Stitching: Pen Gestures that Span Multiple Displays

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- How can a user dynamically forge a purposeful connection between two or more target devices that do not *a priori* know one another's network address?
- Currently a significant research problem for system implementation, interaction design, and social/behavioral observation

Spontaneous Device Sharing Problem

Solution Requirements

- Connection
  - How is connection established?
- Command
  - What type of connection is required?
- Operands
  - What info is shared?
- Geometry
  - What is the spatial relationship between the devices?
- Coexistence
  - How do connection gestures coexist with traditional interactions?
- Proxemics
  - How do the users share physical space?

Previous Work

- Requires special hardware
  - Overhead cameras
  - RFID tags
- Requires manual configuration
  - IP addresses of other devices
  - Geometry of devices

- Bluetooth
  - No way to distinguish target device (must know device name and select from list)
- IrDA
  - No positioning flexibility
  - Devices must remain still

Established Solutions

- Synchronous gestures
  - Hold devices together and shake them
  - Bump devices together
  - Simultaneously press a button on each device

One Current Solution

- A new type of synchronous gesture
- Uses commonplace pen input capabilities
- Continuous pen-based gesture that starts on one device and ends on another

Stitching

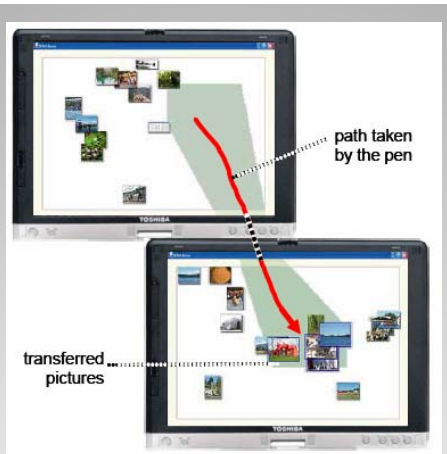

Figure 1. Here, a user gives some photos to another user by stitching from the top tablet to the bottom tablet.

StitchMaster: Copy / Move Photos

Figure 6. Gallery: The right tablet displays a full-screen view of an image that the presenter selects on the left tablet.

StitchMaster: Gallery

Establishing a Connection

- Connection established by making stitch from source to destination
- Stitching server
  - All devices send pen events
  - Can be located on one of the devices or on a dedicated server
  - Synchronizes time between the devices
  - Finds matching pen traces
    - On match, alerts both devices and sends IP addresses

- Pen movement on first device stops near the screen border
- Pen movement must have occurred on the device for a period of time (>250 ms)
- Pen movement on second device starts near the screen border
- Pen movement on second device must occur for a period of time (>100 ms)
- Delay between end of movement on first device and start of movement on second device must be minimal (<1.5 s)
- Direction of pen leaving first device and entering second device must be within specified angle tolerance (<20 deg)
- These requirements were sufficient to prevent false positives

Establishing a Connection: Recognizing the Stitch

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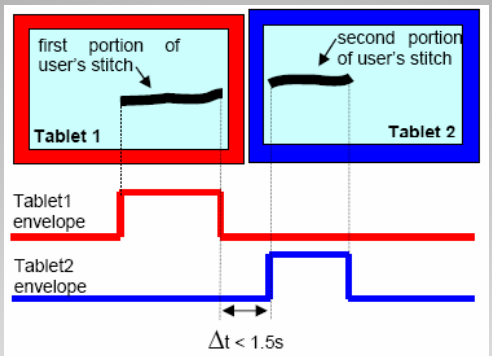

Figure 3. Conceptual diagram of stitching recognition.

User Feedback

- Once minimum stroke time on second device has passed, devices emit a chirp
- Give visual feedback (e.g. animate photos moving from one device to the other)

Specifying Connection Type: Multi-Device Commands

- Local prefix menu
  - Select operation locally, then stitch
- Remote postfix menu
  - Stitch, then select operation on remove device
- Local postfix menu
  - Stitch, then select operation on local device
- Remote prefix menu
  - Select command on remote device, then stitch

- Requires separate gestures
- Two methods
  - Lasso pictures, then lift pen slightly to continue stitch
  - Lasso pictures, then pause with pen down before completing stitch
- Deselect operands after timeout

Specifying Operands

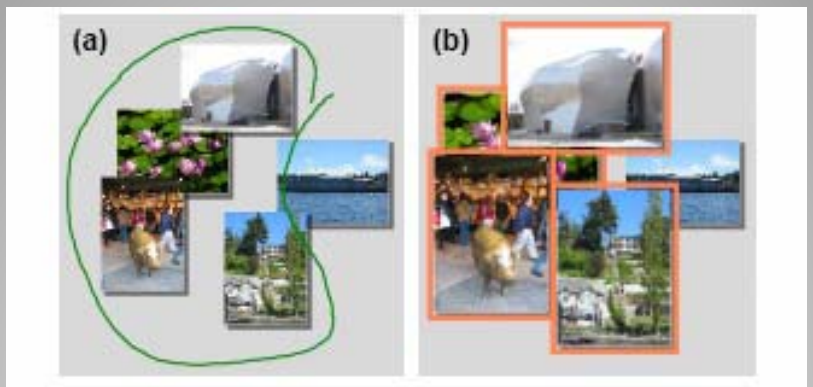

Figure 7. (a) Multiple selection using the lasso gesture. (b) Selected photos scale up and highlight in orange.

Specifying Operands

- Inferred by the stitch
- Ignore spacing between devices
- Use trigonometry to determine offset
- Offset used for image scaling, cross-device animation, etc.

Spatial Relationship

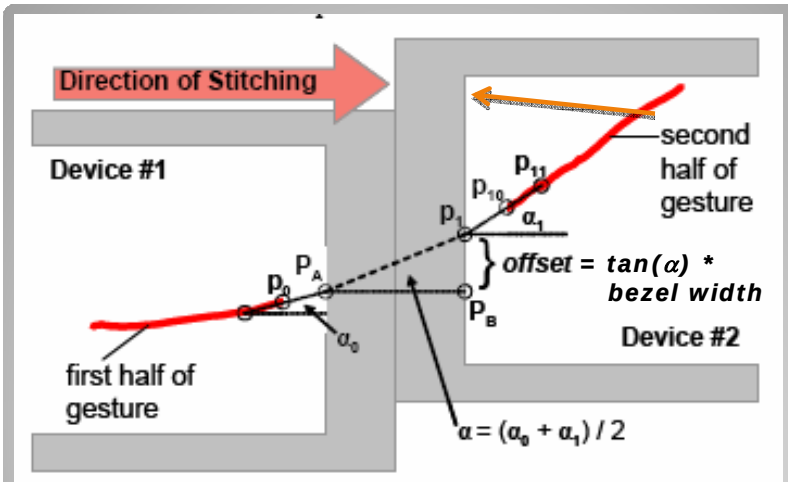

Figure 8. Fitting a line to the user's pen gesture.

Spatial Relationship

Coexistence of Stitching and Traditional Interactions

- Traditional interactions
  - Tracking
    - Pen hovers above screen but still in range
    - Takes getting used to, but can coexist with traditional interaction without any workarounds
  - Dragging
    - Pen moves while touching screen
    - Conventional interaction
    - Supported by assuming everything is a stitch at first and sending the stroke to the device if the stitch server doesn't detect a stitch
  - Out of Range
    - Pen is not in the range of the screen
    - Would require an additional device for recognition

Sharing Physical Space

- Intimate space
  - Devices touching one another
- Personal space
  - Tablets can be up to a few feet apart
  - Establish a connection with one stitch then maintain connection between devices for sending commands
  - Some things would not be supported (e.g. animations or full screen across both devices)
  - Increase timeout to allow longer stitch creation time

Sharing Physical Space

- Social space
  - After connection, devices can be moved further apart
  - Further commands done only on local device
    - Drag picture to edge of device and pause to transfer
- Public space
  - Why bother?

Usability Testing: Experiment

- 12 Participants in pairs
  - 1 Female-Female
  - 3 Female-Male
  - 2 Male-Male
- Given 3 minute practice session to learn basic pen moves
- Given tasks to perform without instruction on how to do them

Usability Testing: Results

- All 12 could establish a connection with a stitch in 1 or 2 tries
- All but 2 could perform a more complex operation
- No preference for dragging vs. tracking
- Users initially wanted to lift the pen after dragging photos instead of tap remote device's screen
  - Support added
- Average response to "Would you use this if it were available?" was 6.7 out of 7
- Many users concerned about security

Usability Testing: Proxemics

- Users wanted to avoid touching tablets
- Users didn't seem to like selecting command on other users tablets
  - Possible fix: local postfix menus

- Avoid unwanted contact/intrusion
  - Porches
    - Each tablet could have a PDA porch
  - Candy dish
    - Shared PDA between both tablets

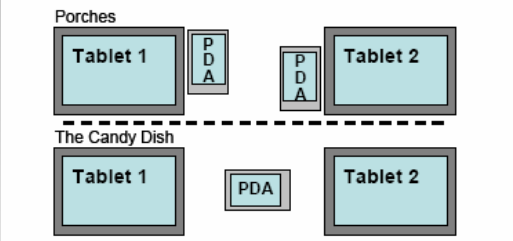

Figure 9. Changing the proxemics of file sharing by using tablet computers and PDA's together.

Possible Future Expansion

- Cooperative stitching
  - One user begins stitch, other user(s) complete it
  - Easily supports many-to-one

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