

ORNL Software Expo 2023 – Gavin Wiggins – wigginsg@ornl.gov – <https://gavinw.me>

Background

CPU vs GPU: the CPU has a few powerful processors whereas a GPU has many less powerful processors.

Metal was introduced in 2014 as a low-level GPU access framework for Apple devices. It is used by many of Apple's high-level frameworks such as RealityKit, SpriteKit, and Core Image.

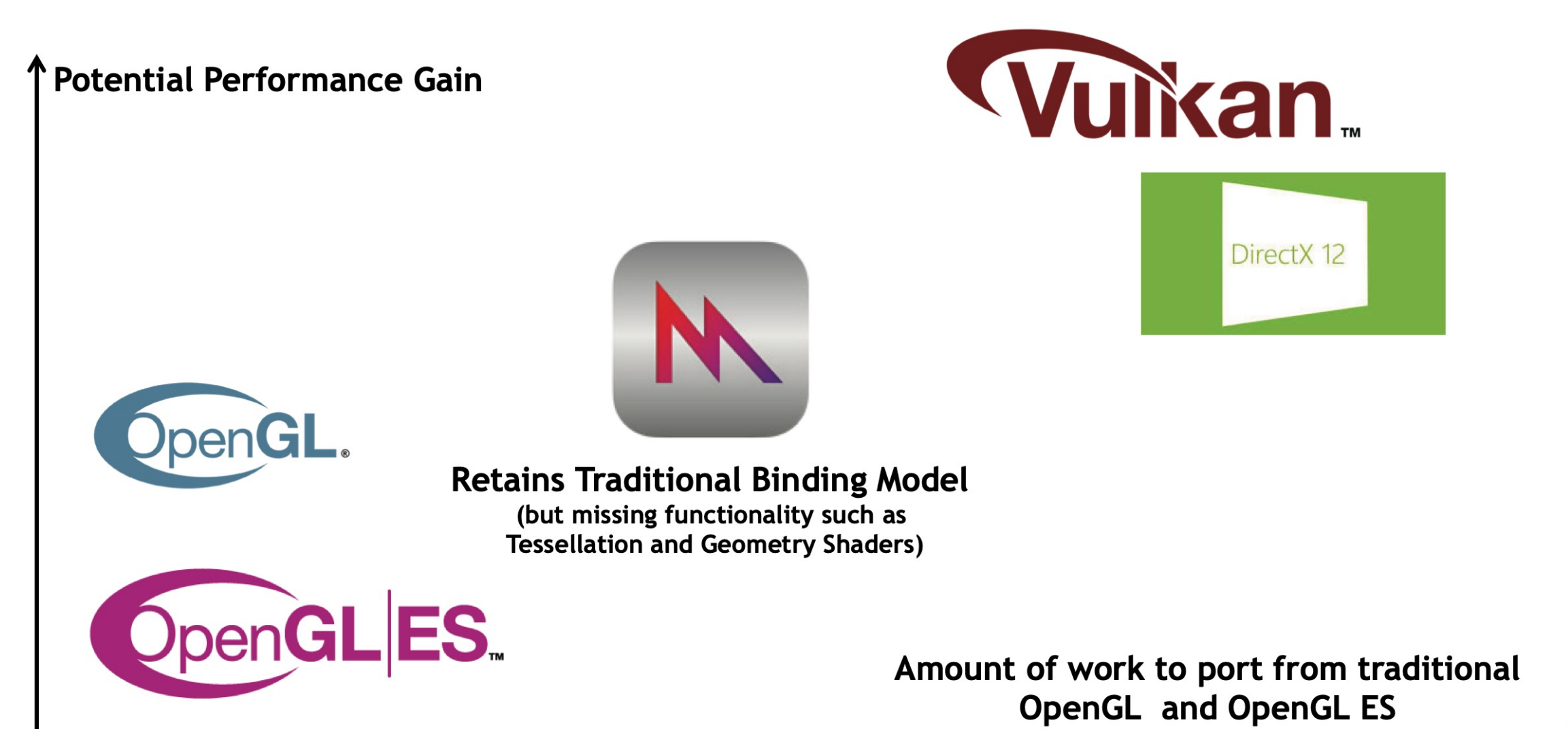
Metal is used for 2D/3D graphics, video processing, scientific research for parallel computations and data analysis, as well as virtual reality for visionOS.

The Metal Shading Language (MSL) is used to write graphics and data-parallel compute code. MSL is based on the C++14 specification.

The MetalKit framework provides utility classes for building Metal apps with the Swift programming language.

More information about Metal and the Swift programming language is available at:

- <https://developer.apple.com/metal/>
- <https://www.kodeco.com/books/metal-by-tutorials>
- <https://www.swift.org>
- <https://metalbyexample.com>



Metal has overall good performance and ease of use compared to other frameworks such as OpenGL and Vulkan. Source: Khronos Group 2016.



Basics of a Metal app

The GPU is represented the the MTLDevice object which accepts a list of commands stored in the MTLCommandQueue.

A pipeline state such as MTLRenderPipelineState tells the GPU what shader functions to use.

Metal buffers denoted by the MTLBuffer object are memory areas that hold the models and textures.

For each frame, the command buffer MTLCommandBuffer stores a list of draw commands. Each draw command is encoded by the MTLRenderCommandEncoder object.

After encoding all the commands, the command buffer is committed to the GPU for drawing. A Metal view displays the rendered graphics in the application.



Gray-Scott model in Metal

The Gray-Scott model represents the following irreversible reactions where P is an inert product.



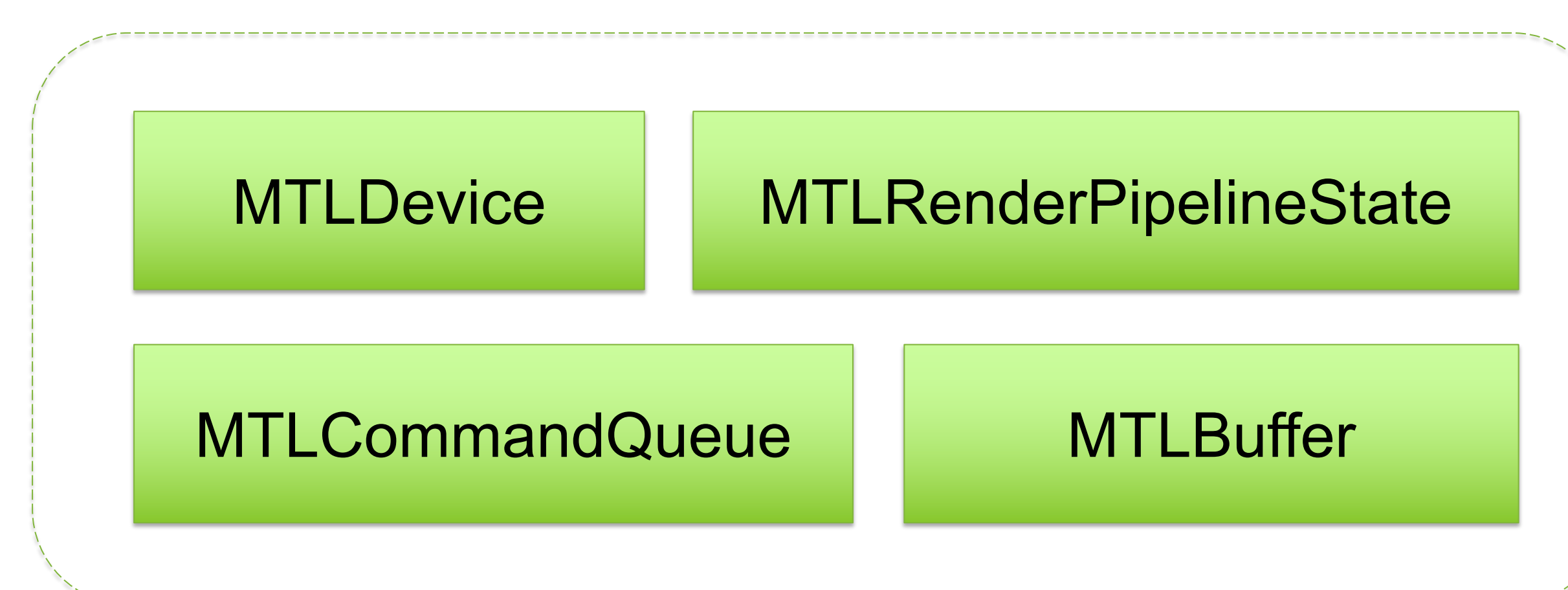
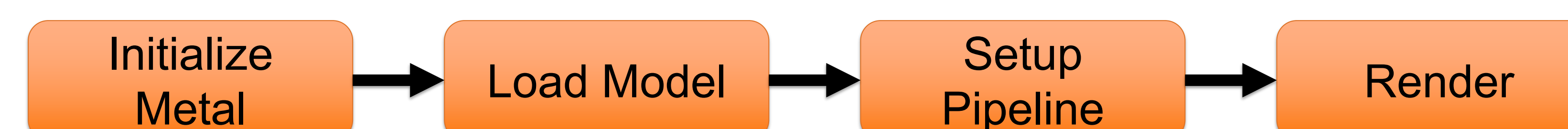
The resulting reaction-diffusion equations are shown below where k is dimensionless rate constant, F is dimensionless feed rate, diffusion coefficients are D_u and D_v , while ∇^2 is the two-dimensional Laplace operator.

$$\frac{\partial U}{\partial t} = D_u \nabla^2 U - UV^2 + F(1 - U)$$

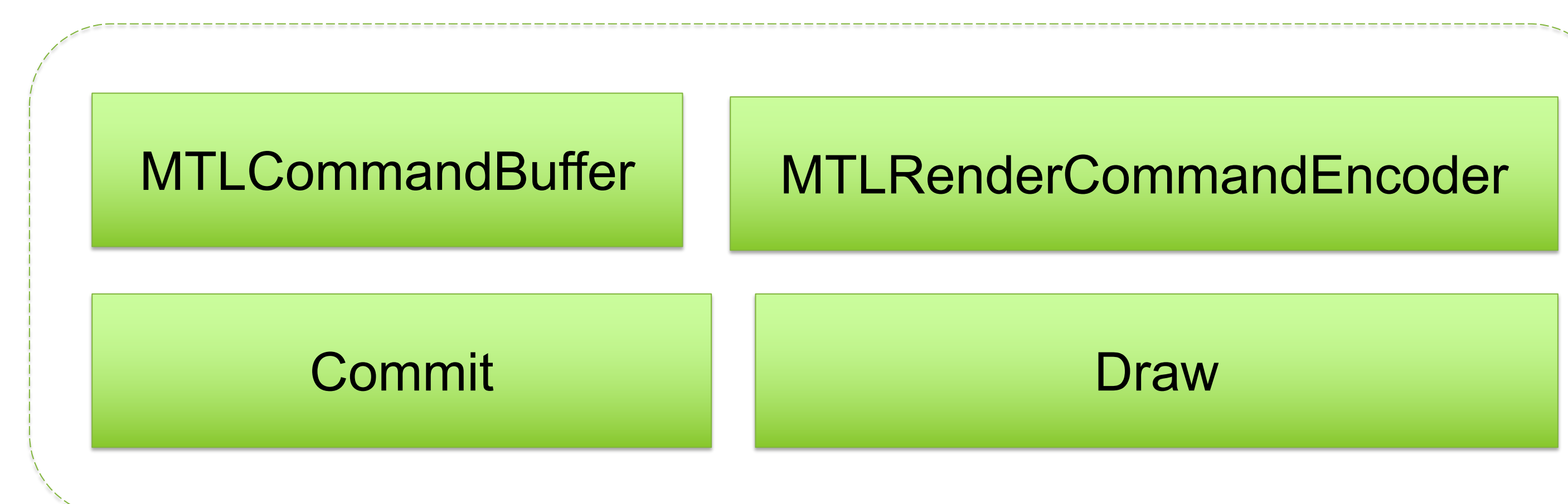
$$\frac{\partial V}{\partial t} = D_v \nabla^2 V + UV^2 - F(1 + k)V$$

An example of a Mac app that uses Metal to compute and visualize the Gray-Scott model is available on GitHub at:

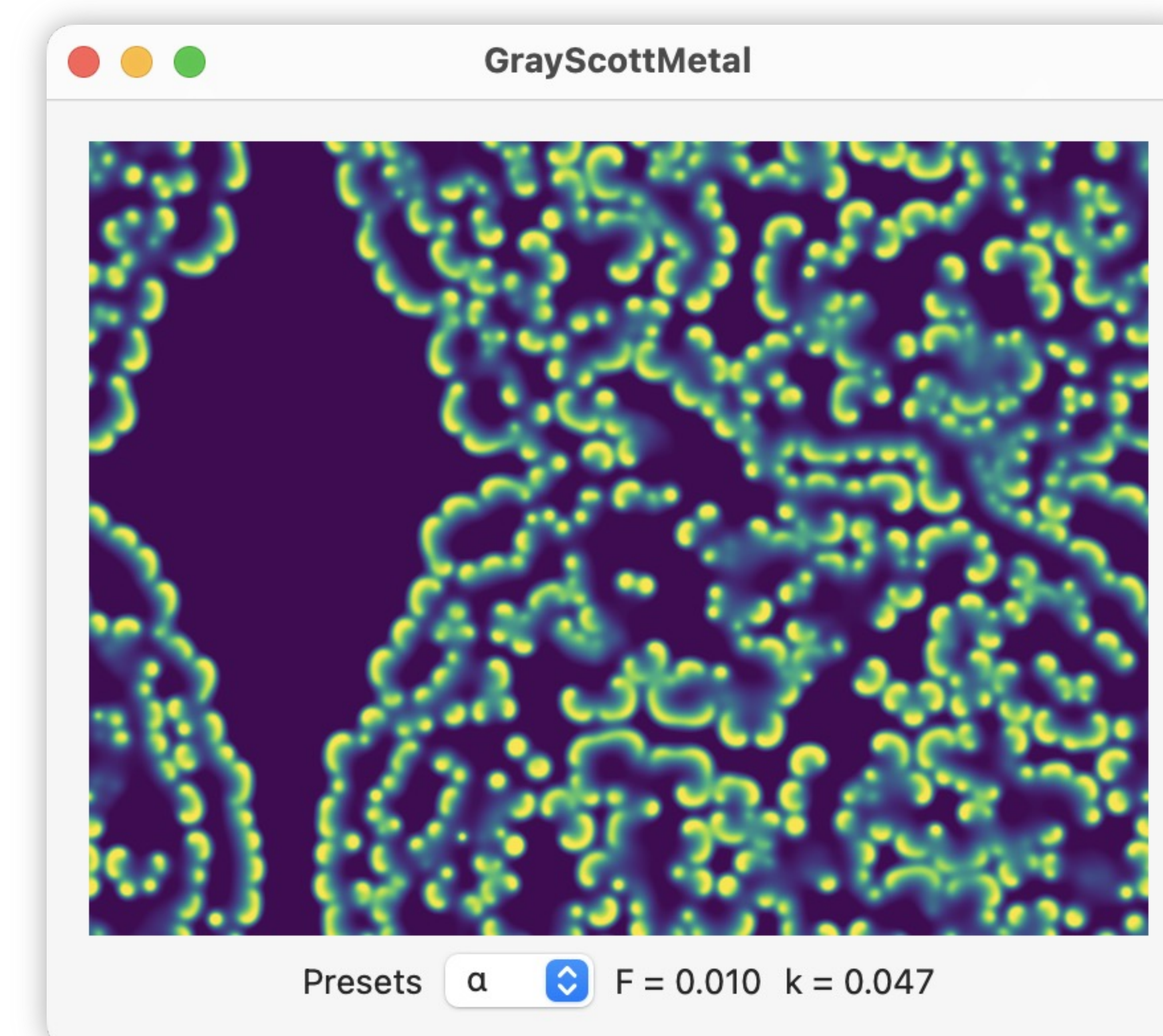
- <https://github.com/wigging/gray-scott>



Setup once in an application



Executed during every render pass



A macOS app with Metal to compute and render the Gray-Scott reaction-diffusion model using the viridis colormap.