Article

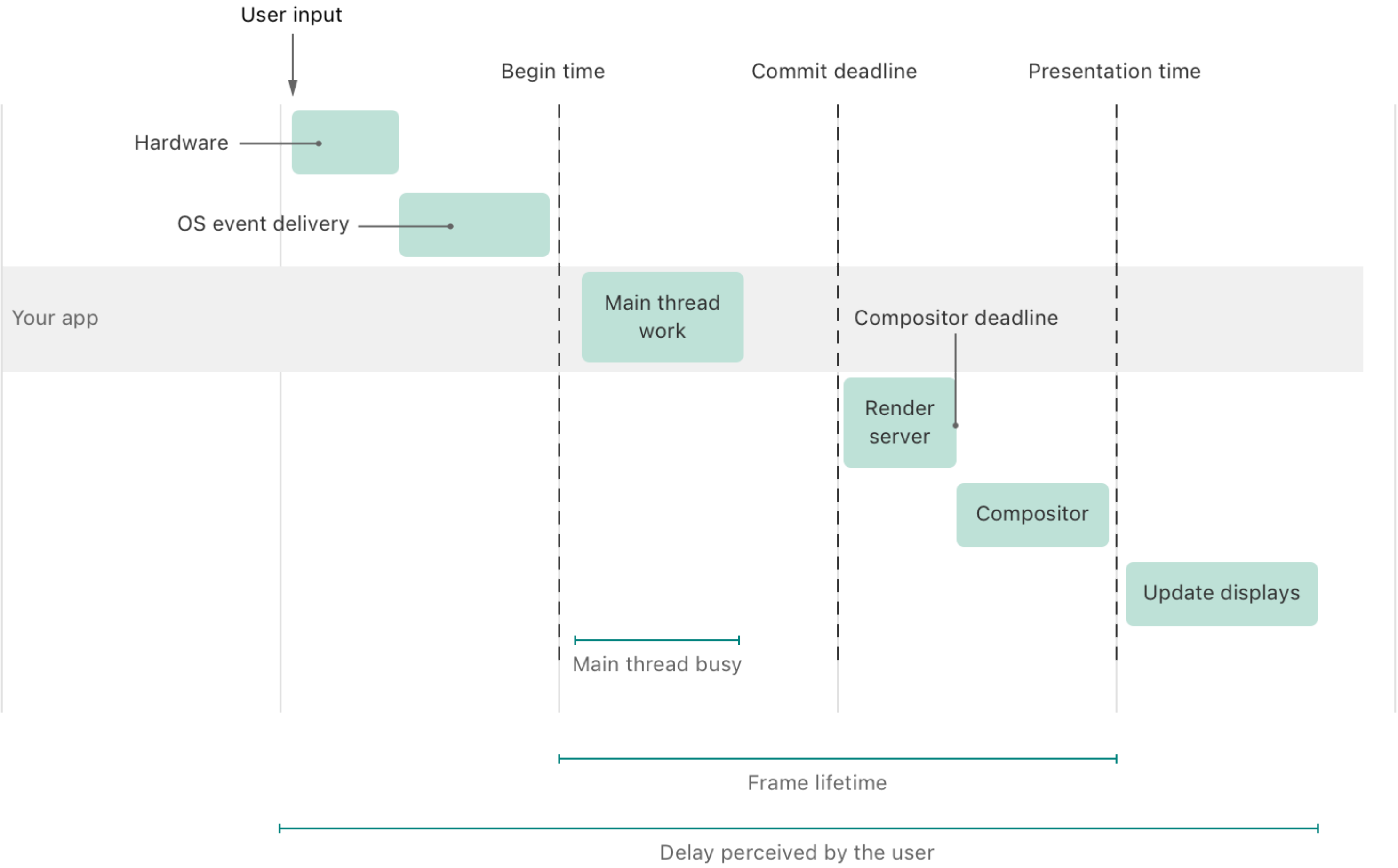
Understanding the visionOS render pipeline

Compare how visionOS handles events and manages its rendering loop differently from other Apple platforms.

Overview

Like other Apple platforms, visionOS renders changes to the UI in response to updates your app makes, input events, callbacks from actions you initiate, timers, and notifications. Unique on Apple Vision Pro, the system renders updates to the images the device displays in order to reposition the UI relative to changes in head position. When the system detects eye and hand movement, deliberate or inadvertent, it requires additional processing to determine what a person is looking at, or interacting with, to calculate a response. The system does a lot more to render an up-to-date UI and account for input from spatial algorithms.

The following diagram illustrates how input propagates through the system and updates content in visionOS:



User input

A person initiates an interaction through a look, hand gesture, a keyboard, or pointing device.

Hardware

Sensors, or other hardware, recognize the input and forward it to the operating system (OS).

OS event delivery

The OS relies on collision detection to determine which entity or entities to direct an interaction to, and the process responsible for handling the user input event — the app that owns the scene where the event occurs.

Main thread work

The system puts the event into an app-specific queue, and your app's main thread picks up those events from the queue and processes them. Your app updates its audio and visual output in response to these events. Your app updates the shared render server with any changes to the UI view hierarchy and 3D RealityKit based content.

Render server

The *render server* is a continuously running process (`backboardd`) that receives updates from all the running apps and other processes with Core Animation and RealityKit content to display. The render server processes the updates and composites them into a single drawable image. It sends this combined image to the compositor.

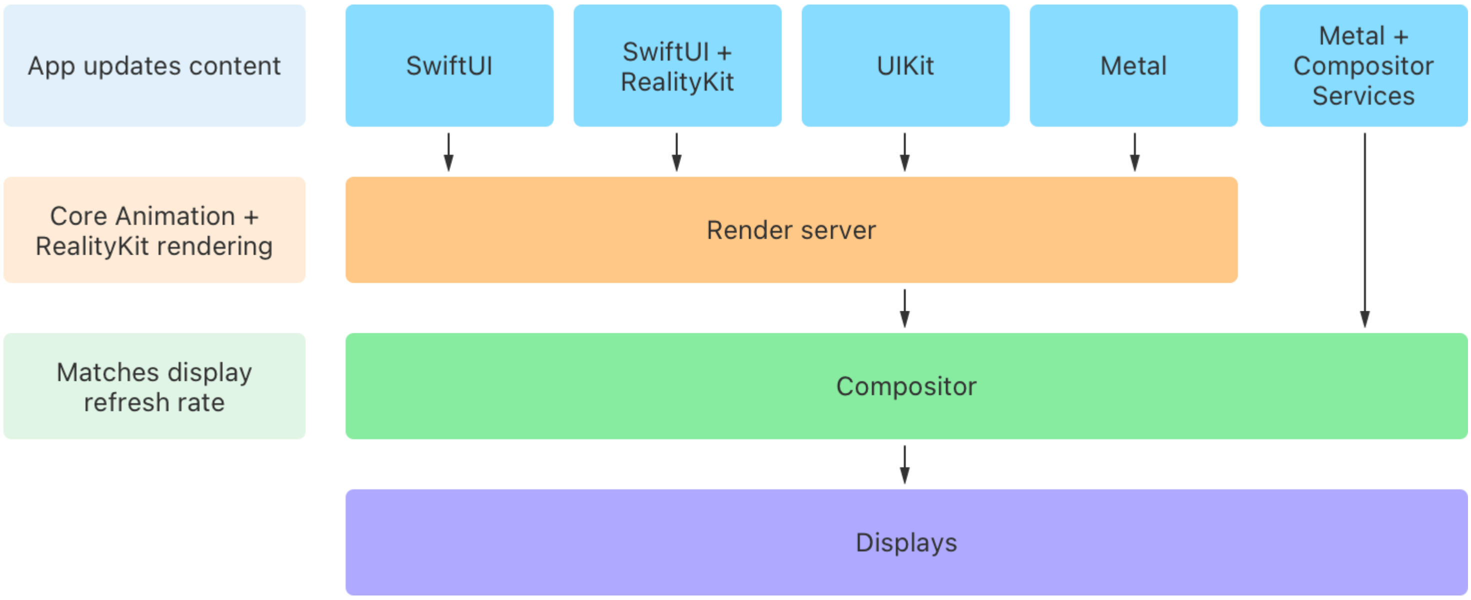
Compositor

The *compositor*, another continuously running process, receives the image frames from the render server, processes data about your surroundings from Apple Vision Pro sensors and cameras, then combines them into a set of images to display. To maintain visual smoothness, the compositor strives to maintain a consistent display refresh rate.

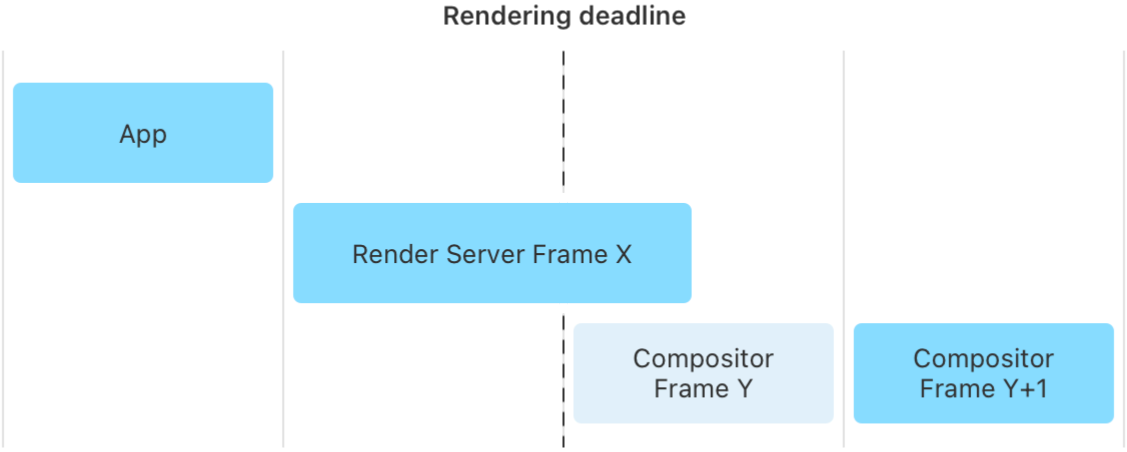
Update display

On visionOS, the display driver wakes up at a regular interval to update the display with the new image from the compositor. This differs from other platforms where the display driver checks at regular intervals with the render server to determine whether the screen needs updating.

In the Shared Space, each app updates its own UI and 3D content and syncs the updates to its view hierarchy and content to the shared render server. This server renders the updates from multiple apps running side-by-side. Then, the render server works with the compositor to generate final images to display of the UI and people's surroundings. Metal apps in a Full Space use the Compositor Services framework to render drawable frames directly to the Compositor, bypassing the render server.


App updates content
SwiftUI
SwiftUI + RealityKit
UIKit
Metal
Metal + Compositor Services
Core Animation + RealityKit rendering
Render server
Matches display refresh rate
Compositor
Displays

If your app running in the Shared Space has content or updates that take too long to render, the render server can miss deadlines. Visual updates you expect in one compositor frame don't show up until a later frame.



Use the RealityKit Trace template in Instruments to profile your app and identify workflows with dropped frames and other rendering and responsiveness bottlenecks. For more information, see Analyzing the performance of your visionOS app. To learn about optimizations you can make in your SwiftUI and UIKit interfaces, see Reducing the rendering cost of your UI on visionOS. To learn about optimizing your RealityKit content, see Reducing the rendering cost of RealityKit content on visionOS.

When using Metal and the Compositor Services framework to bypass the render server, use the Metal System Trace template to profile your app's performance. For more info, see Analyzing the performance of your Metal app.

- Pace your metal frame submissions so that the compositor receives a new frame from your app on each of its updates.
- Maintain a consistent metal rendering frame rate that is equal to the Apple Vision Pro display refresh rate. Use the visualizations in the Display instrument timeline to compare your rendered frame times to the display refresh rate — usually 90Hz on the Apple Vision Pro, but it can be higher under certain environmental conditions.
- Query a new foveation map and pose prediction for each frame immediately before you use it to encode GPU work.
- Avoid long-running fragment and vertex shader executions from your Metal app, or from custom materials with Reality Composer Pro.
- Avoid any long frame stalls. If your app takes too long to submit a new frame to the compositor, the system terminates it.

To learn more about implementing fully immersive Metal apps, see Drawing fully immersive content using Metal and watch the video Discover Metal for immersive apps.

See Also

Performance

Creating a performance plan for your visionOS app

Identify your app's performance and power goals and create a plan to measure and assess them.

Analyzing the performance of your visionOS app

Use the RealityKit Trace template in Instruments to evaluate and improve the performance of your visionOS app.

Reducing the rendering cost of your UI on visionOS

Optimize your 2D user interface rendering on visionOS.

Reducing the rendering cost of RealityKit content on visionOS

Optimize your app’s 3D augmented reality content to render efficiently on visionOS.