Application Level Undo & Recovery:
Applied to the Pencil Application

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Motivation

- Loss of data detrimental to productivity and motivation
- Code/configuration/operator errors could lead to data loss/corruption

Pencil Application

- Open source, cross-platform drawing and animation application
- Written in C++/QT

- Introduce Snapshot/ Replay Facilities

Pencil App

- Clearly defined modules
- Currently unsuitable for micro-reboot, as state is not saved

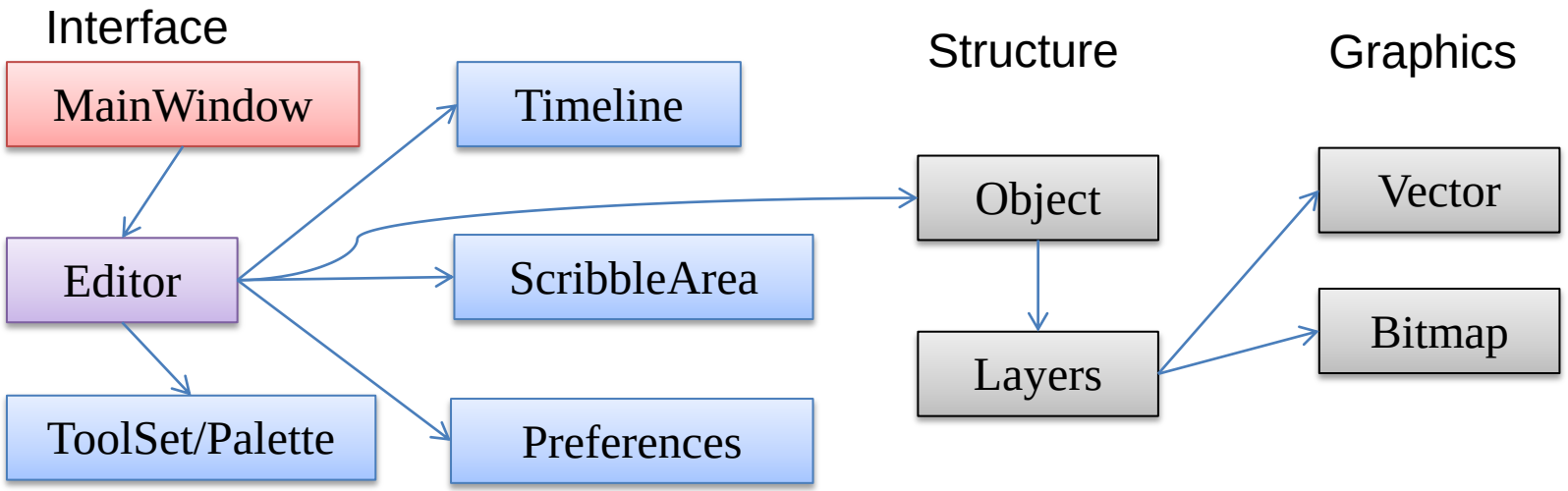


Figure 1: Structural Diagram of Pencil

Methodology

- Periodically take snapshot of user progress
  - Removed at user save/open project events and on successful app exit
- Logging of logical user operations
  - User draw events, tool selection
- Replay and Recovery
  - Automatically on application start, after a crash

Tools Supported

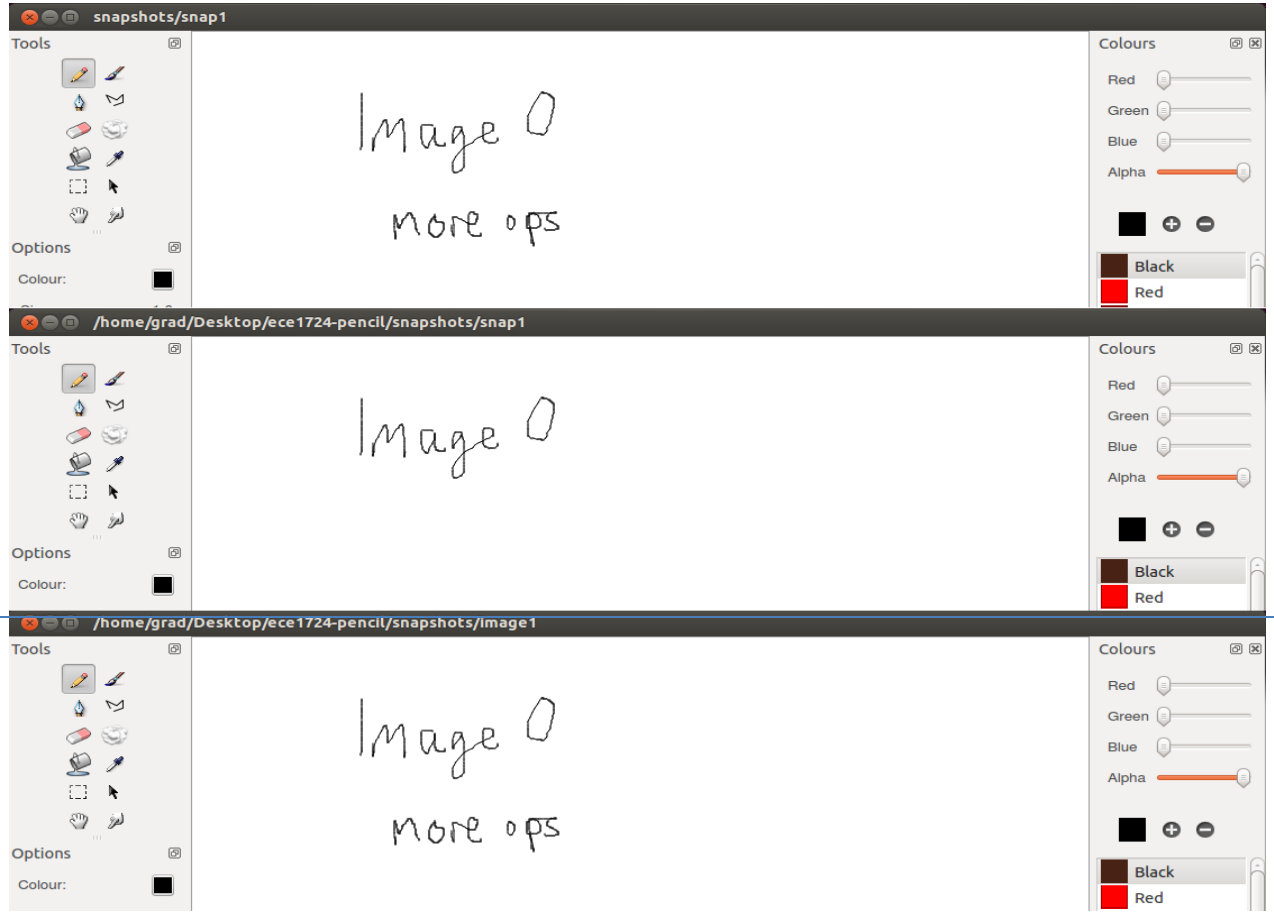
- Saved pencil, pen and eraser tool state for PoC
- Other tools easily extensible through similar log augmentations in Pencil event API
- Developed and evaluated in Linux with QT4

Sample Log File

```
<!DOCTYPE PencilOperationsSaveLog>
<operations>
  <operation toolMode="0" layerType="1" currentLayer="0" currentFrame="1" opPosition="STARTING"/>
  <operation toolMode="0" lastPointY="-94" endPixelX="210" endPixelY="230" currentWidth="1" endPointX="-190"
currentColour="#000000" endPointY="-92" layerType="1" opPosition="DRAWING" antialiasing="1" lastPointX="-190"/>
  <operation toolMode="0" lastPointY="-92" endPixelX="210" endPixelY="231" currentWidth="1" endPointX="-190"
currentColour="#000000" endPointY="-91" layerType="1" opPosition="DRAWING" antialiasing="1" lastPointX="-190"/>
  <operation toolMode="0" lastPointY="-91" endPixelX="210" endPixelY="233" currentWidth="1" endPointX="-190"
currentColour="#000000" endPointY="-89" layerType="1" opPosition="DRAWING" antialiasing="1" lastPointX="-190"/>
  <operation toolMode="0" layerType="1" opPosition="ENDING"/>
...
  <operation toolMode="0" layerType="1" currentLayer="0" currentFrame="1" opPosition="STARTING"/>
  <operation toolMode="0" lastPointY="-65" endPixelX="236" endPixelY="262" currentWidth="1" endPointX="-164"
currentColour="#000000" endPointY="-60" layerType="1" opPosition="DRAWING" antialiasing="1" lastPointX="-167"/>
...
  <operation toolMode="0" lastPointY="-33" endPixelX="344" endPixelY="289" currentWidth="1" endPointX="-56"
currentColour="#000000" endPointY="-33" layerType="1" opPosition="DRAWING" antialiasing="1" lastPointX="-57"/>
  <operation toolMode="0" layerType="1" opPosition="ENDING"/>
</operations>
```

Figure 2: Sample Operations Log File

Evaluation – Functional Correctness




```
grad@grad-desktop:~/Desktop/ece1724-pencil/QImageComparator2$ ./QImageComparator
 ../snapshots/image1.data/*png ../snapshots/image2.data/*png
The images are the same. =]
```

Evaluation Results

User Events in Snapshot	10	10	10	10
User Event Duration	2	2	2	2
Operations tags cached	1	2	5	10
Operation Log Size (kB)	154.0	157.1	184.0	187.8
Avg Time Opening Log per Operation Tag (ms)	17.7	17.3	21.4	22.3
Avg Time Creating Operation Tag (ms)	0.1	0.1	0.1	0.1
Avg Time Closing File per Operation Tag (ms)	11.8	5.3	2.9	1.5
Draw Time per Operation Tag (ms)	0	0	0	0
Replay Time (ms)	40	60	62	64
Total Start up Time (ms)	280	304	309	310

Table 1: Runtime Performance Results

Evaluation Results

User Events in Snapshot	5	10	5	10
User Event Duration	1	1	2	2
Operations tags cached	1	1	1	1
Operation Log Size (kB)	81	121.4	120.1	169.8
Avg Time Opening Log per Operation Tag (ms)	9.2	13.3	12.8	18.9
Avg Time Creating Operation Tag (ms)	0.1	0.1	0.1	0.1
Avg Time Closing File per Operation Tag (ms)	7.8	9.7	9.2	13.7
Draw Time per Operation Tag (ms)	0	0	0	0
Replay Time (ms)	38	60	56	63
Total Start up Time (ms)	299	320	320	319

Table 2: Varying Operations Cache Size

Related Work

- Assure
  - Recover from unknown software errors using rescue points
- Undo for Operators
  - Rewind, Repair and Replay implemented in an email store
- Rx
  - Tolerates both deterministic and nondeterministic faults by replaying operations in a modified execution environment
- Micro-reboot
  - Compartmentalize and restart affected component(s)

Future Work

- User interactive recovery
- Extend to rest of the tools
- Move writing to disk out of critical path of I/O
- Repair/change execution environment to avoid recurrence of the bug
- Supporting propagation/delayed failures

Acknowledgements

- Pencil Online Docs
- Prof. Goel for his guidance and comments on related works in the area
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- QT API documentation engineers

Thank you.

Any questions?