Developer's Guide

Tobii EyeX SDK for Unity

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Tobii Tech

The Tobii EyeX Software Development Kit (SDK) for Unity contains everything you need for building games and applications using the Tobii EyeX Engine API and the Unity 3D engine.

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Introduction

The Tobii EyeX Software Development Kit (SDK) for Unity contains everything you need for building games and applications using the Tobii EyeX Engine API and the Unity 3D engine.

The EyeX SDK for Unity can be used with both the Free and Pro versions of Unity. Stand-alone games/applications built from Unity will run on any platform, but the eye-gaze interaction will only work where the EyeX Engine is available; currently Windows 7, Windows 8.1 and Windows 10.

The code samples in the SDK are written in C#. It is also possible to write your scripts in UnityScript (JavaScript), if you prefer.

The EyeX SDK is available in four variants, for C/C++, .NET, Unity 3D, and Unreal Engine 4. Download links are available on the Tobii Developer Zone.

Getting started

Install and make sure Tobii EyeX is running

As the EyeX SDK builds on the EyeX 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

This guide assumes that you have installed Unity 5.3.1 or later, Personal or Professional edition.

The EyeX SDK is distributed as a plain zip file. Extract it to, for example, c:\EyeXSDK.

In this directory you will find a subdirectory called UnityProject, which is a Unity project that can be opened from Unity using the "File", "Open project" menu option. The project should open without any problems[1], and then it should be possible to switch between scenes and run the game just as you normally do in the Unity development environment. The sample scenes are:

- The **GazeAware3DScene**, which demonstrates the use of the *gaze-aware behavior* in a 3D game environment.
- The **ActivatableGuiScene**, which demonstrates the *activatable behavior*, in EyeX Interaction referred to as *direct clicking*, in the context of a 2D game GUI.
- The **TraceEyeGazeScene**, which demonstrates how to retrieve data from a *gaze point* data stream and the *fixation* data stream.
- The **EyePositionScene**, which demonstrates how to use the *eye position* data stream to change the 3D position of game objects.

[1] We have tested this to the extent possible. But because we cannot test every possible combination of hardware and software, there might be corner cases that we have failed to cover. If you experience any problems when opening or running the sample project, please let us know. Thanks.

- The **MapNavigation** scene, which demonstrates how to use the *fixation* data stream to navigate on a map as well as the *pannable behavior* to scroll.
- The **UserPresence** scene, which demonstrates how the *user presence* state can be used to change the appearance of a game character.
- The **GoalKeeper** scene, which demonstrates how to use the *gaze-aware behavior* in a 2D game environment.
- The **FighterJet** scene, which demonstrates the *activatable behavior*, in a 2D game environment.
- The **Spotlight** scene, which demonstrates how to combine the *user presence* state with the *gaze point* data stream to, literally, shine a light on what a user is looking at.
- The **Calibration** scene, which demonstrates how to launch tools for recalibrating or testing the current calibration.

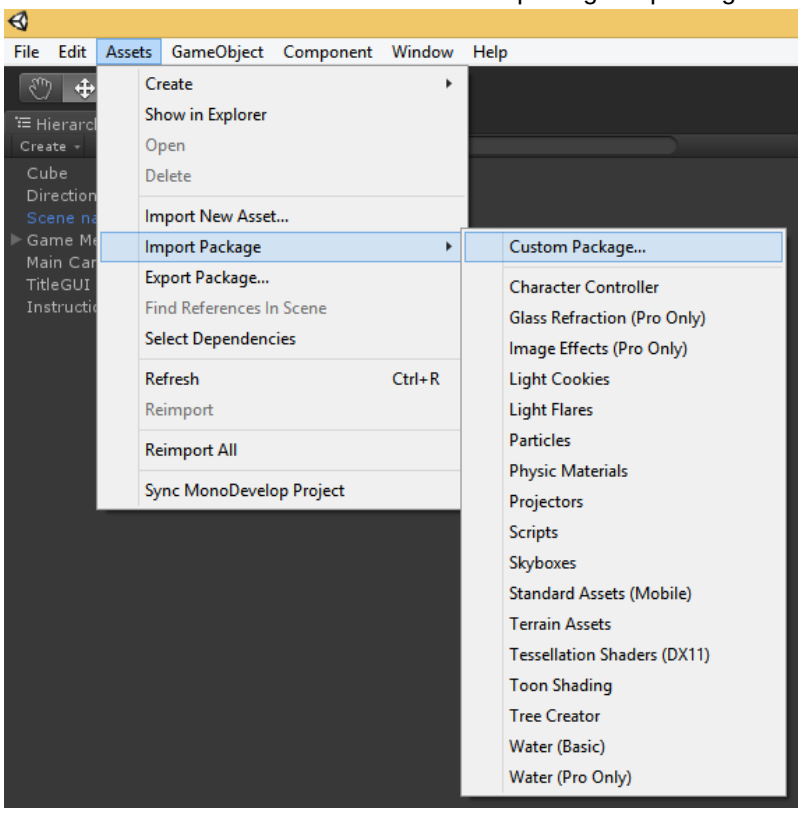
Note. The graphics and gameplay in the sample scenes have been deliberately kept to a minimum so as not to get in the way of the code.

Importing the EyeX Framework to an existing game

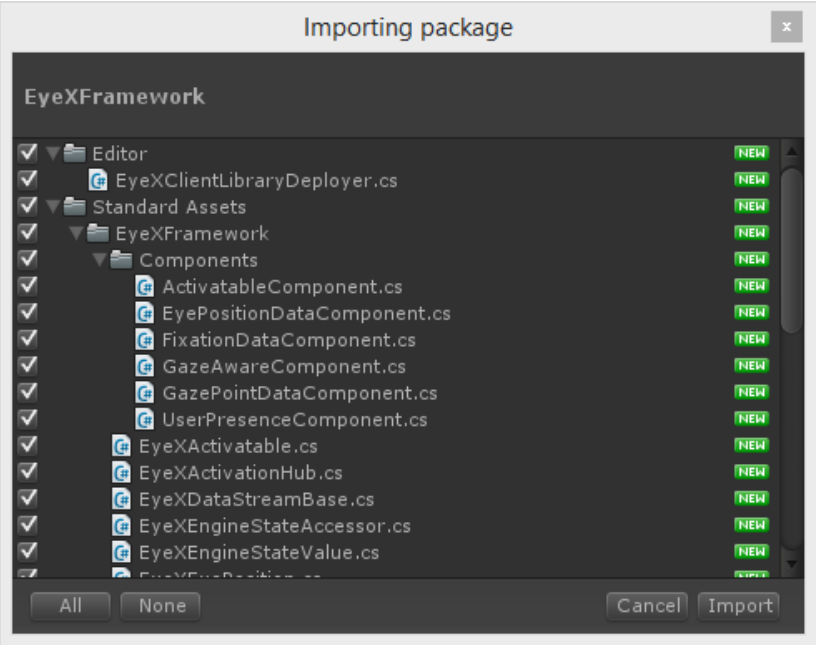
When you feel ready to start using EyeX interaction concepts in your own game, the first thing you need to do is to import the EyeX Framework.

1) Open your Unity project.

2) From the main menu, select “Assets”, “Import Package”, “Custom Package…”, then select the file *EyeXFramework.unityPackage* from the directory where you extracted the EyeX SDK. You can also double-click the file to start importing the package.



3) In the “Importing package” dialog, select the assets you want to import. If you are unsure, it is recommended to select all the assets.



After pressing “Import”, you should be ready to use the EyeX Framework in your game. More information about what the EyeX Framework contains is presented in subsequent chapters.

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.

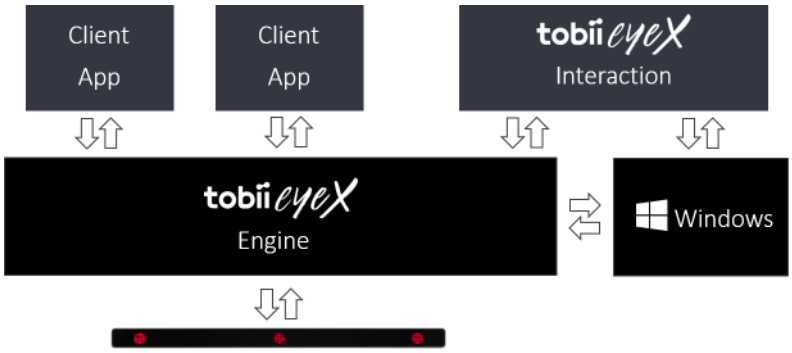
Apart from that, it depends on what you want to do—or how you wish to use the Tobii EyeX interaction concepts in your game or application. Remember that the Tobii Developer Zone is there for you if you need inspiration or if you get stuck.

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.

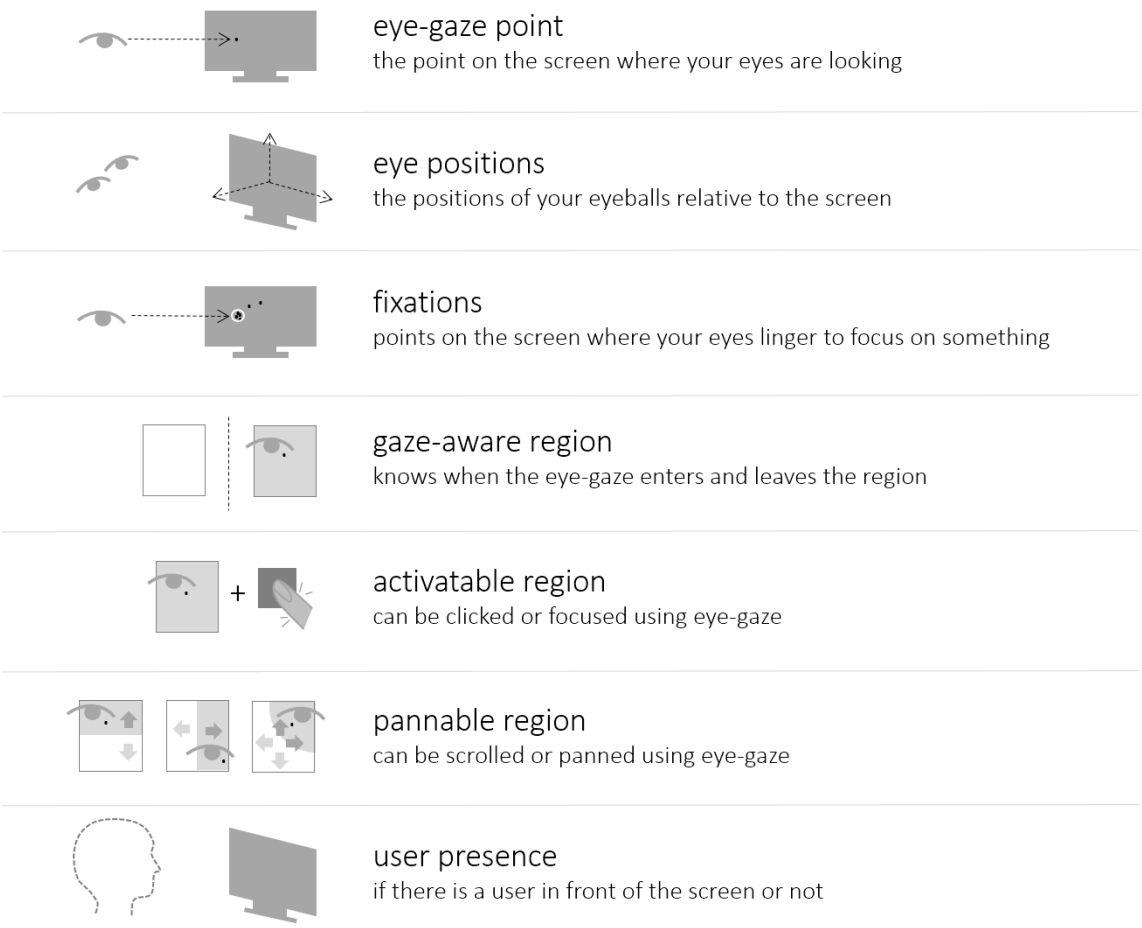


Figure 1 A somewhat simplified view of what the EyeX Engine API can do for you.

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

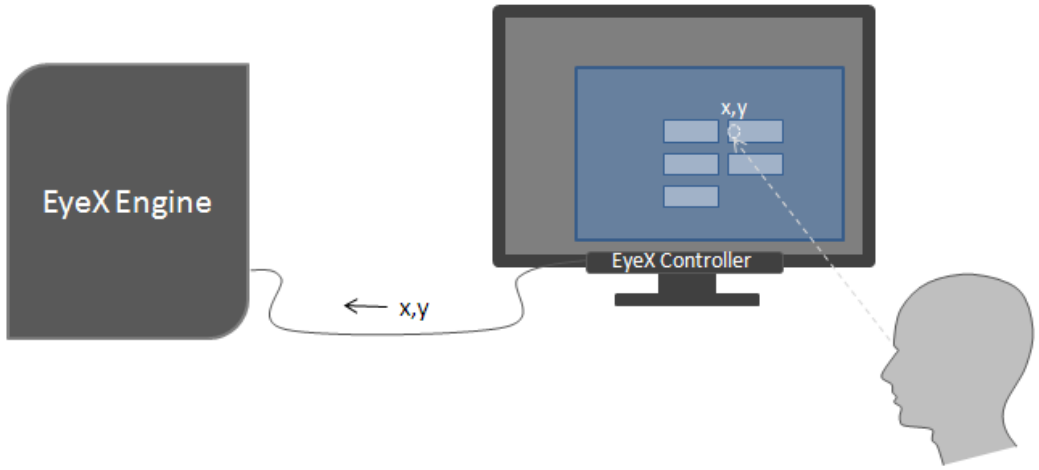
of the display the eye tracker is currently setup for, the currently selected user calibration profile, or if the eye tracker is currently available.

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.

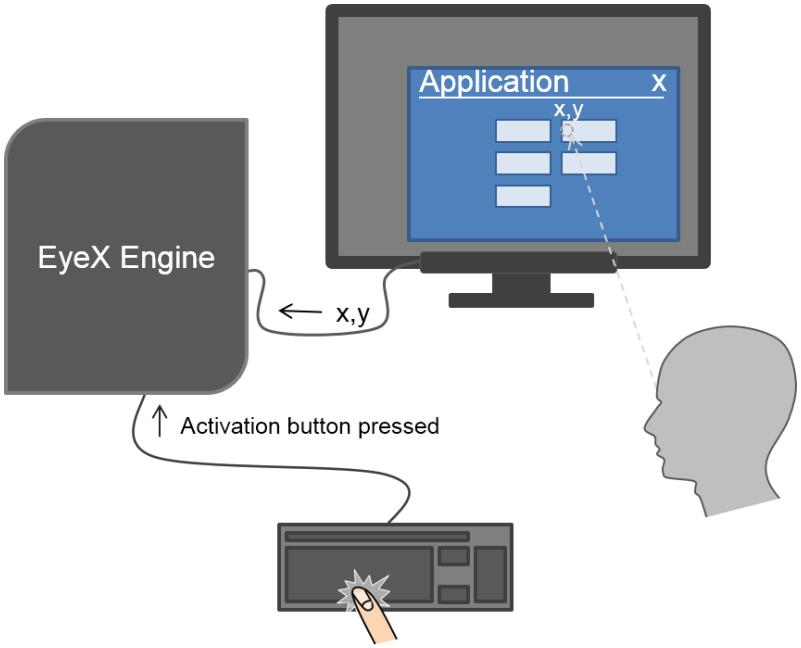
How the engine knows what you are looking at

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.

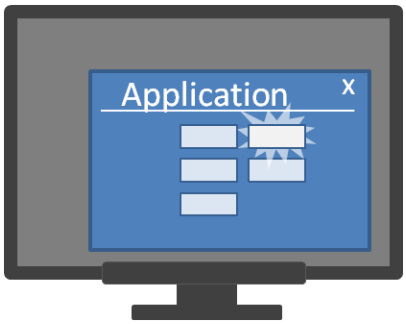


2. The EyeX Engine uses information from the client application to understand what kind of visual object the user is looking at and might want to interact with. Let's say the rectangles on the screen are buttons with the 'Activatable' behavior. That means that they can be clicked using eye gaze. The 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 EyeX framework for Unity

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 Unity 3D developers, the EyeX SDK for Unity includes the **EyeX Framework for Unity**, which is a layer of utility classes built on top of the API exposed by the EyeX Engine client library.

The EyeX Framework for Unity makes it easy to set up data providers for different kinds of EyeX data, as well as for creating region-bound interactors with specific EyeX behaviors, all within your Unity project. There are also a number of ready-made components for the most common API functions.

This section describes the usage of the EyeX Framework for Unity. For a full description of the concepts in the EyeX Engine API, see the section *EyeX Engine API reference*.

Anatomy of the Unity sample project

The Unity sample project included in the SDK package can be thought of as consisting of two parts: the EyeX framework for Unity on one hand and demo scenes and corresponding assets on the other.

The framework script files can be found in the **Assets/StandardAssets/EyeXFramework** directory; there is also an editor class in the **Assets/Editor** directory that helps with deployment of the EyeX client library files. The demo scenes and demo assets are in the **Assets/EyeXDemos** directory.

Note that the script and framework files are all normal C# source code files, licensed with a liberal open source license, so you are free to modify them as you wish.

Tobii EyeX dll's

In addition to the script files in the EyeX Framework for Unity, there are also two dll's that that are needed in order to use EyeX in your Unity project. First, there is the client library called **Tobii.EyeX.Client.dll** that should be in the Unity project directory. Second, there is the client library for .NET, **Tobii.EyeX.Client.Net20.dll**, which should be in the Assets/Plugins directory.

The dll´s in the sample project are 32-bit libraries for use with 32-bit processes. The Unity 4 editor is 32-bit, as is the default player that is packed with the game when you build it as stand-alone. But if you change the build options to create a 64-bit build, then you will need to replace the EyeX dll's with their 64-bit counterparts. Those can be found in the lib/x64 directory.

EyeXHost

The **EyeXHost** class is the hub of the EyeX framework for Unity. The EyeXHost is the single point of contact with the EyeX Engine. There will always be a single instance of this class, and that instance is accessed through the static `GetInstance` method.

Through the EyeXHost you will access the data providers, states and region-bound interactors.

EyeX Data Providers

The EyeX framework for Unity contains a number of data providers. These are convenience classes that wrap a data stream or a so called global interactor. A data provider has methods for `Start()` and `Stop()` and a property `Last` that always contain the most recent value if the provider has been started.

To get a reference to a data provider of a specific type, the corresponding get method is called on the EyeXHost:

- `GetGazePointDataProvider(GazePointDataMode mode)`
- `GetFixationDataProvider(FixationDataMode mode)`
- `GetEyePositionDataProvider()`

The mode parameters specify the kind of processing the EyeX Engine should perform.

The `Last` value is updated asynchronously from the EyeX Engine, independent of the frame rate of the game. This means that if the `Last` value is read multiple times in a frame (for example from the Update method in different `MonoBehaviour` scripts), the value returned can be different for each call.

For more information about the different kinds of data streams available, see the section *Data streams*.

Example: A script that prints the current gaze point

Below is a script that initiates a gaze point data provider, starts it, and in the `Update()` method gets the gaze point value from the Last property and prints its screen coordinates.

```
using Tobii.EyeX.Framework;
using UnityEngine;

public class GazePointPrinter : MonoBehaviour
{
    private EyeXHost _eyeXHost;
    private IEyeXDataProvider<EyeXGazePoint> _gazePointProvider;

    public void Awake()
    {
        _eyeXHost = EyeXHost.GetInstance();
        _gazePointProvider = _eyeXHost.GetGazePointDataProvider(
                                        GazePointDataMode.LightlyFiltered);
    }

    public void OnEnable()
    {
        _gazePointProvider.Start();
    }

    public void OnDisable()
    {
        _gazePointProvider.Stop();
    }

    public void Update()
    {
        var gazePoint = _gazePointProvider.Last;
        print(string.Format("X: {0}  Y: {1}",
              gazePoint.Screen.x, gazePoint.Screen.y));
    }
}
```

The `EyeXGazePoint` object that is returned by the `Last` property include convenient methods called `Screen, GUI`, `Viewport` and `Display`, to get the gaze point in other coordinate systems. Please refer to the section about Physical Pixels and Unity Coordinate Systems below.

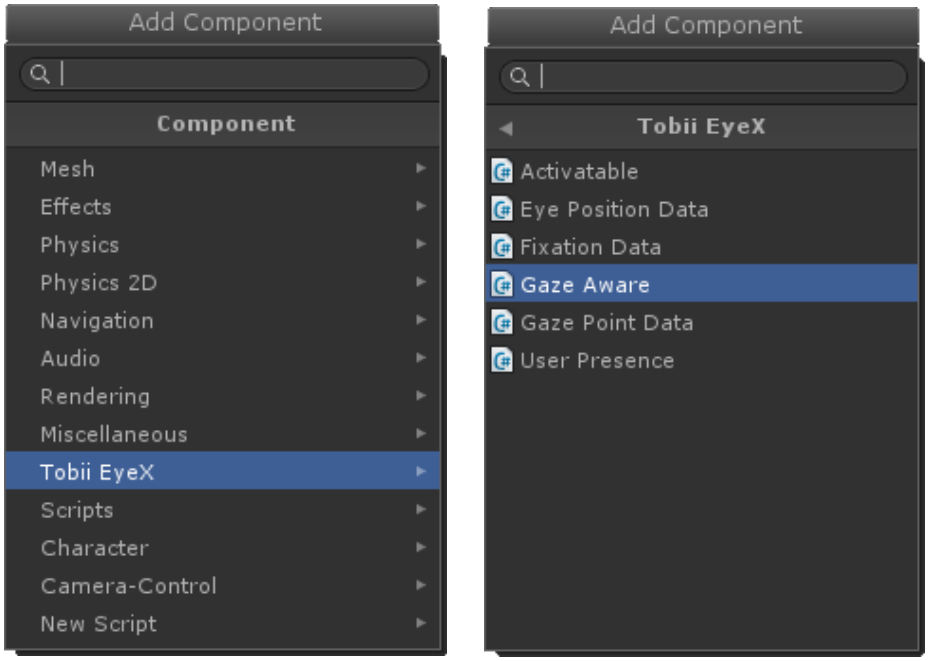
To make sure that the gaze point is within the bounds of the width and height of the `UnityEngine.Screen`, use the query method `IsWithinScreenBounds`. The `IsValid` method returns true if the gaze point contains a gaze point value detected by the EyeXEngine. A valid value can be negative or larger than the width and height of the `UnityEngine.Screen` if the user is looking outside of the bounds of the game.

Using components to access EyeX Engine API functionality

In version 1.1 of the EyeX Framework, we have introduced components to encapsulate the most common scenarios. The Data Stream components should be straight forward to use. The components for EyeX Behavior, on the other hand, only work if you have a limited amount of game objects in your game. They do not scale well and have some inherent limitations how well they will map the user's eye-gaze to a specific game object. But for simple games and prototypes these behavior components enable you to easily add and try out Tobii EyeX interaction concepts. More information about the

different aspects of EyeX Engine API can be read in the section *Overview of the Tobii EyeX Engine API*.

To attach an EyeX Framework component to a game object, click “Add Component” and browse to the “Tobii EyeX” sub menu, where you can select the component of choice.



The examples below show how the EyeX Framework components are used from other scripts. Note that the component is retrieved in the `Update()` method for brevity reasons, but it is not recommended that you do this in your own application or game. Always cache components you're planning to use in your script's `Start()` method. You may also want to use the `RequireComponent` attribute on your script to clarify dependencies to one or several types of components.

Gaze Point Data

Gaze point data exposes the point on the screen where your eyes are looking. To use this component from another component script, simply retrieve the component and get the last gaze point. The last gaze point have several convenience methods to convert the eye position coordinates to other coordinate systems. An example of how to use the Gaze Point Data component can be found in the *GazeAware3D* and *Spotlight* demo scenes.

```
void Update()
{
    // Get the last gaze point.
    var lastGazePoint =
            GetComponent<GazePointDataComponent>().LastGazePoint;

    if(lastGazePoint.IsWithinScreenBounds)
    {
        // Get the point in screen space coordinates.
        var screenSpace = lastGazePoint.Screen;
    }
}
```

Eye Position Data

The eye position data component exposes the positions of your eyeballs relative to the screen. An example of how to use the Eye Position Data component can be found in the *EyePosition* demo scene.

```
void Update()
{
    // Get the last eye position.
    var lastEyePosition =
           GetComponent<EyePositionDataComponent>().LastEyePosition;

    if(lastEyePosition.IsValid)
    {
        // Get the position of the left eye.
        var leftEyePosition = new Vector3(lastEyePosition.LeftEye.X,
            lastEyePosition.LeftEye.Y, lastEyePosition.LeftEye.Z);
    }
}
```

Fixation Data

Fixation data exposes the points on the screen where your eyes linger to focus on something. An example of how to use the Fixation Data component can be found in the *MapNavigation* demo scene.

```
void Update()
{
    // Get the last fixation point.
    var lastFixation =
           GetComponent<FixationDataComponent>().LastFixation;

    if(lastFixation.IsValid && lastFixation.IsWithinScreenBounds)
    {
        if(lastFixation.EventType == FixationDataEventType.Begin)
        {
            // A fixation started.
        }
        else if(lastFixation.EventType == FixationDataEventType.Data)
        {
            // Fixation data is being retrieved.
        }
        else if(lastFixation.EventType == FixationDataEventType.End)
        {
            // The fixation ended.
        }

        // Convert the fixation point to screen space.
        var screenSpace = lastFixation.GazePoint.Screen;
    }
}
```

Gaze-aware

Adding a Gaze-aware component to your GameObject makes it possible to know when the user is looking at it. An example of how to use the Gaze-aware component can be found in the *GoalKeeper* demo scene.

```
void Update()
{
    if(GetComponent<GazeAwareComponent>().HasGaze)
    {
        // The game object is being looked at.
    }
}
```

Activatable

By adding an activatable component to your GameObject, it can be clicked or focused using eye-gaze. In short: EyeX tells you which object the player looked at when pressing a specified activation key in your game. An example of how to use the Activatable component can be found in the *FighterJet* demo scene.

```
void Update()
{
    if(GetComponent<ActivatableComponent>().HasActivationFocus)
    {
        // The game object has activation focus.
    }
    if(GetComponent<ActivatableComponent>().IsActivated)
    {
        // The game object has been activated.
    }
    if(Input.GetKeyDown(KeyCode.Space)) // Trigger activation focus mode
    {
        GetComponent<ActivatableComponent>().ActivationModeOn();
    }
    if(Input.GetKeyUp(KeyCode.Space)) // Trigger an activation
    {
        GetComponent<ActivatableComponent>().Activate();
    }
}
```

Pannable

Adding a pannable component to your GameObject makes it possible to receive a panning velocity when the user is looking at the component while panning is ongoing. For example, while the user is holding down a specified panning key.

```
void Update()
{
    // Get the panning velocity.
    Vector2 velocity = GetComponent<PannableComponent>().Velocity;

    if(Input.GetKeyDown(KeyCode.Space)) // Trigger panning to begin
    {
        GetComponent<PannableComponent>().BeginPanning();
    }
    if(Input.GetKeyUp(KeyCode.Space)) // Trigger panning to end
    {
        GetComponent<PannableComponent>().EndPanning();
    }
}
```

An example of how to use panning can be found in the MapNavigation scene.

User Presence

The user presence component is perfect for those situations when you want to know if the user is looking at the screen. An example of how to use the User Presence component can be found in the *UserPresence* demo scene.

```
void Update()
{
    if(GetComponent<UserPresenceComponent>().IsUserPresent)
    {
        // The user is present.
    }
}
```

Most of the API functionality will be accessed from the components. However, if you are interesting in knowing more about what the EyeX Framework contains, there are other classes to look at.

Region-based Interactors

The EyeXHost object keeps a repository, or cache, of so called region-based interactors, that it uses when responding to queries from the engine. A region-based interactor is an interactor that is tied to a specific region on the screen and has an EyeX behavior defined for that region.

For example, a game object in a 2D game may have an interactor associated with its bounding box on the screen. As long as the player looks at or close to the game object, the EyeXHost will continuously send the interactor to the EyeX Engine with a position and size that correspond to the game object's current position and size. Region-based interactors are created using the **EyeXInteractor** class and need to be registered with the EyeXHost to be sent to the EyeX Engine.

Example: Creating an EyeXInteractor with the Gaze-aware EyeX behavior

The following code snippet shows how an interactor with the Gaze-aware EyeX behavior is created and registered with the EyeXHost.

```
var interactor = new EyeXInteractor(interactorId, EyeXHost.NoParent);
interactor.EyeXBehaviors.Add(new EyeXGazeAware());
var locationRect = new Rect(xPosition, yPosition, width, height);
interactor.Location = new ProjectedRect() { isValid = isVisible,
                                            rect = locationRect,
                                            relativeZ = 1000 };
_eyeXHost.RegisterInteractor(interactor);
```

In every rendering frame, the location of the EyeXInteractor has to be updated if the location of the region it corresponds to has moved. This is done by setting a new `Location` on the EyeXInteractor. To get hold of a registered EyeXInteractor, call the method `GetInteractor(interactorId)` on the EyeXHost.

Example: Creating an EyeXInteractor with the Activatable behavior

The activatable behavior can be created in a similar banner as in the Gaze-aware example above. The main difference is that there are other types of events that can be generated by the activatable

behavior, i.e. **tentative focus**, **activation focus** and **activation**. To learn more about what these events mean, take a look at the general section about the activatable behavior.

When creating an EyeXActivatable instance, one can choose whether or not to enable the tentative activation focus events; the default value is false. The constructor also requires a reference to an IEyeXActivationHub object, which makes sure that activation-related events appear consistently within rendering frames: two objects should not be activated on the same time.

```
interactor.EyeXBehaviors.Add(new EyeXActivatable(_eyeXHost.ActivationHub) {
IsTentativeFocusEnabled = true });
```

Then, in the `Update()` method or other suitable part of the code where you want to know the player's activation intentions, you can call `IsActivated()` or `GetActivationFocusState()` on the interactor you are interested in. The possible activation focus states are `None`, `HasActivationFocus` and `HasTentativeActivationFocus`.

EyeXGameObjectInteractorBase

The EyeX Framework for Unity contains a base class called **EyeXGameObjectInteractorBase** that is a MonoBehaviour that can automatically create an EyeXInteractor that corresponds to the bounding box of the game object the script is attached to.

EyeXGameObjectInteractorBase keeps the screen location of the game object updated, based on a viewport projection using the main camera. You can try different settings of the `Mask Type` property in the inspector to find a better working approximation of the game object's bounds. Note that the used projection and ray-casting works well in 2D but not optimally in 3D.

The scripts that derive from EyeXGameObjectInteractorBase have to implement the abstract method `GetGameObjectInteractorEyeXBehaviors()`. This method should return a list of the EyeX behaviors that the game object interactor should have.

Example: Adding the Gaze-aware behavior to a game object interactor

The following code snippet shows how a game object interactor can be made gaze-aware by having a script deriving from the EyeXGameObjectInteractorBase and implementing the method that returns the list of EyeX behaviors the interactor should have.

```
protected override IList<IEyeXBehavior>
                                    GetEyeXBehaviorsForGameObjectInteractor()
{
    return new List<IEyeXBehavior>() { new EyeXGazeAware() };
}
```

Then, in the `Update()` method of the same script, you can call the `GameObjectInteractor.HasGaze()` method to know whether the player's eye-gaze is currently on the game object or not.

Alternatives to using the EyeX framework for Unity

The EyeX framework for Unity is NOT the One True Way to hook up a game with the EyeX Engine. Its use of projected rectangles and a repository of interactors is just one design alternative out of many. If you have a scene with several game objects partially obscuring each other, so that the projections

don't work that well, or if you have a busy scene with lots and lots of game objects, then this design alternative might not be the best choice for you. For example, you might want to use ray casting/sphere casting when looking up interactors instead of keeping them in a repository; that's another design with its own pros and cons.

Physical pixels and Unity coordinate systems

Points on the screen are always given in **physical pixels** in the EyeX Engine API.

Unity, on the other hand, uses several coordinate systems:

- The 3D world coordinate system, which can be projected to screen space coordinates using the `Camera.WorldToScreen` method.
- The screen space coordinate system. This coordinate system is bottom-left based and inside the game window, which will be in different positions on the screen depending on if you're in windowed mode, full-screen mode, or running within the Unity editor.
- The viewport coordinate system which is a normalized form of the screen space system.
- The GUI space coordinate system. This coordinate system is like the screen space system but with the y axis in the opposite direction; the origin is in the top left corner of the game window.

The Unity sample project includes helper functions for mapping between the coordinate systems. These should be enough for most Unity games, but you can always replace them with your own if you need more advanced functionality. In that case we'd recommend reading the section on physical pixels in the C/C++ developer's guide for more in-depth coverage of coordinate transformations.

Debugging with Unity and MonoDevelop

The EyeX client library has been adapted for use with the Mono runtime and the Mono soft debugger. Debugging works as usual with EyeX library code, with one exception:

Due to a limitation of the Mono soft debugger, stack frames won't be displayed correctly for callbacks from unmanaged threads. This means that breakpoints placed in callback functions, such as HandleEvent and HandleQuery, won't trigger the way you would normally expect. The script will still break on the breakpoint, but you might not see it in MonoDevelop. So before you declare the process hung and reach for the task manager to kill it, have a look at the continue button in MonoDevelop. Chances are that you have struck a breakpoint without noticing it, and that you can resume by pressing the continue button.

And remember that you can always use Unity's print function to generate a debug trace as an alternative to placing breakpoints in the callback functions.

Building and distributing your game

Your game can be built as a stand-alone Windows executable using the "File", "Build settings" or "File", "Build & Run" menu commands from Unity, as usual. If you have imported the editor class **EyeXClientLibraryDeployer** from the EyeX Framework, this class will automatically copy the correct, 32-bit or 64-bit, version of the EyeX client library to the game directory. If you do not have that class in your project so you will have to copy that file yourself. That is: copy the file called *Tobii.EyeX.Client.dll* from the Unity project directory to the directory where your game was just built—the same directory as the .exe file, that is. Also, note that if you wish to build your game for the x86_64 architecture, then

you will need to replace the EyeX dll's in the Unity project with those from the lib/x64 directory in the EyeXFramework folder.

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. If you create an installer for your game, then you can add these libraries as a merge module and have them installed automatically.

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.

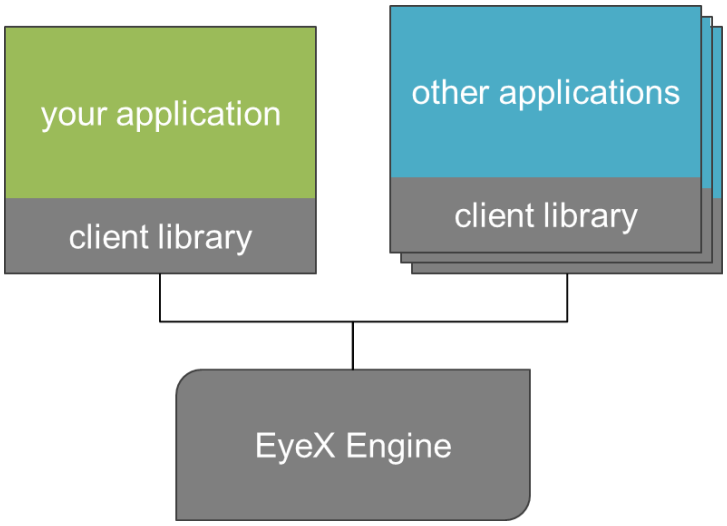


Figure 2 Your application and its relationship to the EyeX Engine.

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.

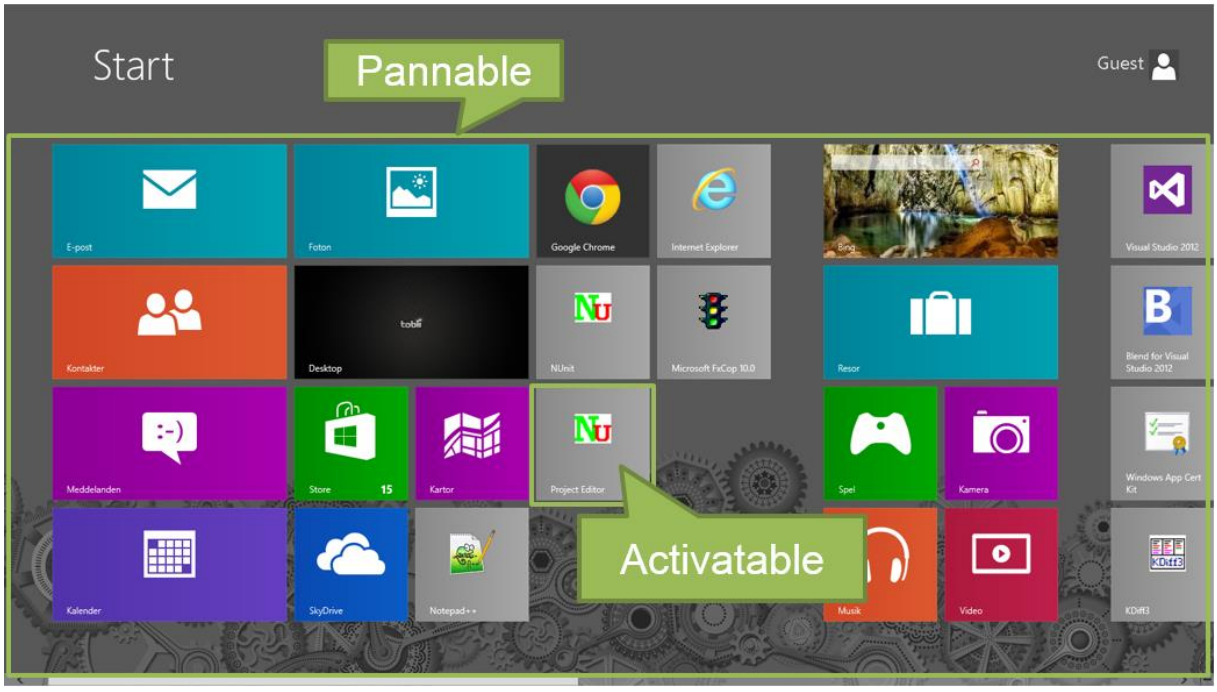


Figure 3 Examples of region-bound interactors

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[2] 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.

The Query-Snapshot cycle

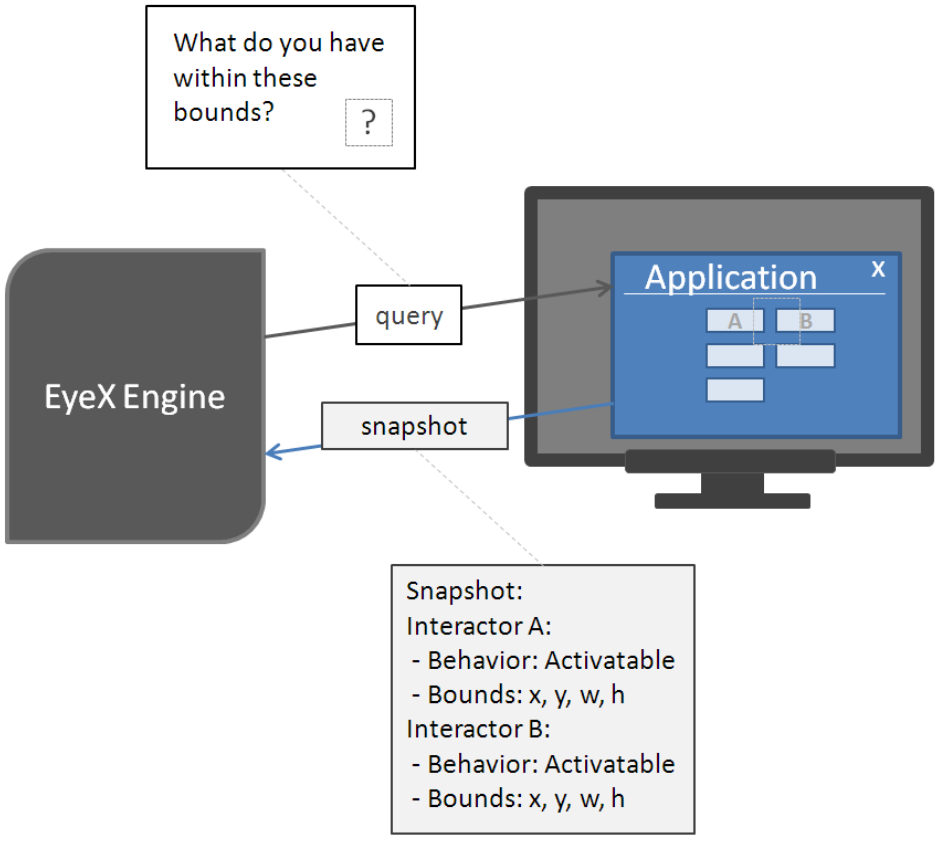


Figure 4 The Query-Snapshot cycle.

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.

[2] "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.

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.

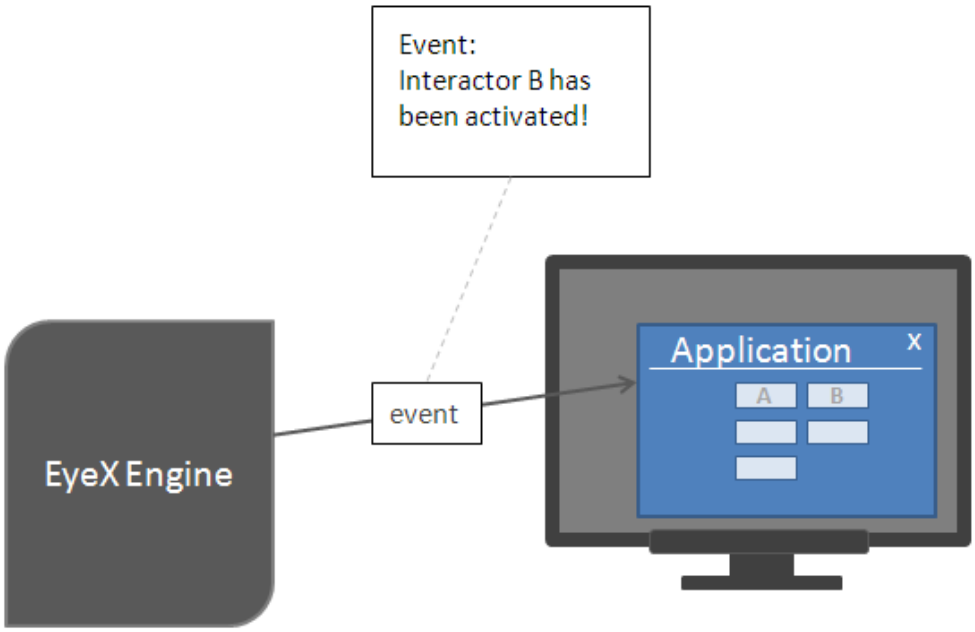


Figure 5 Event notification on a region-bound interactor

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.

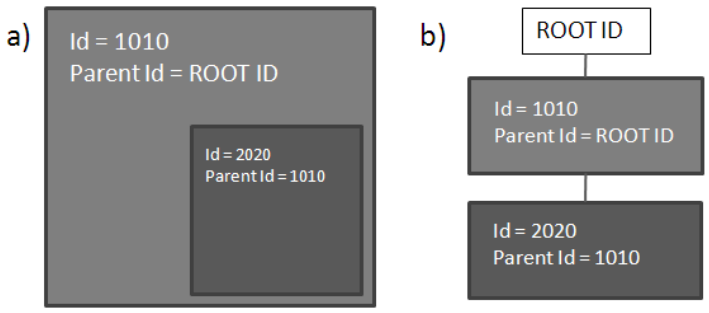


Figure 6 a) Nestled interactors, where the child interactor is overlapping its parent interactor. b) The corresponding interactor tree-structure.

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 a interactor tree-structure so that the interactors overlap as intended. This is illustrated in Figure 7 and Figure 8.

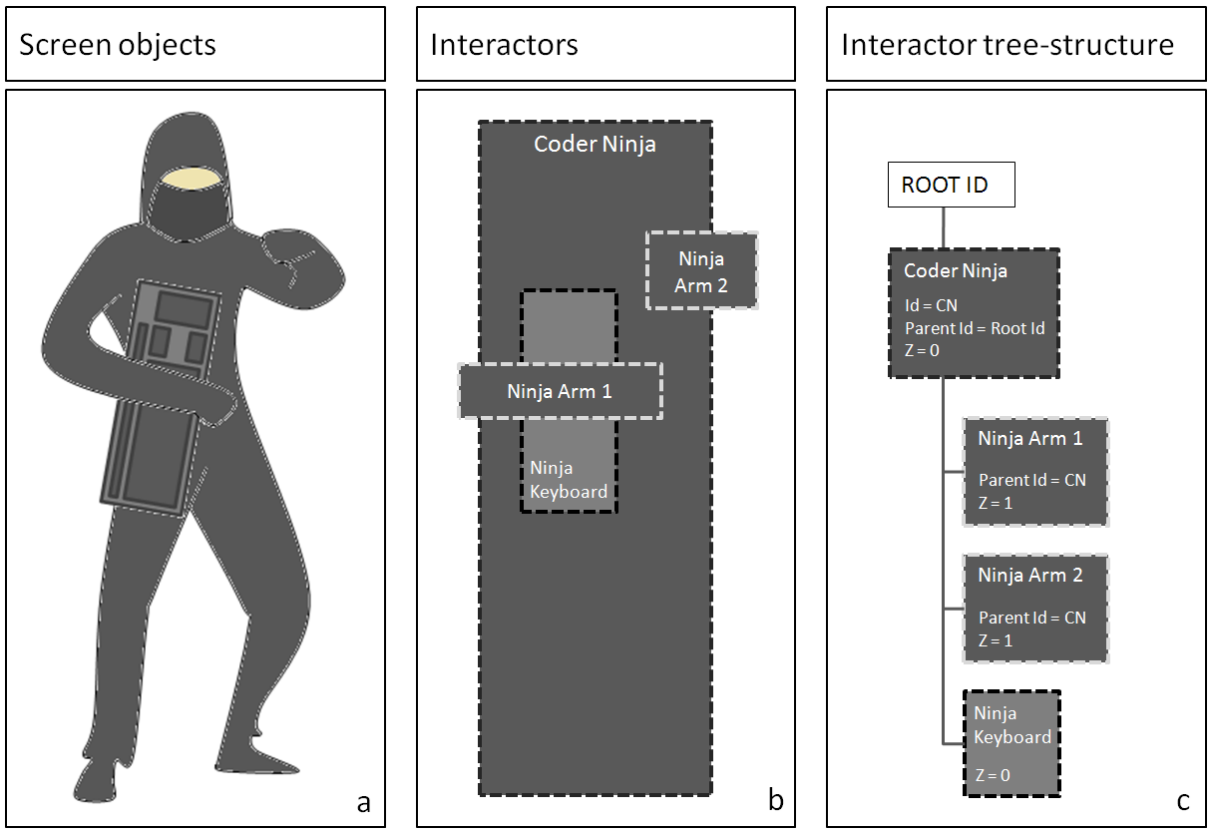


Figure 7 a) Coder Ninja with Ninja Keyboard b) Corresponding overlapping interactors. c) By making the Ninja Arm 1 and the Ninja Keyboard children of the Coder Ninja, but with different Z order, the EyeX Engine is told that they are both in front of the Coder Ninja, but that the arm is in front of the keyboard. The Z order of the other arm does not matter, since it does not overlap any of its siblings.

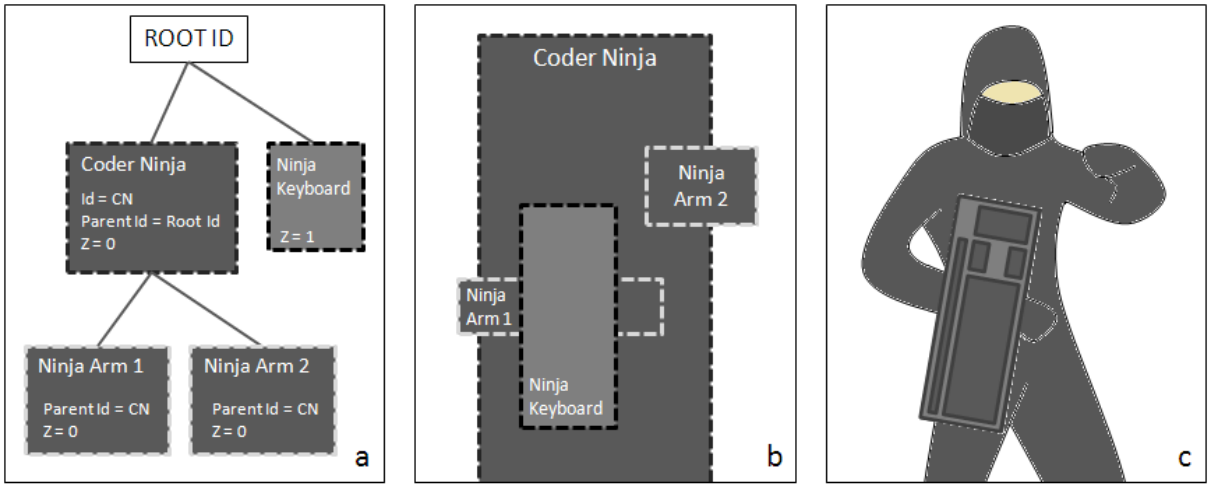


Figure 8 Making the Ninja Keyboard a higher Z order sibling of the Coder Ninja (a), would not only put it in front of the Coder Ninja but also all of Coder Ninja's child interactors, including the Ninja Arm 1 (b and c).

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.

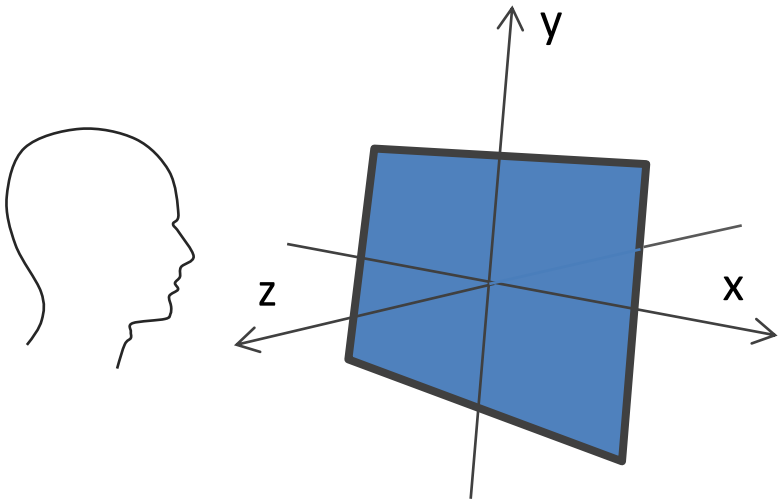


Figure 9 The 3D coordinate system used by the EyeX Engine.

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.

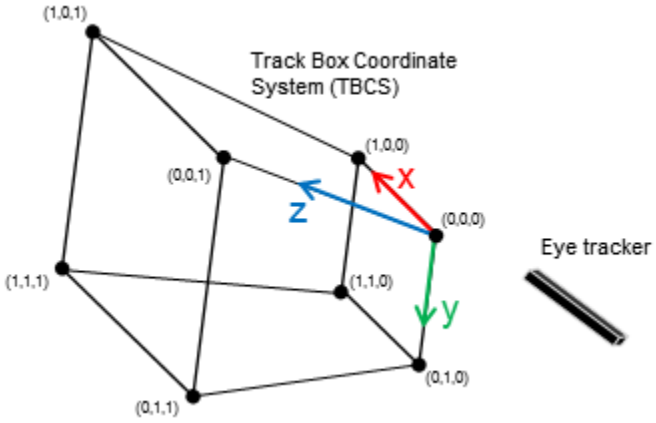


Figure 10 The track box coordinate system.

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 Unity 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.

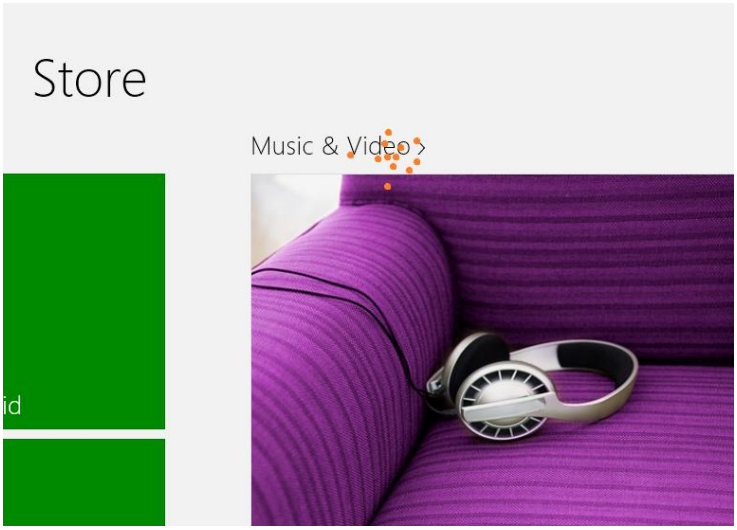


Figure 11 The gaze point is an inherently noisy signal. The orange dots on this screenshot represent the user's gaze point during a fraction of a second. Filtering makes the point cloud shrink towards its center, but also respond slower to rapid eye movements.

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.

The gaze point is given in physical pixels. If you haven't already done so, take a look at the section called Physical pixels and Unity coordinate systems below for an explanation of how these pixels relate to Unity's coordinate systems.

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.

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. See the section 3D Coordinate system for a description of the coordinate system used.

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

Good to know about the Eye position data from the EyeX Controller

There are some limitations to the smoothness of the eye position data stream from the EyeX Controller eye tracking device.

The distance of the eyes to the eye tracker is not updated while the user's eyes are moving in 3D space. It is only updated when the user's eyes have been still for a moment. This is because the tracker needs to have some images taken in sequence at a similar distance before the correct distance can be calculated.

This means that the eye position will follow smoothly when moving the eyes and the head at a roughly fixed distance from the screen, like when you are leaning from side to side, but it will not follow smoothly when the eyes and the head is moved depth-wise relative to the eye tracker, like when you are leaning towards or away from the computer monitor. In the latter kind of movement, there will be a jump from estimated eye positions to the calculated eye positions when the movement is stopped.

The calculated distance to the eyes may have an offset depending on the user's eye size, so the eye position values should not be used for absolute positioning.

Any user experience based on the eye position data stream should be designed with these limitations in mind.

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.

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

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.

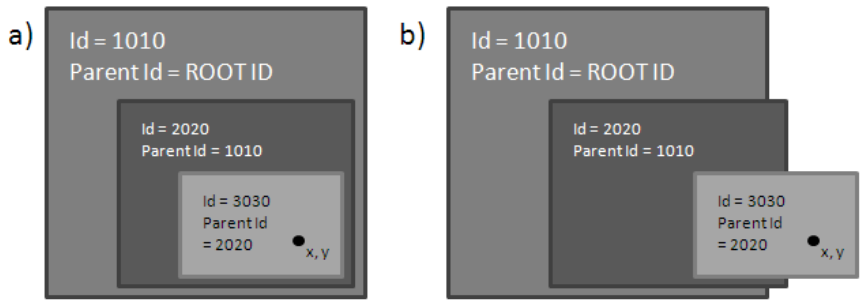


Figure 12 Nested Gaze-aware interactors: The gaze point at (x, y) is considered to be within the bounds of the parent interactors, no matter if it is a) geometrically within or b) geometrically outside the parent interactors' bounds. Moving the gaze point between child interactors does not trigger any 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[3] 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.

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.

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

- 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.