameter on the activatable behavior so that the interactor will receive events whenever the tentative activation focus changes. Please note that it might be costly for performance to have events fired continuously by the EyeX Engine when the tentative activation focus changes. In a future version of the engine we might introduce power states, where tentative activation focus

changed events are not available in low power modes. That said, our current recommendation is to not have an interaction depend solely on tentative activation focus events.

When the user is just about to activate an activatable interactor using an activation button or command, the EyeX Engine enters a mode called activation mode. In this mode, the engine uses even more refined heuristics to decide which activatable interactor is truly in focus and about to be activated. In this mode, the interactor that the user is looking at will have *activation focus*. It will no longer have tentative activation focus. There will always be at most one interactor in focus, either with tentative activation focus or activation focus. The EyeX Engine enforces this rule across all applications, so that several applications that uses EyeX Interaction can run in windows next to each other without confusing the user with multiple focuses/highlights. By default, activatable interactors will always receive *activation focus changed* events when they get or lose the activation focus. This means that these focus changes are suitable to use for visualization of for example pressing or releasing an activatable button.

Action command 'Activate'
The action command corresponding to the *activated* event is the *activate* command. It can be used on its own or together with the *activation mode on/off* commands to implement an interaction involving activatable regions.

When the EyeX Engine receives an *activate* command it will decide which interactor is looked at and send an *activated* event for that interactor. As soon as the command is received and handled in the engine, the engine will switch the activation mode off.

Action command 'Activation Mode On'
In order for interactors to get the *activation focus* described above (see *Activation event 'Activation Focus Changed'*), the EyeX Engine first has to be in the *activation mode*. This mode is switched on using the *activation mode on* command. There is a caveat, though: the engine can only be in one mode simultaneously and some modes override others. The panning mode (described in section *Pannable behavior*) overrides the activation mode, but the activation mode cannot override the panning mode. If the EyeX Engine is in panning mode and receives an *activation mode on* command, it will ignore it. This means that it is not possible to get activation focus on an interactor while panning is ongoing. If this was not the case, the result could be distracting highlights on items one is just scrolling past. If the EyeX Engine on the other hand receives a *panning begin* command when already in activation mode, it will switch to panning mode, and then switch back to activation mode after *panning end* has been received and handled in the engine.

The recommended way to use the activation mode with activatable buttons[2] is to switch it on when the user is just about to activate the button, and then use the *activation focus true* event to trigger a visual feedback which button is about to be clicked (for example by making it look pressed in the GUI). If the activation is triggered by pressing a physical key on the keyboard, a good time to send the *activation mode on* command would be when the physical button is pressed down. Then, the *activate* command could be sent when the physical button is released.

[2] These recommendations are specific for clickable buttons and might not be suitable for other types of activatable regions and interactions involving the activatable behavior.

Action command 'Activation Mode Off'
When the *activation mode on* command has been received by the EyeX Engine, the activation mode will stay on until the engine receives either an *activation mode off* or an *activate* command. This means that the client application typically never has to send an *activation mode off* command.

All action commands are global
All action commands are global, meaning that they apply to the EyeX Engine as a whole. This means that an activation command sent by your client application can trigger an activation of an activatable interactor in another client application. Since you most likely only will send an activation command when your client application window has input focus, it is most probable that your users will only focus on items in your application when invoking activation commands through it. But bear this possibility in mind when designing your application and its action command handling algorithms.

Design and visual feedback
The way you design your application can have a huge effect on the usefulness of the activatable behavior. Here are some guidelines to help you make the best use of this interaction concept:

- Give the user something to focus on: a visual hotspot. This can be as simple as the caption on a button. Sometimes there are several visual hotspots on an interactor, for example, an icon and some text. That's fine too.
- Make sure that the visual hotspots of different interactors are sufficiently separated. For example, add more spacing around the visual elements, and/or make them larger. Note that spacing can be more effective than size.
- Be careful with any visual feedback given; it can be helpful but it can also be distracting. For example, instead of highlighting a whole button, you can highlight only the text or the visual hotspot of the button.

Pannable behavior
An interactor with the Pannable behavior represents a region on the screen that can be panned or scrolled using eye-gaze and a secondary input. For example: a reading pane could be scrolled vertically upwards or downwards as long the user holds down a specific keyboard key and looks at the top or bottom of the reading pane.

To implement the pannable behavior for a region, the client application sends *action commands* to the EyeX Engine and reacts to the *events* the EyeX Engine sends in return. In short: the client application informs the engine that a panning/scrolling interaction is ongoing, the engine informs the client application how to adapt the panning/scrolling speed and direction depending on where the user is looking.

Panning profiles and available panning directions
There are two parameters on the pannable behavior that specify the kind of panning it will generate: the panning profile and the available panning directions.

The panning profile decides what velocities to trigger when the user is looking at different parts of the pannable area. These velocities and trigger areas are optimized for the particular kind of panning or scrolling that the profile corresponds to. For example, the vertical panning profile uses velocities and trigger areas optimized for vertical scrolling, like scrolling a web page, where looking at the upper part of the pannable area will trigger upward velocities, while looking at the lower part will trigger downward velocities. The radial panning profile is optimized for panning in all directions, like panning around a map, and triggers velocities in any direction the user is looking.

In addition to the panning profile, there is also a parameter to set the available panning directions. This might at first seem like redundant information: if I have set a vertical panning profile, then the available panning directions should be up and down, right? Yes and no. The panning profile decides how the panning should work in general and limits the available panning directions according to the velocity profile. But even though a pannable area in general should be possible to scroll both up and down, it might not always be in a state where both directions are available. This is where the parameter for available panning directions comes in handy: it can be used to dynamically keep the set of available directions up-to-date with the current state of the pannable area. For example, it can be used to temporarily remove the up direction while a vertically scrollable area displays its topmost contents and cannot be scrolled up.

Setting the available panning directions only affects the panning behavior if it restricts the number of directions as compared to the directions available for the specific panning profile. If it is set to *none*, there will be no panning events raised by the EyeX Engine for this particular pannable interactor. If it is set to *all*, you will still only get vertical velocities if the panning profile is set to vertical.

Dynamically updating the available panning directions might be critical to make the panning work correctly at end-states. For example, if the GUI component that implements the pannable area has some automatic bouncing or rubber-band effect when reaching its end-states, you might get a very peculiar behavior if the contents is moved simultaneously by panning velocities and the bouncing mechanism. For other cases of GUI components and implementations it might be fine to leave the available panning directions unchanged throughout the interaction, and just ignore the panning events that are not applicable in a specific end-state.

Panning events

While the user is panning and looking at a pannable area, the EyeX Engine continuously raises panning events to the pannable interactor. The panning events contain velocity information: in what velocity the pannable area currently should be panned in the horizontal and vertical directions, expressed in pixels per second. It is these events the client application uses to continuously update the ongoing motion of the contents in the pannable area.

Note that the velocities in the panning events describe the panning behavior of the pannable area itself and not its content. For example, to scroll down a web page (a pannable area), the texts and images on the page (the content) should move up. So, depending on how the scrolling is implemented in the client application, the velocities in the panning events can be used as is, or they have to be inverted.

The EyeX Engine will keep firing panning events as long as there are velocity changes and as long as it believes the area can be panned in the direction indicated by the user's eye-gaze (and the available panning directions).

Action command: 'Panning Begin'

There are two action commands associated with a continuous panning interaction. To start panning, and put the the EyeX Engine in the panning mode, the client application sends the *panning begin* command to the engine.

While in the panning mode, the EyeX Engine continuously sends panning events with velocity information as described above in the section about panning events.

The panning mode overrides any ongoing activation mode.

Action command: 'Panning End'

The *panning end* command will end an ongoing panning and switch off the panning mode in the EyeX Engine. If the panning mode was entered from an ongoing activation mode, the engine will go back to the activation mode.

All action commands are global

All action commands are global, meaning that they apply to the EyeX Engine as a whole. This means that a panning begin command sent by your client application can trigger panning in another client application depending on where the user is looking. Bear this possibility in mind when designing your application and its action command handling algorithms.