Interpreting Multitouch Gestures

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Interpreting Multitouch Gestures

1. Background
2. Gestures
3. Proton
   - Gesture Notation
   - Static Analysis Process
   - Architecture
4. Proton++
   - New Notation
   - User Study
5. Conclusion

Background

- Multitouch systems are readily available
- Phones, tablets, computers, etc
- Touches

Background

- Basic low level touches
  - Down
  - Move
  - Up
- Composing these touch events into sequences
- Most systems call these sequences gestures

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Gestures

- Definition: Functionality allowing a touchscreen, track pad, etc. to register multiple points of contact made on the surface simultaneously
- Tools currently available
  - Proton
  - Proton++
  - Others including: Gesture Studio, Gesture Coder, GeForMT, etc.

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Proton

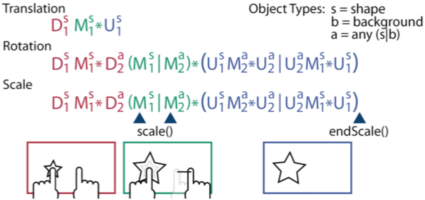
- Multitouch framework
- What is its main purpose?

Proton: Regular Expressions

- Proton uses regular expressions to denote gestures
- Kleene star * = zero or more (any)
- | = or

$$E^{O_{Type}}_{T_{ID}}$$

E ϵ {D,M,U}, O_{type}: object hit, T_{id}: touch ID



Translation

$D^s_1\ M^s_1{*}U^s_1$

Object Types: s = shape
b = background
a = any (s|b)

Rotation

$D^s_1\ M^s_1{*}D^a_2\ (M^s_1|M^a_2){*}(U^s_1M^a_2{*}U^a_2\,|\,U^a_2M^s_1{*}U^s_1)$

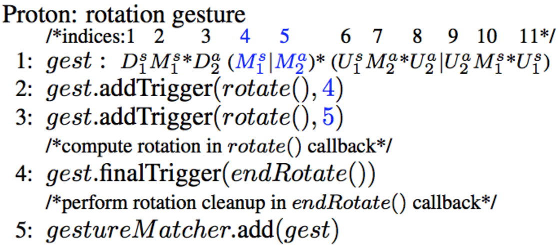
Scale

$D^s_1\ M^s_1{*}D^a_2\ (M^s_1|M^a_2){*}(U^s_1M^a_2{*}U^a_2\,|\,U^a_2M^s_1{*}U^s_1)$

Figure: Proton regular expressions

Proton: Regular Expressions

- Indices
- Triggers applied on 4, 5
- Callback functions



Proton: rotation gesture

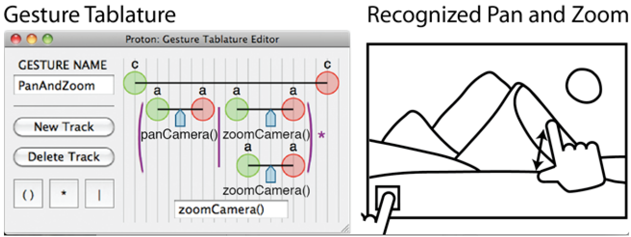
```
    /*indices:1   2     3    4    5       6   7    8    9   10   11*/
$gest : D_1^s M_1^s{*} D_2^a \, (M_1^s | M_2^a){*} \, (U_1^s M_2^a{*} U_2^a | U_2^a M_1^s{*} U_1^s)$
$gest$.addTrigger($rotate()$, 4)
$gest$.addTrigger($rotate()$, 5)
    /*compute rotation in $rotate()$ callback*/
$gest$.finalTrigger($endRotate()$)
    /*perform rotation cleanup in $endRotate()$ callback*/
$gestureMatcher$.add($gest$)
```

Figure: Regular expression triggers callbacks

Proton: Gesture Tablature

- Guitar tablature
- $\triangle$ = panCamera()
- $\triangle$ = zoomCamera()

$$D_1^c M_1^c * (D_2^a (M_1^c | M_{2_\triangle}^a) * U_2^a M_1^c *$$
$$| D_2^a (M_1^c | M_2^a) * D_3^a (M_1^c | M_{2_\triangle}^a | M_{3_\triangle}^a) * (U_3^a (M_1^c | M_2^a) *$$
$$U_2^a M_1^c * | U_2^a (M_1^c | M_3^a) * U_3^a M_1^c *)) * U_1^c$$



GESTURE NAME

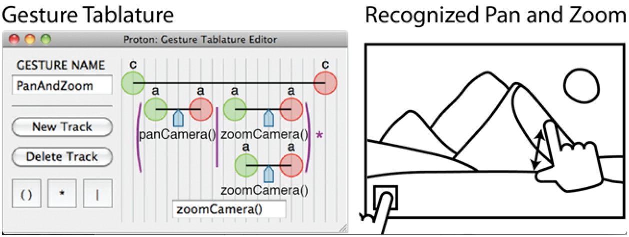
PanAndZoom

Figure: Proton gesture tablature creation tool

Proton: Gesture Tablature

- Guitar tablature
- $\triangle$ = panCamera()
- $\triangle$ = zoomCamera()

$$D_1^c M_1^c * (D_2^a(M_1^c|M_{2_\triangle}^a) * U_2^a M_1^c * |D_2^a(M_1^c|M_2^a) * D_3^a(M_1^c|M_{2_\triangle}^a|M_{3_\triangle}^a) * (U_3^a(M_1^c|M_2^a) * U_2^a M_1^c * |U_2^a(M_1^c|M_3^a) * U_3^a M_1^c *)) * U_1^c$$



Gesture Tablature

Recognized Pan and Zoom

GESTURE NAME: PanAndZoom

Figure: Proton gesture tablature creation tool

Proton: Gesture Tablature

- Guitar tablature
- $\triangle$ = panCamera()
- $\triangle$ = zoomCamera()

$$D_1^c M_1^c * (D_2^a(M_1^c|M_{2_\triangle}^a) * U_2^a M_1^c *$$
$$|D_2^a(M_1^c|M_2^a) * D_3^a(M_1^c|M_{2_\triangle}^a|M_{3_\triangle}^a) * (U_3^a(M_1^c|M_2^a) * U_2^a M_1^c *$$
$$|U_2^a(M_1^c|M_3^a) * U_3^a M_1^c *)) * U_1^c$$

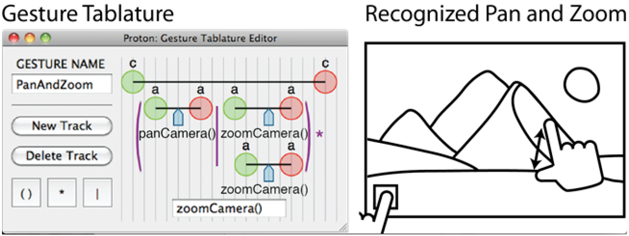
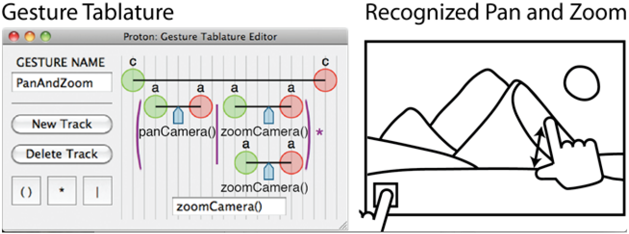


Figure: Proton gesture tablature creation tool

Proton: Gesture Tablature

- Guitar tablature
- $\triangle$ = panCamera()
- $\triangle$ = zoomCamera()

$$D^c_1 M^c_1 * (D^a_2(M^c_1|M^a_{2_\triangle}) * U^a_2 M^c_1 *$$
$$|D^a_2(M^c_1|M^a_2) * D^a_3(M^c_1|M^a_{2_\triangle}|M^a_{3_\triangle}) * (U^a_3(M^c_1|M^a_2) * U^a_2 M^c_1 *$$
$$|U^a_2(M^c_1|M^a_3) * U^a_3 M^c_1 *)) * U^c_1$$



Gesture Tablature

Recognized Pan and Zoom

Proton: Gesture Tablature Editor

GESTURE NAME

PanAndZoom

Figure: Proton gesture tablature creation tool

Proton: Gesture Tablature

- Guitar tablature
- $\color{blue}\triangle$ = panCamera()
- $\color{magenta}\triangle$ = zoomCamera()

$$D_1^c M_1^c * (D_2^a(M_1^c|M_{2_{\color{blue}\triangle}}^a) * U_2^a M_1^c *$$
$$|D_2^a(M_1^c|M_2^a) * D_3^a(M_1^c|M_{2_{\color{magenta}\triangle}}^a|M_{3_{\color{magenta}\triangle}}^a) * (U_3^a(M_1^c|M_2^a) * U_2^a M_1^c *$$
$$|{\color{red}U_2^a(M_1^c|M_3^a) * U_3^a M_1^c *)) * U_1^c}$$

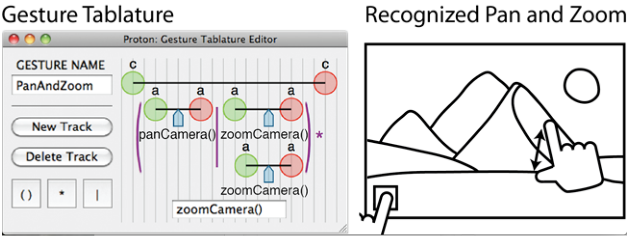


Figure: Proton gesture tablature creation tool

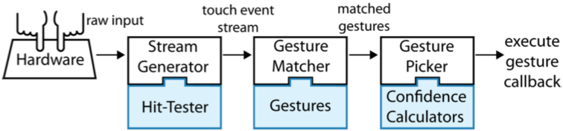
Static Analysis of Gesture Conflicts

- Regular expressions that have the same prefixes
- Ambiguity resulting from this
- Caught at compile time for developers
- Helpful tool, possible through the use of regular expressions

Proton: Development to User Input

- Tablature supports construction of gestures
- Gesture sets
- Proton then uses these gesture sets to go from user input to associated callback functions
- Possible through Proton's architecture

Proton: Architecture



- Three main components
  - Stream generator
  - Gesture matcher
  - Gesture picker

Proton: Architecture

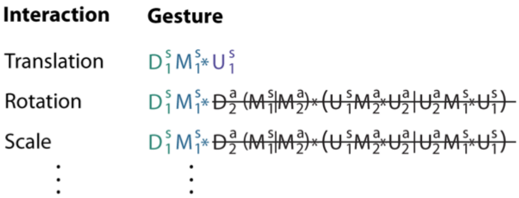
Stream Generator: Hit-Tester

- Used to determine the O_{type} hit
- Developers must include all objects possibly being hit in a scene

Proton: Architecture

Gesture Matcher: Gestures

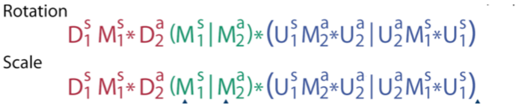
- Developers must create a gesture set with all possible gestures
- Matches incoming stream with gesture set



Interaction	Gesture
Translation	$D_1^s M_1^s{*} U_1^s$
Rotation	$D_1^s M_1^s{*}$ ~~$D_2^a (M_1^s \mid M_2^a){*} (U_1^s M_2^a{*} U_2^a \mid U_2^a M_1^s{*} U_1^s)$~~
Scale	$D_1^s M_1^s{*}$ ~~$D_2^a (M_1^s \mid M_2^a){*} (U_1^s M_2^a{*} U_2^a \mid U_2^a M_1^s{*} U_1^s)$~~
⋮	⋮

Proton: Architecture

Gesture Picker: Confidence Calculators



Rotation

$$D_1^s M_1^s {*} D_2^a (M_1^s | M_2^a) {*} (U_1^s M_2^a {*} U_2^a | U_2^a M_1^s {*} U_1^s)$$

Scale

$$D_1^s M_1^s {*} D_2^a (M_1^s | M_2^a) {*} (U_1^s M_2^a {*} U_2^a | U_2^a M_1^s {*} U_1^s)$$

Figure: Proton expressions for rotate and scale

- Confidence calculator applies a confidence score between 0 and 1 to each expression
- Highest score is returned and executed
- Determined from attributes associated with these expressions
- Are the touches in scale moving away or towards each other?

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Proton++

- Extended framework built on Proton
- Uses much of the same processes
- 5 new touch attributes
  - Direction
  - Pinch
  - Touch area
  - Finger orientation
  - Screen location

Proton++: Whats new

Proton++ has very important upgrades

- These new attributes allow for more dynamic regular expressions
- Stream generator splits into multiple streams
- Allows for multiple user applications

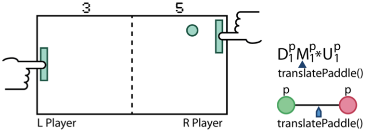
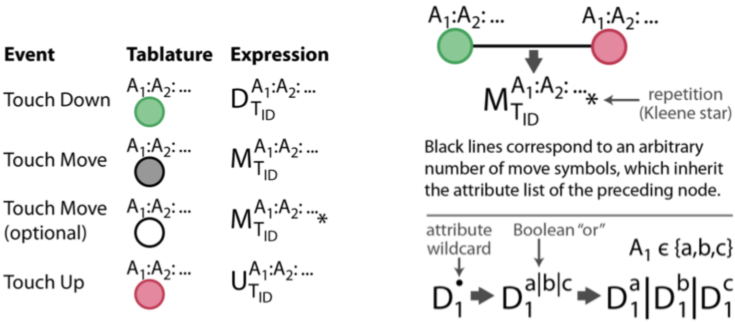


Figure: Pong application where Proton++ splits stream generator to allow for two gesture matchers to run at the same time

Proton++: New Notation

New form: $E_{T_{ID}}^{A_1:A_2:A_3\dots}$

- $E \in \{D, M, U\}$
- A_n are the attributes linked to the touch
- T_{ID} Touch-id



Event	Tablature	Expression
Touch Down	A_1:A_2: ... 🟢	$D_{T_{ID}}^{A_1:A_2:\dots}$
Touch Move	A_1:A_2: ... ●	$M_{T_{ID}}^{A_1:A_2:\dots}$
Touch Move (optional)	A_1:A_2: ... ○	$M_{T_{ID}}^{A_1:A_2:\dots *}$
Touch Up	A_1:A_2: ... 🔴	$U_{T_{ID}}^{A_1:A_2:\dots}$

Black lines correspond to an arbitrary number of move symbols, which inherit the attribute list of the preceding node.

attribute wildcard
Boolean "or"
$A_1 \in \{a,b,c\}$
$D_1^{\bullet} \rightarrow D_1^{a|b|c} \rightarrow D_1^a|D_1^b|D_1^c$

Figure: Proton++ syntax for tablature and regular expression

Examples of Proton++

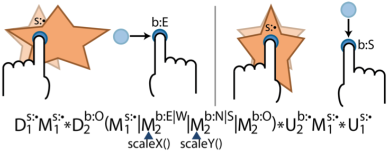

s:•
b:E
s:•
b:S
$D_1^{s:\bullet} M_1^{s:\bullet} * D_2^{b:O} (M_1^{s:\bullet} | M_2^{b:E|W} | M_2^{b:N|S} | M_2^{b:O}) * U_2^{b:\bullet} M_1^{s:\bullet} * U_1^{s:\bullet}$
scaleX()
scaleY()

Figure: Proton++ regular expression for scale gesture

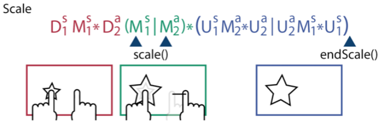
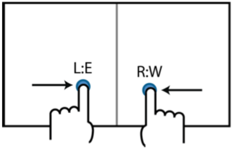

Scale
$D_1^s M_1^s * D_2^a (M_1^s | M_2^a) * (U_1^s M_2^a * U_2^a | U_2^a M_1^s * U_1^s)$
scale()
endScale()

Figure: Proton scale regular expression

Examples of Proton++



$$D_1^{L:O}M_1^{L:O}{*}D_2^{R:O}(M_1^{L:O}|M_2^{R:O}){*}\ldots$$
$$(M_1^{L:E}(M_1^{L:E}|M_2^{R:O}){*}M_2^{R:W}|M_2^{R:W}(M_1^{L:O}|M_2^{R:W}){*}M_1^{L:E})\ldots$$
$$(M_1^{L:O|E}|M_2^{R:O|W}){*}(U_1^{L:O|E}M_2^{R:O|W}{*}U_2^{R:O|W}|U_2^{R:O|W}M_1^{L:O|E}{*}U_1^{L:O|E})$$

executeMenuCommand()

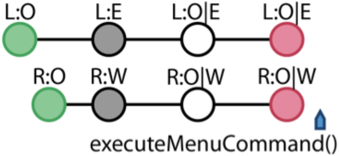


Figure: Figure at the top is the regular expression for opening a menu with two hands, and bottom is that regular expression in tablature form. Possible through the use of direction.

Proton++: User Study

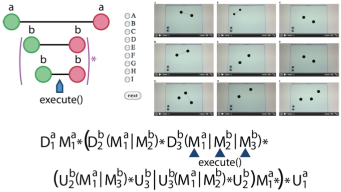
- Recruited 12 experienced programmers
- Checked for correctness and time of understanding
- Two parts
  - Part 1: Basic gestures
  - Part 2: Trajectory

Proton++: User Study Part 1

Part 1:

- Different gesture representations affect participant's understanding of basic gestures
- 3 different representations
  - Tablature
  - Regular expressions
  - iOS event-handling

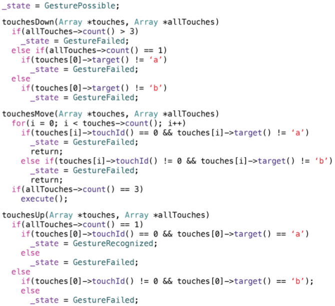
Proton++: User Study Part 1



$$D^a_1\, M^a_1{*}\left(D^b_2\,(M^a_1|M^b_2){*}\,D^b_3(\underset{\blacktriangle}{M^a_1}|\underset{\blacktriangle}{M^b_2}|\underset{\blacktriangle}{M^b_3}){*}\right.$$

$$\left.(U^b_2(M^a_1|M^b_3){*}U^b_3\,|\,U^b_3(M^a_1|M^b_2){*}U^b_2)M^a_1{*}\right){*}\,U^a_1$$

Figure: Gesture Tablature and Regular Expression



```
_state = GesturePossible;

touchesDown(Array *touches, Array *allTouches)
  if(allTouches->count() > 3)
    _state = GestureFailed;
  else if(allTouches->count() == 1)
    if(touches[0]->target() != ‘a’)
      _state = GestureFailed;
  else
    if(touches[0]->target() != ‘b’)
      _state = GestureFailed;

touchesMove(Array *touches, Array *allTouches)
  for(i = 0; i < touches->count(); i++)
    if(touches[i]->touchId() == 0 && touches[i]->target() != ‘a’)
      _state = GestureFailed;
      return;
    else if(touches[i]->touchId() != 0 && touches[i]->target() != ‘b’)
      _state = GestureFailed;
      return;
  if(allTouches->count() == 3)
    execute();

touchesUp(Array *touches, Array *allTouches)
  if(allTouches->count() == 1)
    if(touches[0]->touchId() == 0 && touches[0]->target() == ‘a’)
      _state = GestureRecognized;
    else
      _state = GestureFailed;
  else
    if(touches[0]->touchId() != 0 && touches[0]->target() == ‘b’);
    else
      _state = GestureFailed;
```

Figure: iOS Event-handling

Proton++: User Study Part 1

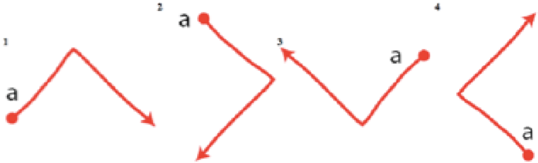
Results:

- Tablature recognition: 23.50s
- Regular expression recognition: 49.25s
- iOS event-handling recognition: 110.99s

Proton++: User Study Part 2

Part 2:

- Identify gestures that use both hit-target attributes and the direction attribute for specifying trajectory
- Presented a gesture, and set of four images
- Asked to identify corresponding gesture to correct image



Proton++: User Study Part 2

Results:

- Gesture Tablature: 17.82s
- Regular expression: 35.49s
- iOS event-handling: 75.29s

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Conclusion

- Background and gestures
- Proton
  - Proton regular expressions
  - Proton gesture tablature
  - Architecture
- Proton++
  - New attributes
  - User study

Questions

Bibliography

- K. Kin, B. Hartmann, T. DeRose, and M. Agrawala. Proton++: A customizable declarative multitouch framework. In Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology, UIST 12, pages 477486, New York, NY, USA, 2012. ACM.
- K. Kin, B. Hartmann, T. DeRose, and M. Agrawala. Proton: Multitouch gestures as regular expressions. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 12, pages 28852894, New York, NY, USA, 2012. ACM.