Erae Shape Editor

Technical Reference & Architecture

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Overview

The Erae Shape Editor is a visual layout editor and expressive MIDI controller for the Erae Touch II hardware surface. Built with JUCE as both a VST3 plugin and standalone application, it provides a complete authoring environment for designing touch-responsive zones on the Erae's 42×24 LED grid, assigning MIDI behaviors, and applying real-time visual and physics-based touch effects.

The software communicates with the Erae II over USB MIDI using the Embodme SysEx API, rendering layouts in real time on the hardware LED surface while streaming multi-touch finger events back to the host for MIDI generation, effect processing, and modulation output.

Key Capabilities

- 5 shape types with full geometric editing (rect, circle, hex, polygon, pixel)
- 5 MIDI behaviors including MPE polyphonic expression
- 19 touch effects (8 visual, 11 physics-based)
- 5 visual rendering styles per shape
- Multi-page layouts with up to 8 pages
- Real-time LED rendering on Erae II hardware
- Modulation routing to MIDI CC, pitch bend, pressure, CV, OSC, and MPE
- Shape library with 19 built-in effect templates and user persistence
- Gesture looper for recording and replaying touch sequences
- DAW feedback: incoming MIDI highlights matching shapes

Architecture

Source Organisation

Directory	Responsibility
`Source/Core/`	Undo/redo, selection, clipboard, shape library, gesture looping, alignment tools
`Source/Model/`	Shape data model, layout, presets, JSON serialisation
`Source/UI/`	JUCE components: grid canvas, sidebar tabs, colour picker, theme, panels
`Source/Erae/`	Hardware connection, SysEx protocol, finger stream parsing
`Source/MIDI/`	Behavior engine, MPE allocator, MIDI/OSC/CV output, DAW feedback
`Source/Effects/`	Touch effect engine (19 types), effect state, modulation dispatch
`Source/Rendering/`	LED pixel rendering, widget state, per-finger colour palette
`Tests/`	Automated test suite (506 assertions)

Class Hierarchy

The plugin follows a standard JUCE architecture with `EraeProcessor` (audio thread) and `EraeEditor` (UI thread) as entry points.

`EraeProcessor`
: Owns the `MultiPageLayout`, `BehaviorEngine`, `TouchEffectEngine`, `EraeConnection`, `MPEAllocator`, `GestureLooper`, and all output objects (MIDI, OSC, CV).

`EraeEditor`
: Owns the `GridCanvas`, `SelectionManager`, `SidebarTabBar`, `ShapeLibrary`, and all UI panels.

`MultiPageLayout`
: Contains up to 8 `Layout` pages, each holding a vector of `Shape` pointers.

`TouchEffectEngine`
: Maintains per-shape `ShapeEffectState` maps, advances physics at 20 fps, and dispatches modulation.

Threading Model

- **Audio thread**: `processBlock()` reads CV channels, dispatches finger events through the behavior engine, updates effect state.
- **UI thread**: Layout editing, selection, undo/redo, canvas rendering.
- **Timer thread**: 20 fps timer for effect advancement, LED rendering, gesture looper, DAW feedback polling.
- Thread safety via `juce::SpinLock` for finger state, MIDI state, CV output, and OSC output.

Shape Types

Five shape types are supported, all deriving from a common `Shape` base class:

Type	Parameters	Description
Rectangle	x, y, width, height	Axis-aligned rectangle on the grid
Circle	x, y, radius	Circle centred at (x,y)
Hexagon	x, y, radius	Regular hexagon (isomorphic layout)
Polygon	x, y, vertices[]	Arbitrary convex or concave polygon
Pixel	x, y, cells[]	Freeform grid cells (painted individually)

Each shape carries: colour (7-bit RGB for Erae hardware), behavior type & parameters, visual style, effect parameters, and an optional description.

MIDI Behaviors

Behavior	Description
Trigger	Note on/off on touch down/up. Configurable velocity curves and latch mode.
Momentary	Note held while touching. Independent velocity and aftertouch pressure curves.
NotePad	MPE per-finger polyphony. Pitch bend (X), slide CC74 (Y), pressure (Z). 10 scale quantisations with glide.
XYController	Two independent CC values from X/Y position. 7-bit or 14-bit high-resolution.
Fader	Single CC from finger position along one axis. 7-bit or 14-bit.

MPE Allocation

The `MPEAllocator` manages MIDI channels 2–16 (15 channels) for polyphonic per-finger expression in the lower zone. Channel 1 is reserved for global messages.

Velocity & Pressure Curves

Four curve types are available for both velocity and aftertouch: Linear, Exponential, Logarithmic, and S-Curve.

Touch Effects

19 touch effect types are available, divided into visual effects and physics-based simulations. All effects run at 20 fps and produce normalised modulation values (modX, modY, modZ in $[0, 1]$) that can be routed to any output target.

Visual Effects (8)

Effect	Description
Trail	Fading dot trail following finger motion
Ripple	Concentric expanding rings from touch point
Particles	Burst of particles from touch with configurable lifetime
Pulse	Rhythmic brightness oscillation at touch location
Breathe	Slow sinusoidal glow across the entire shape
Spin	Rotating dots around the touch point
Orbit	Dots orbiting a pivot finger; radius controlled by second finger
Boundary	Convex hull outlined between multiple fingers

Physics-Based Effects (11)

Effect	Description
String	1D wave equation with fixed endpoints; plucked by two-finger placement
Membrane	2D wave equation on shape-relative grid; touch creates displacement
Fluid	Navier–Stokes velocity field with semi-Lagrangian advection
Spring Lattice	2D mass-spring grid with nearest-neighbour coupling
Pendulum	Single or double pendulum with Lagrangian dynamics
Collision	Elastic ball collision with gravity and wall bouncing
Tombolo	Erosion/deposition cellular automaton (sandpile model)
Gravity Well	N-body gravitational attraction with particle spawning
Elastic Band	Chain of spring-connected nodes between anchor fingers
Bow	Stick-slip friction model (Helmholtz motion)

Wave Interference	Superposition of point-source circular waves

Shape-Relative Grid Fields

Grid-field effects (Membrane, Fluid, Spring Lattice, Tombolo, Wave Interference) allocate simulation grids sized to the shape's bounding box rather than the full 42×24 surface. Touch coordinates are translated to shape-local space:

```
gridWidth  = ceil(bbox.xMax - bbox.xMin)
gridHeight = ceil(bbox.yMax - bbox.yMin)
localX = touchX - bbox.xMin
localY = touchY - bbox.yMin
```

For rendering, grid coordinates are offset back to absolute surface position using stored `gridOriginX/Y` values.

Modulation Normalisation

All effects normalise their modulation output to the shape's bounding box:

$$modX = clamp\left(\frac{x - x_{\min}}{x_{\max} - x_{\min}},\ 0,\ 1\right)$$

This ensures consistent 0–1 modulation output regardless of shape position or size on the surface.

Modulation Targets

Effect modulation values can be routed to:

- MIDI CC (configurable channel and CC number)
- Pitch Bend (14-bit)
- Channel Pressure
- CV (constant-value audio channels, 1V/oct or 0–1)
- OSC (UDP messages to configurable host:port)
- MPE (per-finger X/Y/Z expression)

Visual Styles

Each shape can be rendered with one of five visual styles, both on-screen and on the Erae II hardware:

Style	Description
Static	Solid colour fill
Pressure Glow	Colour intensity tracks finger pressure
Fill Bar	Vertical or horizontal fill level follows finger position
Position Dot	Bright dot tracks finger position within shape
Radial Arc	Arc sweeps based on finger angle from shape centre

Preset System

Built-in Presets (11)

Preset	Description
Drum Pads	4×3 grid of trigger pads (GM mapping)
Piano	Two-octave chromatic keyboard layout
Wicki-Hayden	Isomorphic hexagonal note layout
Fader Bank	8 vertical faders (CC 1–8)
XY Pad	Single large XY controller
Buchla Thunder	Irregular zones inspired by Don Buchla's Thunder controller
Auto Harp	Chord-strumming strips
Harmonic Table	Tonnetz-adjacent hexagonal pitch layout
Kaoss Pad	Large XY zone with effect overlay
Circle of Fifths	Radial arrangement of 12 keys
Tonnetz	Neo-Riemannian hexagonal pitch network

Effect Templates (19)

Each of the 19 touch effects has a pre-configured template in the shape library: a shape with appropriate geometry, colour, NotePad behaviour, Pressure Glow visual style, and the effect type pre-assigned with MPE modulation.

Shape Library

The shape library provides persistent storage for shape configurations:

- 19 built-in effect templates (protected from deletion or rename)
- User-saved shapes with JSON persistence
- Operations: Save, Place, Flip H/V, Duplicate, Delete, Rename (double-click)
- Preview with animated effect visualisation for entries with effects

Hardware Integration

Connection

The editor auto-detects the Erae II via USB MIDI, connecting to the "Lab" port for output and "Main" port for input. An auto-reconnect timer handles USB disconnection.

SysEx Protocol

Communication uses Embodme's SysEx API with 7-bit bitisation for binary data. Key operations:

- `enableApi()` / `disableApi()` — acquire/release control of the LED surface
- `drawPixel(x, y, r, g, b)` — set individual LED colour
- `drawRect(x, y, w, h, r, g, b)` — fill rectangular region
- `drawImage(data)` — send full-frame image chunk (all 24 rows)
- `clearZone()` — blank the LED surface

Finger Stream

Finger events are received as bitised SysEx containing:

- 64-bit finger ID (unique per touch)
- Action type: Down, Move, Up
- X, Y position (float, grid coordinates)
- Z pressure (float, 0–1)

LED Rendering

The `EraeRenderer` converts layout state, widget state, and effect state into Erae II pixel commands at 20 fps. Full-frame image chunks are used to avoid visible flashing.

Output Formats

Output	Details
MIDI	16-channel output. Channel 1 global, channels 2–16 MPE lower zone. Note on/off, CC, pitch bend, aftertouch.
OSC	UDP mirror of all MIDI and effect events to configurable host:port.
CV	Up to 32 audio channels. 1V/oct pitch, 0/1 gates, 0–1 continuous modulation.
DAW Feedback	Incoming MIDI from DAW highlights matching shapes with pulsing glow.

Gesture Looper

The gesture looper records and replays finger event sequences:

- **Record**: Captures raw `FingerEvent` stream with timestamps
- **Replay**: Loops events through the full MIDI and effect pipeline
- **ID Remapping**: Replayed finger IDs use bit 63 set to avoid collision with live fingers
- **Transport**: Controlled via toolbar buttons or Erae II hardware Play/Stop buttons

Build System

Targets

Target	Description
`EraeShapeEditor_Standalone`	Standalone application
`EraeShapeEditor_VST3`	VST3 plugin
`EraeTests`	Test binary (506 assertions)

Dependencies

- JUCE 7.0.9 (fetched via CMake `FetchContent`)
- C++17 compiler
- JUCE modules: `juce_audio_utils`, `juce_audio_basics`, `juce_audio_processors`, `juce_gui_basics`, `juce_core`, `juce_graphics`, `juce_audio_devices`

Build Commands

```
cmake -B build -DCMAKE_BUILD_TYPE=Release
cmake --build build --target EraeShapeEditor_Standalone
cmake --build build --target EraeTests
./build/EraeTests_artefacts/Release/Erae\ Tests
```

Test Suite

The test suite validates the complete effect template and shape library system with 506 automated assertions across 9 test groups:

Test Group	Checks	Coverage
Effect Templates	190	All 19 templates: name, type, colour, behavior, visual style, effect params
Shape Clone	10	Type preservation across all 5 shape types
Shape Library	25	Built-in protection, user entry CRUD, index bounds
Library Save/Load	10	JSON round-trip with colour and type preservation
Place on Canvas	57	All 19 templates placed with correct type and effect params
Shape Dimensions	37	Bounding box accuracy for all template shapes
JSON Round-Trip	77	Full serialisation/deserialisation for all shapes
Unique Colours	1	All 19 templates have distinct colours
Grid-Field Sizing	29	Shape-relative grid init, OOB safety, coordinate translation

Keyboard Shortcuts

Shortcut	Action
Ctrl+Z / Ctrl+Shift+Z	Undo / Redo
Ctrl+A	Select All
Ctrl+C / X / V	Copy / Cut / Paste
Ctrl+D	Duplicate
Delete / Backspace	Remove selected
Arrow keys	Nudge selected shape
V	Select tool
B	Paint tool
E	Erase tool
R / C / H / P / G	Draw Rect / Circle / Hex / Polygon / Pixel
Scroll wheel	Zoom
Middle-click drag	Pan

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