Lecture 14:
Command Objects & Support for Undo

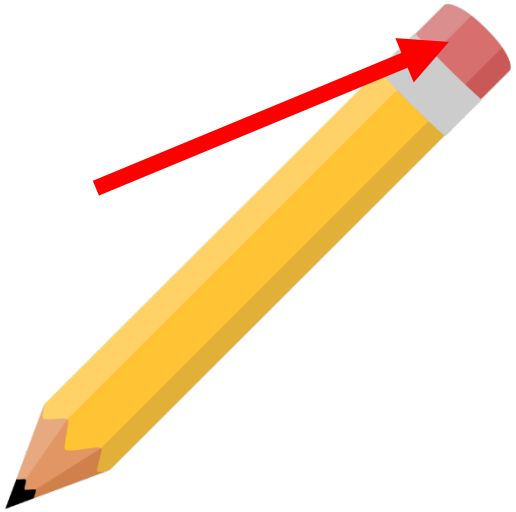
05-431/631 Software Structures for User Interfaces (SSUI)

Fall, 2020

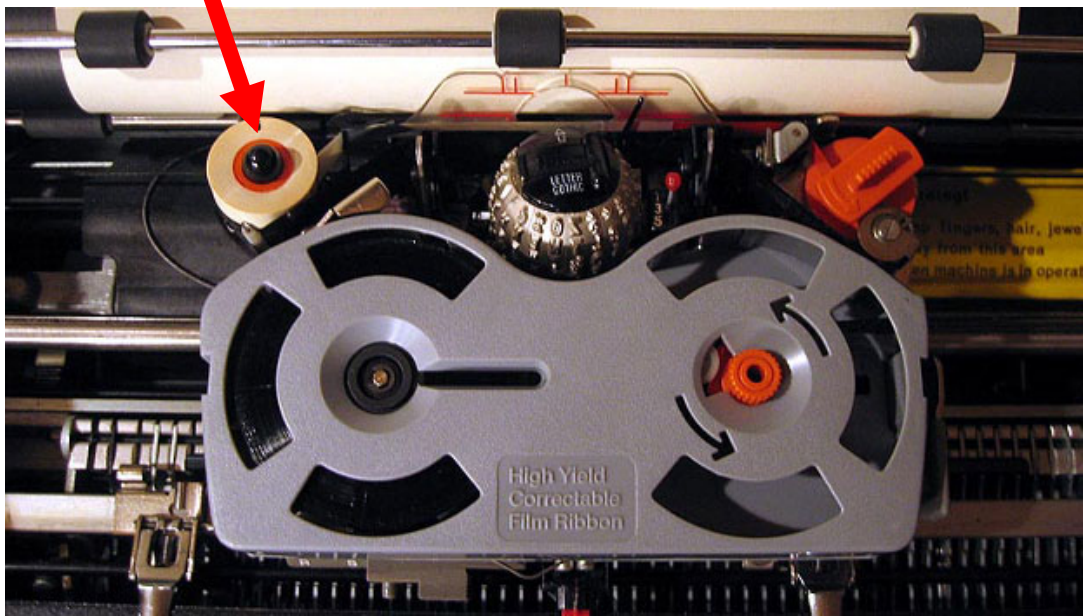
Logistics

- Midterm exam grades and comments posted
  - Please check it
  - Self-reported time to finish: average = **3.5 hours**; min=2, max=6
  - Exam grade average = 90, min=74.5; max=96.5
  - Go over answers
- Midterm course grades on SIO
- Please take the midterm survey by https://www.surveymonkey.com/r/SSUI2021midterm
- Homework 4 due on Thursday
- This lecture is how to do HW 5

Early Undo



Invented 1951 by
Bette Nesmith Graham



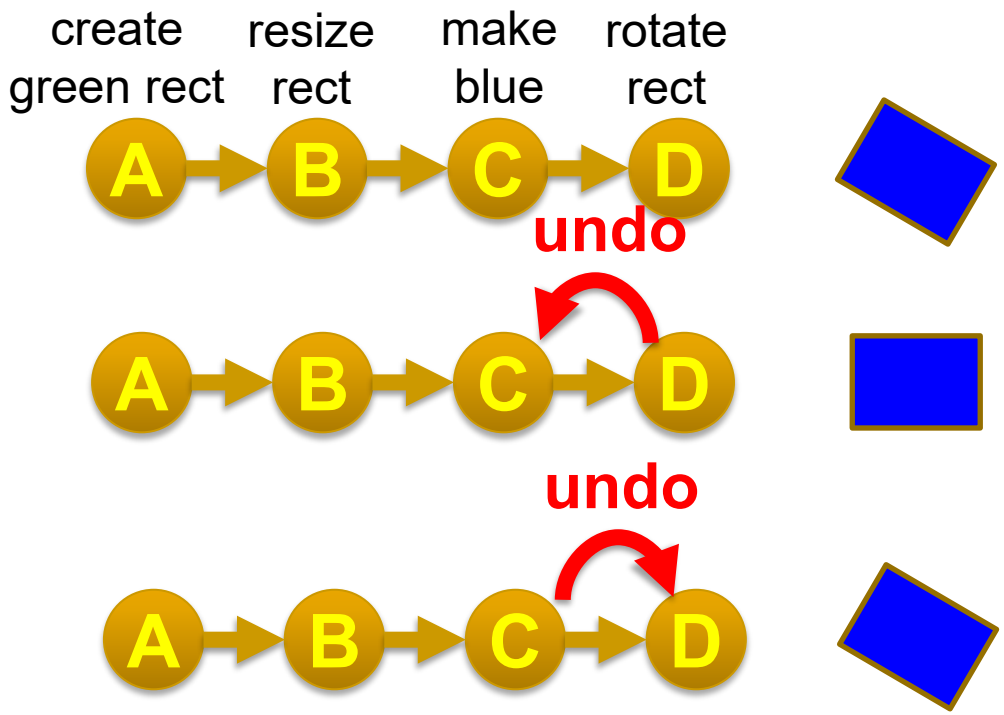
IBM Correcting
Selectric II
1973

Computer “Undo”

- Undo is reversing a previous operation so that it no longer is in effect
  - Usually ^Z
  - For web apps, sometimes the Back button in a browser
- Cancel is stopping an operation *while it is in progress*
  - Often ESC key or the “Cancel” button in a dialog box

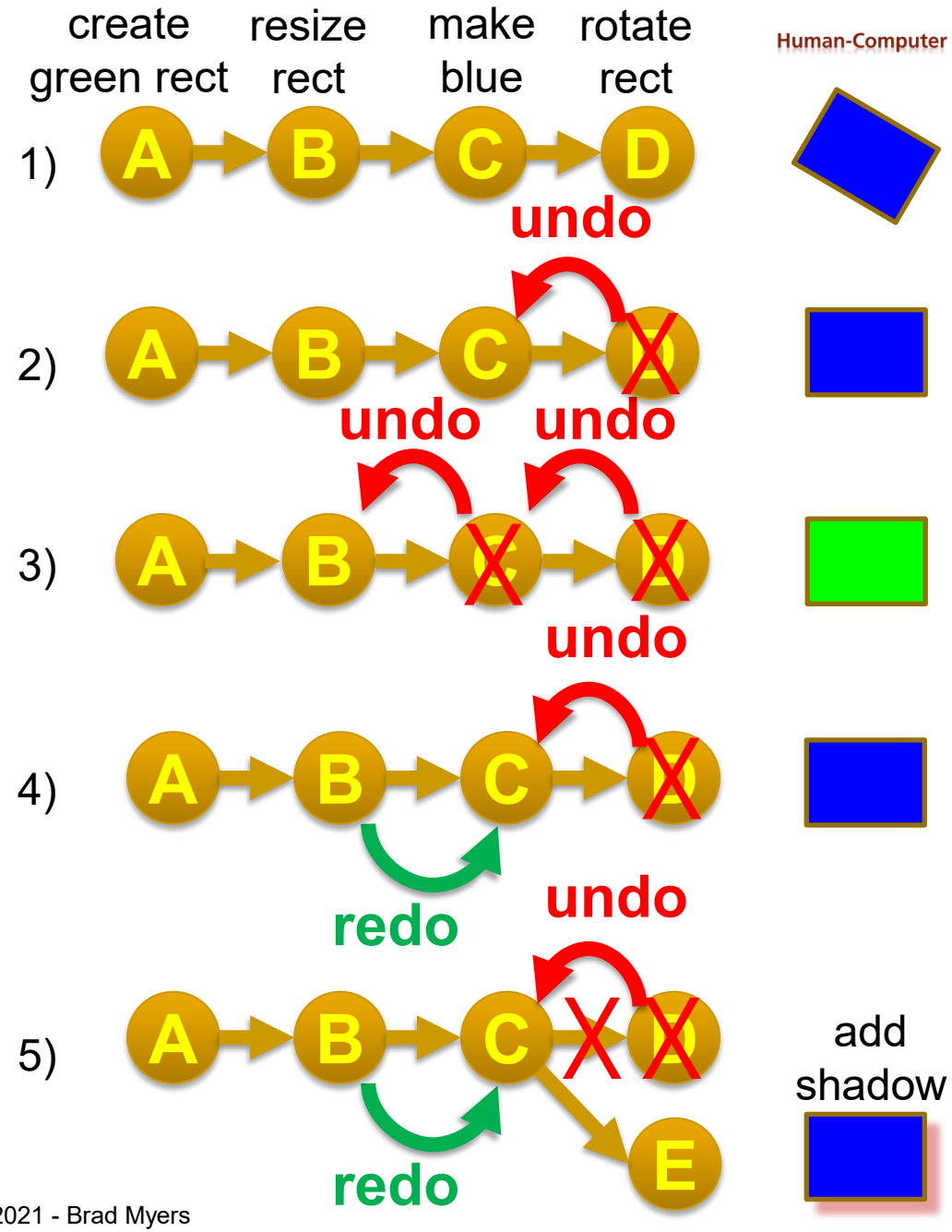
Single Level Undo

- Just toggles the latest item on the list

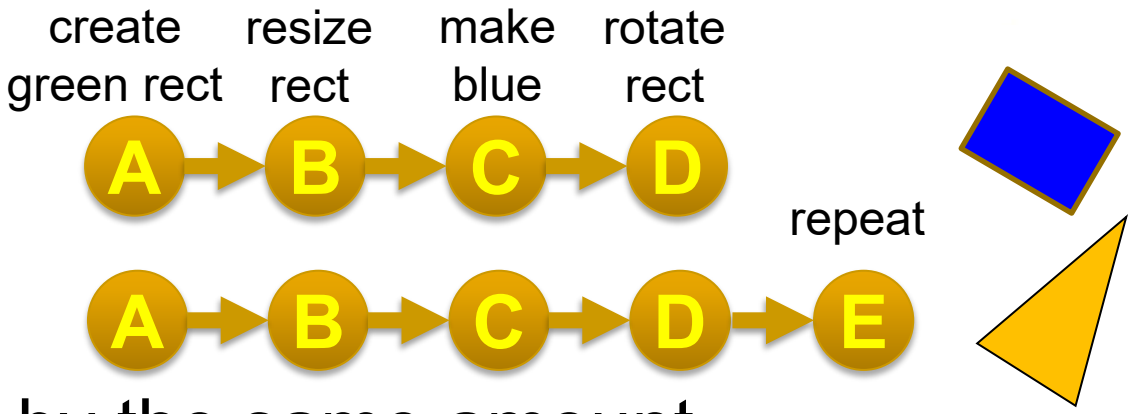


Linear Undo

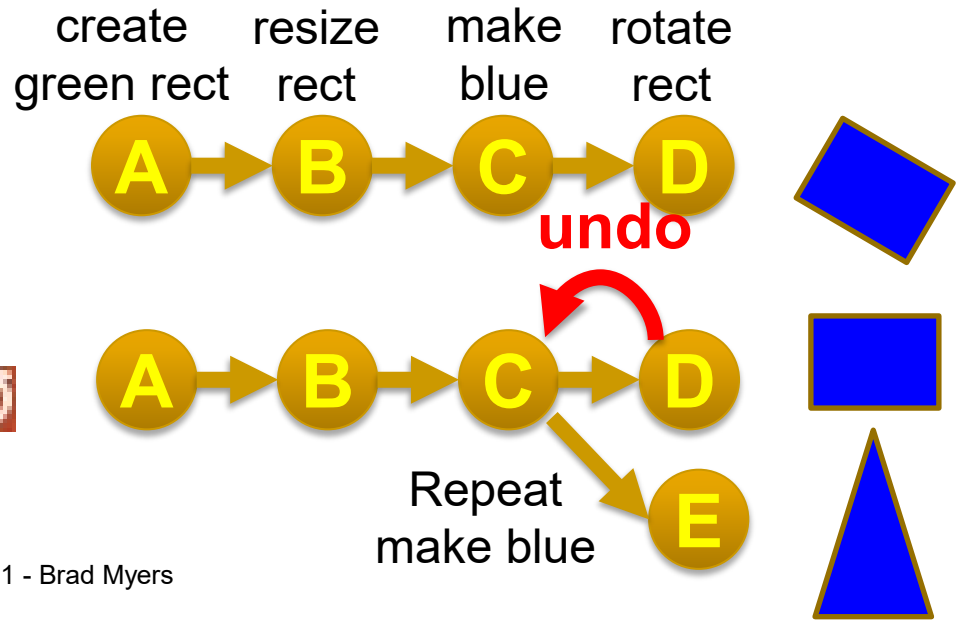
- Keep a list of all operations
- Undo (^Z) goes backwards, repeatedly
- Redo (^-Shift Z or ^Y) goes forwards *after an undo*
  - Undo the undo
- New operations remove anything undone – it is lost forever



Repeat



- Does the previous operation again on *the current selection*
- E.g., rotate *something else* by the same amount
  - Really useful
- Goes on the undo stack just like normal operations
- Typically, uses same shortcut key as Redo
  - But might want to repeat the previous command after an undo
  - Office changes icon
- Repeat is often not available



Complications: Operations *not* put on Undo Stack

- Scrolling
  - Might be useful to have a “go back”, like with hyperlinks
  - See research later
- Changing the selection
  - not undoable, doesn’t change undo stack
  - My Topaz system made this available for undo – see later
- Changing the value of controls, if doesn’t affect any objects
  - Changing the color of the next-drawn object
- Copy (as in Cut-Copy-Paste)
  - Clipboard changes are not affected by undo
    - Lots of clever strategies take advantage of this
    - Also not possible since clipboard is global and undo is per-application
- Saving to file is not undoable
  - Old: blocks off all previous operations
  - Current: not put on undo stack so can undo past saves

Complications: operations that are collected

- Multiple characters typed grouped into one undo
  - Similarly, multiple backspaces
- Used of arrow keys to “nudge” graphics often grouped into 1 operation

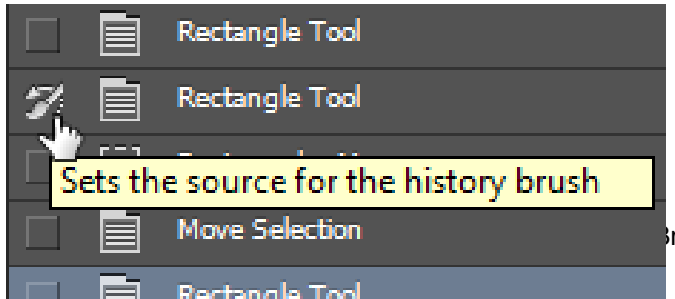
- Or, one operation causes *multiple entries* on undo stack: teh_ → the_ (auto-correct; text)

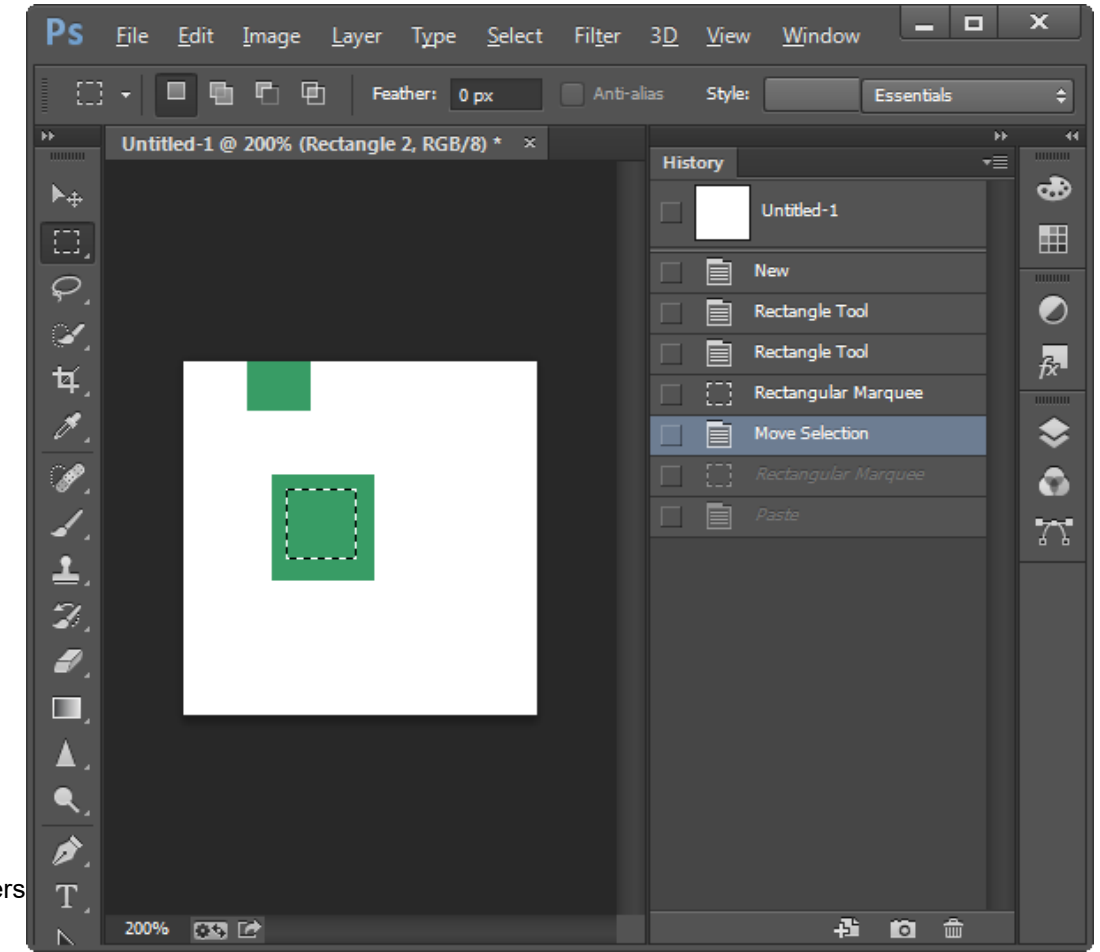
Undo in Various Programs

- See details for how Linear Undo works in PowerPoint
  - Good reference for expected behaviors
  - Note how selection changes as a result of undo
- Many programs have “unusual” designs for undo
  - Outlook – single level; undo delete – not selected (so hard to find)
  - Emacs editor – weird “switch directions” undo – forward/backwards
  - PhotoShop – 2 or 3 different undo mechanisms

Adobe PhotoShop

- History pane displays previous operations
- ^Z – one-level undo that toggles undo/redo – until V2019
- Also Shift-^Z, Alt-^Z - linear undo forwards and backwards
  - Redo list erased on new operations
- "History brush"
  - Select point in past and brush area – returns to the way it was in the past
  - Can't "skip" operations
  - Is selective by *region*, but not by *time*



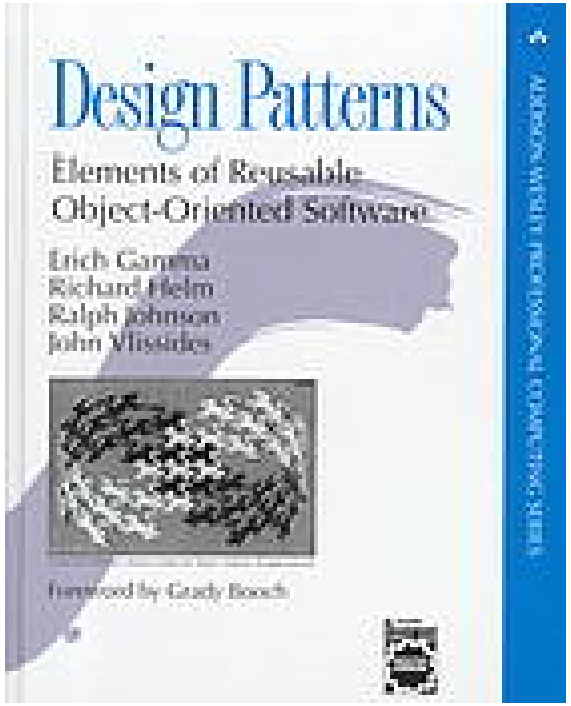


Undo implementations

- Need a central list of operations
- Where to store the old values?
  - With objects that are modified
    - E.g., a rectangle keeps track of all its former locations
    - Called “Memento Pattern” (Wikipedia)
    - But limited in kinds of editors – doesn’t work for text, paint
  - In a global list
    - But what to store for each operation?
  - Using the Command Object pattern
    - Store in the command object itself
    - Then it stays with the operation
    - No confusion about which parameters for which operation

Command Object Pattern

- Wikipedia: “An object is used to encapsulate all information needed to perform an action or trigger an event at a later time. This information includes the method name, the object that owns the method and values for the method parameters.”
- Was in original “Design Patterns” book (1994)
- Better separation between action and widgets
- Clearer place to store information needed for undo



HW 5 design for Command Objects

- Abstract class that all operations extend:
  `class CommandObject`
- Methods for Execute, Undo, Redo etc., that specific commands override
- Variables for saved values in the command object itself

```
export default class CommandObject {
  constructor(controls, addToUndoStack = true) {
    this.undoHandler = controls;
    this.addToUndoStack = addToUndoStack; // is this the kind of operations that is queued?
    this.targetObject = undefined; // object this command affected
    this.newValue = undefined; // new value used by the command
    this.oldValue = undefined; // previous (old) value for the object
  }
```

Sub-classes of command object

- Create a subclass of CommandObject for each kind of command

```
import CommandObject from "./CommandObject";

export default class ChangeFillColorCommandObject extends CommandObject {
  constructor(undoHandler) {
    super(undoHandler, true);
  }
```

  - Also: CreateObjectCommandObject, ChangeBorderColorCommandObject, ChangeBorderWidthCommandObject, etc.

Standard Process for using a Command Object

1. When the user clicks menu item (e.g., to change color), or starts an action (like create object), **allocate** a new command object of the correct type

```
curCmd = new ChangeFillColorCommandObject(undohdlr);
```

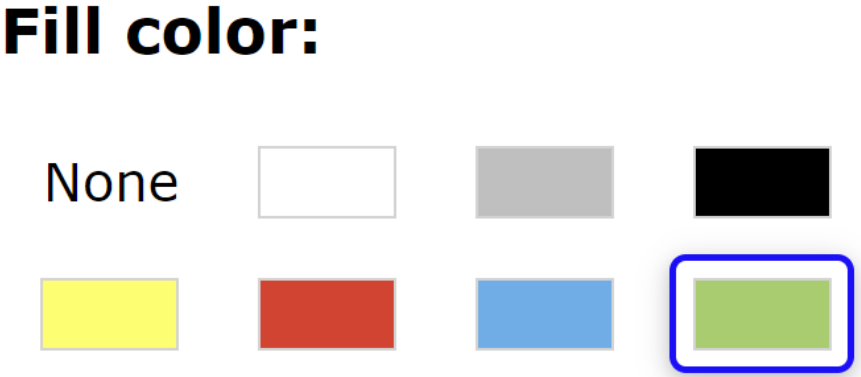
2. Call that object's `execute()` method, which will:
   a) Save all the information needed to undo/redo/repeat the action later
   b) Perform the action
   c) Put this command object on the undo list

- Each kind of object will have a *different* execute method
- What does `ChangeFillColorCommandObject.execute()` need to store?

Provided Example:

ChangeFillColorCommandObject

- Command object that is used when change the fill color
- What to store?

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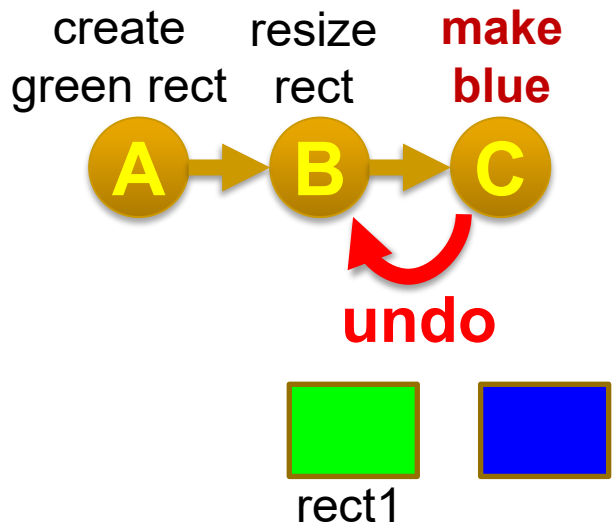
    this.newValue = undefined; // new value used by the command
    this.oldValue = undefined; // previous (old) value for the object
  }
```

Example:

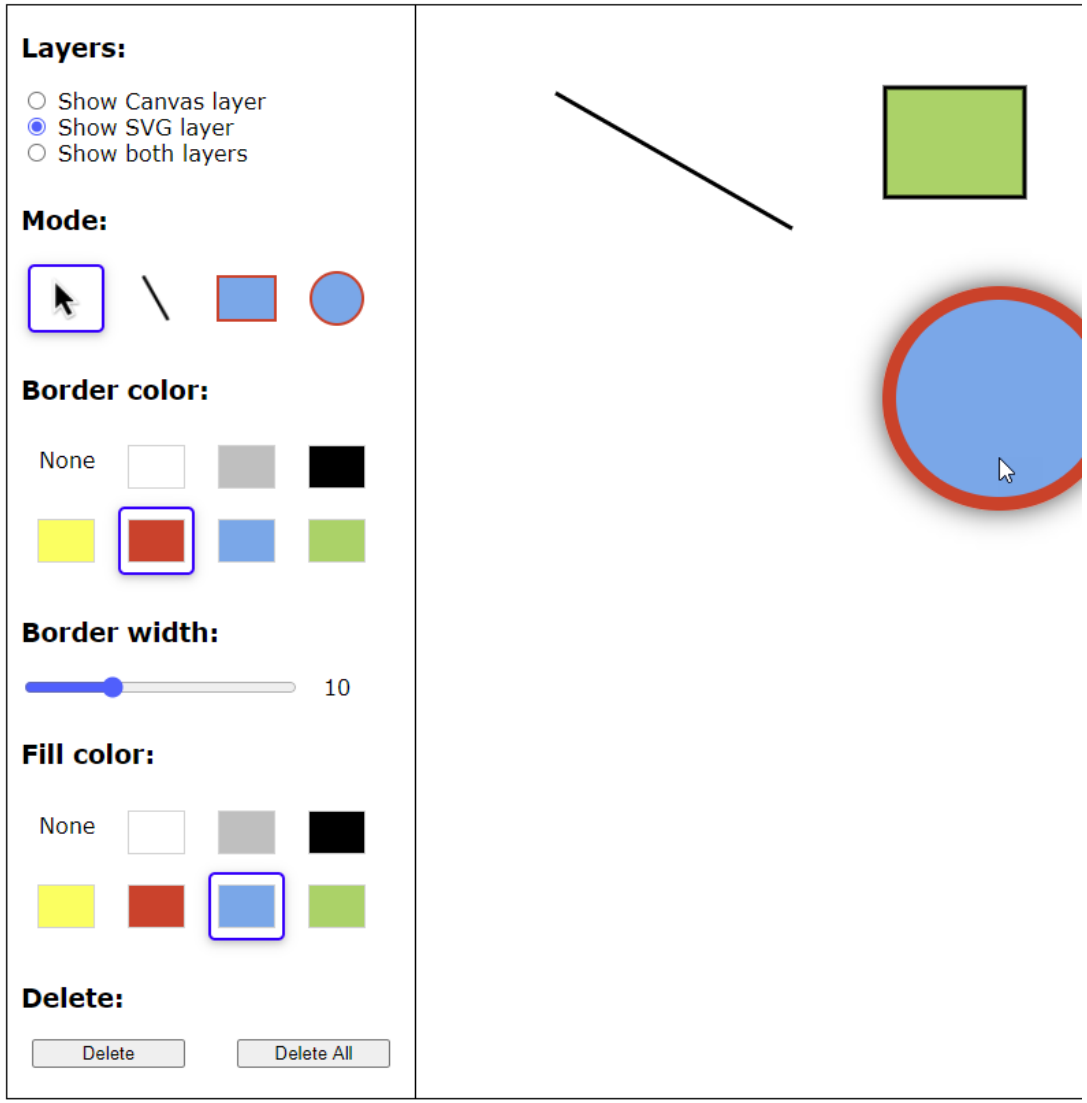
- SVG Change fill color: C
- Target object = `rect1`
- Old value = "`green`"
- New value = "`blue`"




```
class ChangeFillColorCommandObject extends CommandObject
```

Values

- `newValue` and `oldValue` often need to be an object with many values
- What to store for *create* in HW 3?
  - *All values used:*
    - Type (line/rect/ellipse)
    - Coordinates for create
    - Border color
    - Border width
    - Fill color
  - For SVG, can store the created object, but not for canvas
- Why can't you just get values from the palette?



Command Object Methods

- Execute / Do
  - The actual operation of the command, like to change the fill color
  1. Gets parameters from the global variables *and saves them in the Command Object itself*
  2. Execute the command
  3. Save the command object on the undo stack
     - Real operation will be a little more complicated
- For `ChangeFillColorCommandObject:`

```
execute() {
   if (selectedObj !== null) { // global variable for selected object
        this.targetObject = selectedObj; // save the object
        this.oldValue = selectedObj.fillColor; //get current color
       this.newValue = fillColorWidget.currentColor; //new color
        selectedObj.fillColor = this.newValue; //actually perform the change
       if (addToUndoStack)
         this.undoHandler.registerExecution({...this}); //load me onto undolist
                // which will also potentially remove pending undone commands
        }
}
```

Other Command Object Methods

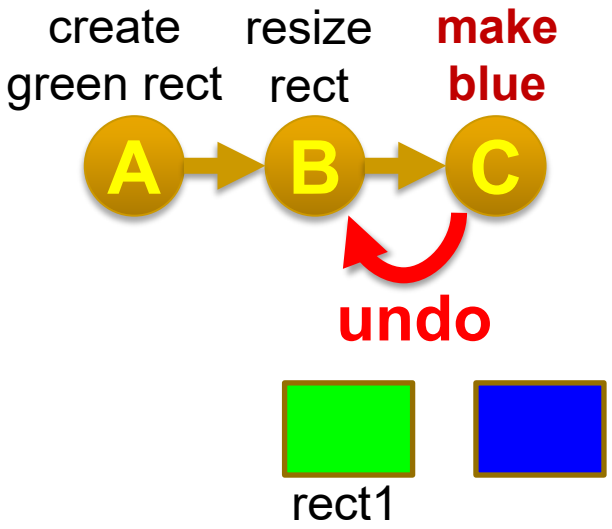
- `canExecute()` – whether the execute method will work now
  - For change color – just if there is an object selected
- `canRepeat()` – whether repeat will work now
  - For change color – just if there is an object selected and a previous color

```
canExecute() {
    return selectedObj !== null;
}
canRepeat() {
    return (selectedObj !== null) && this.newValue;
}
```

Undo & Redo

- Undo method – make the object have its old value

```
undo() {
    this.targetObject.fillColor = this.oldValue;
    // make sure this object is selected, which will
    // also fix the palette to show this object's color
    becomeSelected(this.targetObject);
    ** now fix the undo stack **
}
```

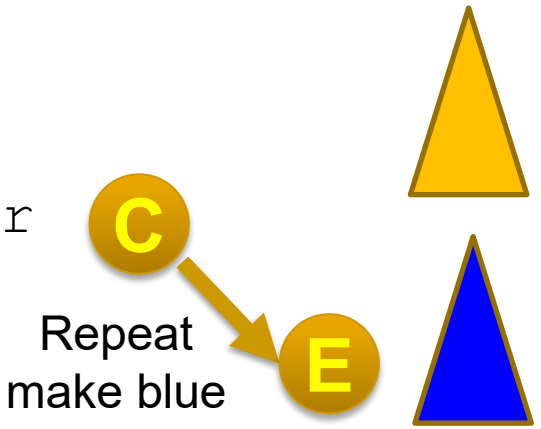


- Redo = undo the undo

```
redo() {
   this.targetObject.fillColor = this.newValue;
   becomeSelected(this.targetObject);
   ** now fix the undo stack **
}
```

Repeat

- Apply same color to the currently selected object
  - Different object, so might have a different old color
- Remember, this operation is added to the undo stack
- Note: *not* the palette's current color – use saved `newColor`
- Need to allocate a new command object for repeat



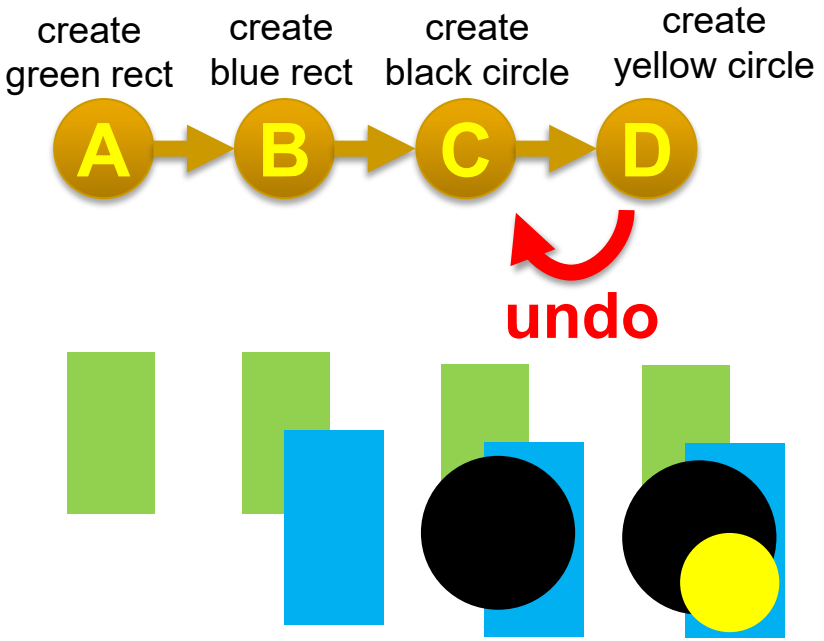

```
repeat() {
  if (selectedObj !== null) {
    this.targetObject = selectedObj; // get new selected obj
    this.oldValue = selectedObj.fillColor; //obj's current color
    // no change to newValue - comes from operation that was copied
    selectedObj.fillColor = this.newValue; //actually change
    if (addToUndoStack)
        this.undoHandler.registerExecution({...this});
}
```

Change Color Control

- When the user clicks on a color, that is different from the current object's color, then:
  - Create a new `ChangeFillColorCommandObject`
  - Call its execute method

Implementing Undo for Canvas

- How can “undraw” an operation for the Canvas?
  - Note: *not* part of homework 5
- Just have to save a copy of the canvas before each operation
  - Redo can perform the operation again – do **not** need to store *both* before and after images
  - Optimization – save only the parts of the screen that changed
- Why not redo everything from the beginning each time?
  - Too slow in realistic situations

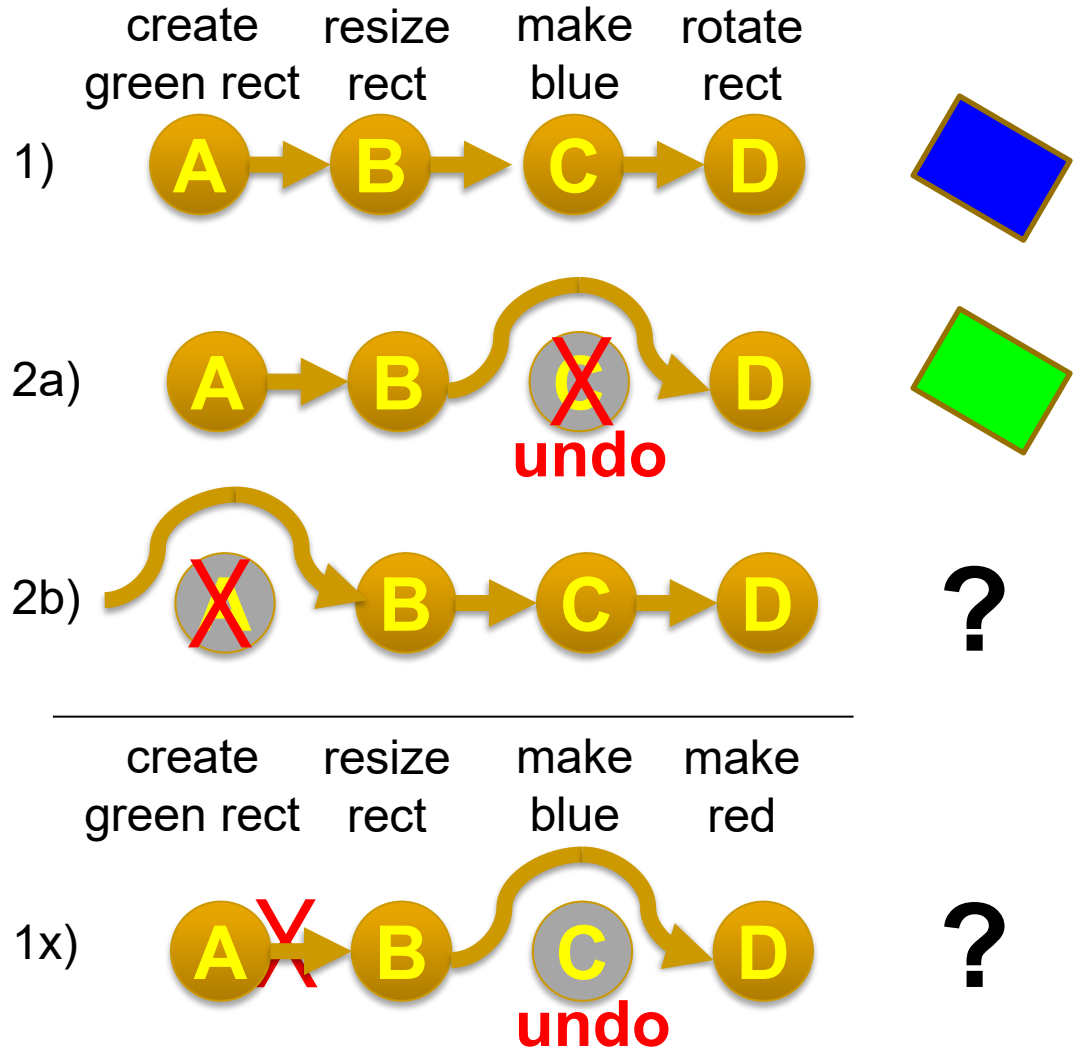


Linear Undo Handler

- Has to keep the undo stack, and keep track of which operation should be undone / redone / repeat
- Methods for
  - register a command object (after executed)
  - doUndo – call this when user hits the undo menu item
  - Undo Available? – controls greying out the undo menu item
    - Just checks if there is a command on the undo stack
  - doRedo, doRepeat, redo/repeat available?

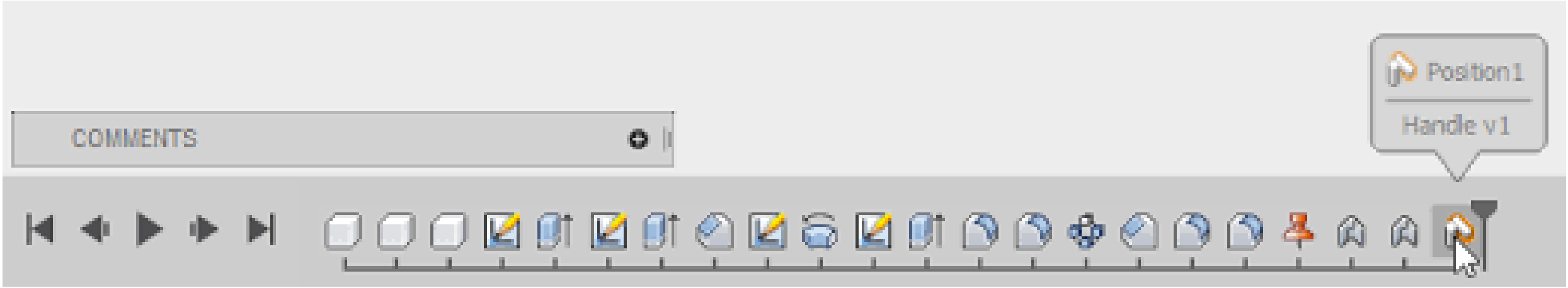
Advanced: Selective Undo

- Reach back into history and **select** which operation to undo
- "Script model"
  - As if that operation was just removed
- Often unclear what this means!



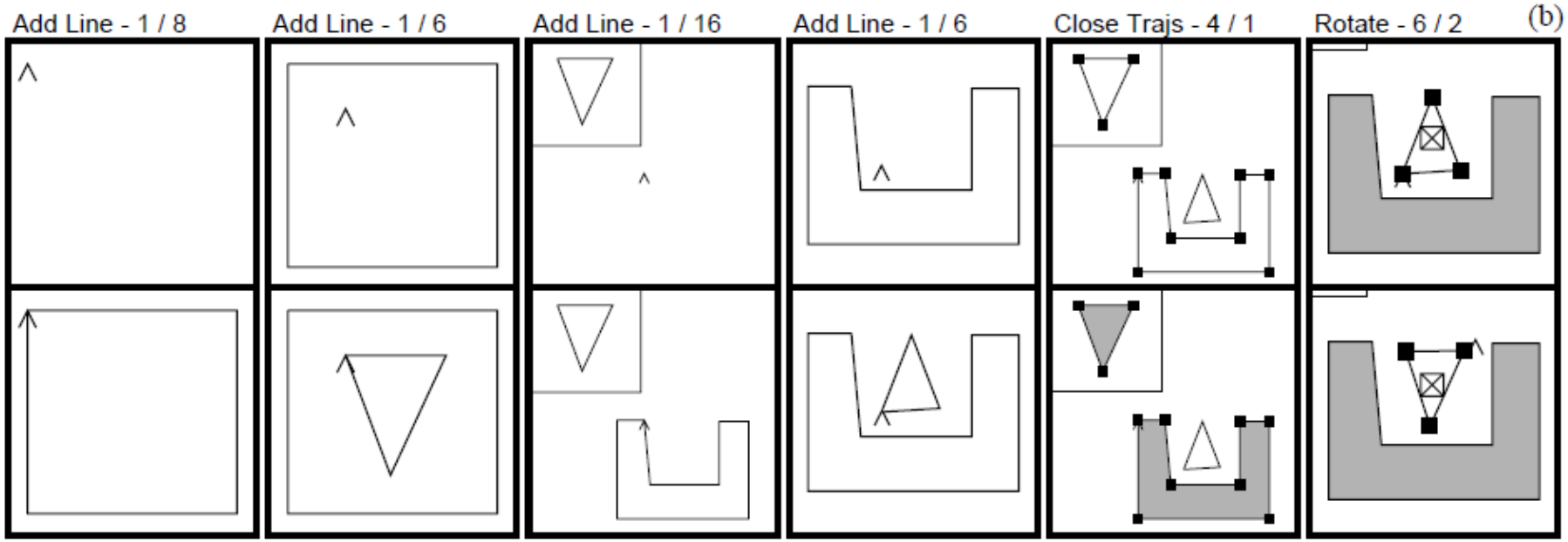
Timeline view in Fusion 360

- Fusion 360 (a CAD software) from AutoDesk
  https://www.autodesk.com/products/fusion-360/blog/master-the-timeline-browser-preferences/
- Provides graphical timeline for undo
- Complete collection of every change made to your design
  - Selective undo (“suppress”) also affects later operations that depend on it



Kurlander's Graphics Histories

- Kurlander, D. and Feiner, S. Editable Graphical Histories. Proc. 1988 IEEE Workshop on Visual Languages. (Pittsburgh, Oct. 10-12, 1988). 127-134. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=18020&isnumber=662
- Video (2:42)
- Before and after scenes for each operation
- Can undo back to any point
  - Can then *change things* and redo the operations afterwards
  - Basically, the "script" model of undo/redo

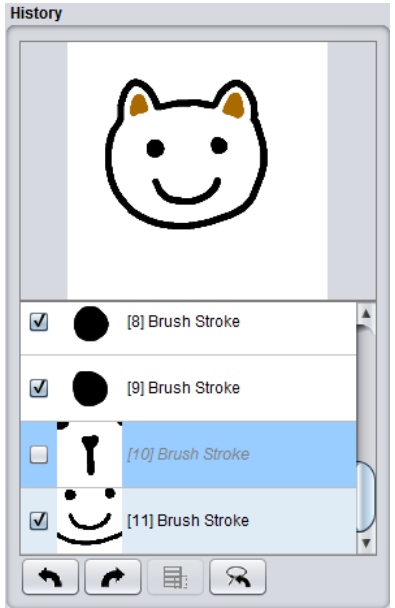


Aquamarine

- Brad A. Myers, Ashley Lai, Tam Minh Le, YoungSeok Yoon, Andrew Faulring, Joel Brandt, "Selective Undo Support for Painting Applications", Proceedings CHI'2015: Human Factors in Computing Systems, Seoul, Korea, April 18-23, 2015. pp. 4227-4236. http://dl.acm.org/citation.cfm?doid=2702123.2702543
- **A**llowing **Q**uick **U**ndoing of **A**ny **M**arks **A**nd **R**epairs to **I**mprove **N**ovel **E**diting

- Selective undo of past operations in a paint program using the script model
  - Can't use inverse model in paint because can't change affected pixels in current context
  - No dependencies among objects as there are in a drawing program
  - Issue: spatial dependencies:
    - Copy and paste
    - Flood fill (paint bucket)

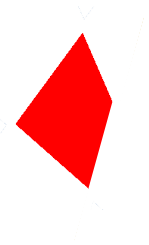
Short Video: 0:30
Video: 4:35



Selective Undo by Region

- Selective Undo by Region
  - Regular linear undo but only for operations in the region
  - Avoids the ambiguities
  - Available in PhotoShop, our research system for code editing in Azurite:

    YoungSeok Yoon and Brad A. Myers. "Supporting Selective Undo in a Code Editor," *37th International Conference on Software Engineering, ICSE 2015. Florence, Italy, May 16-24, 2015. 223-233 (volume 1).* pdf and video.

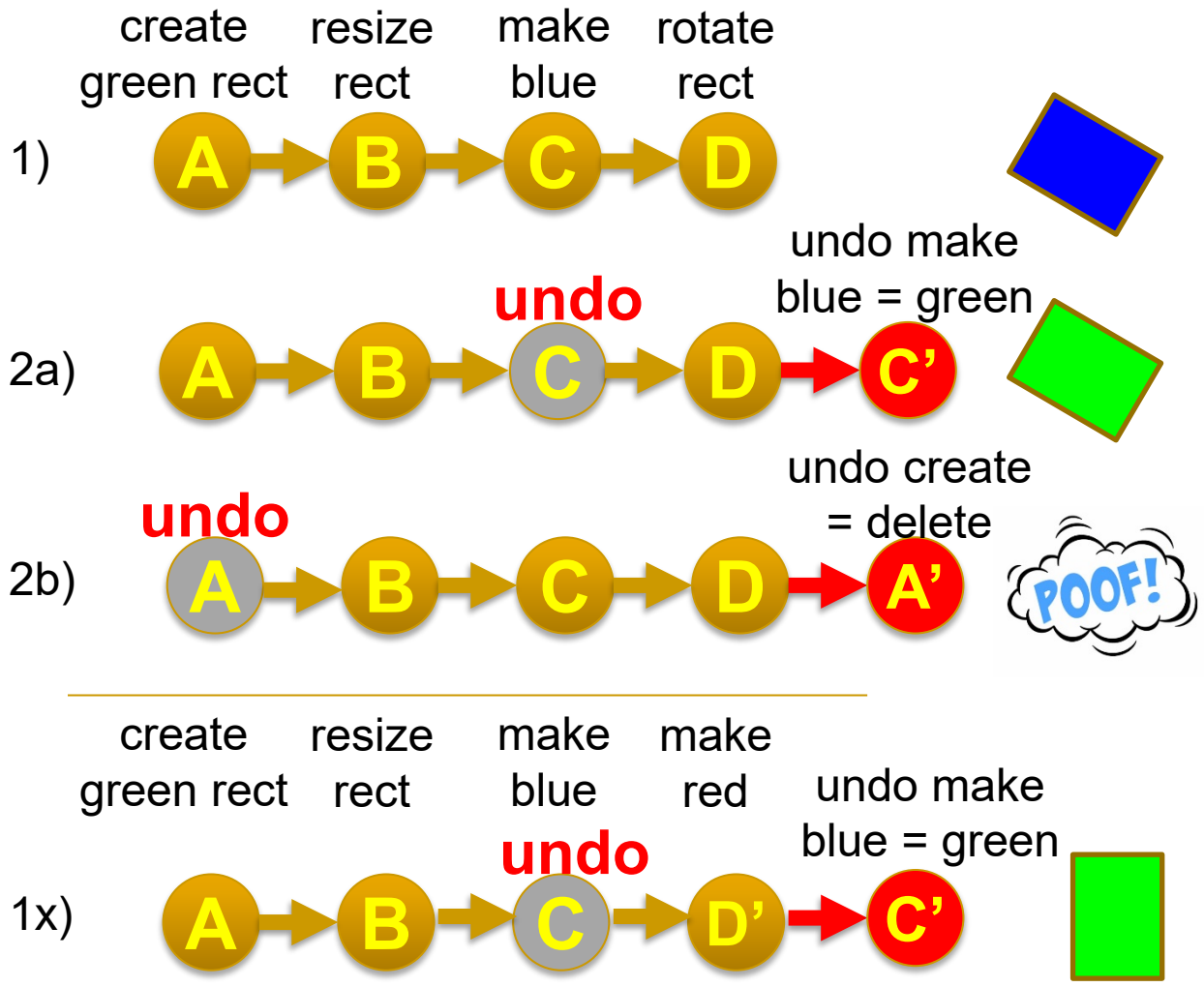


Direct Selective Undo or Inverse Model

- Gina:

  Thomas Berlage. "A Selective Undo Mechanism for Graphical User Interfaces Based on Command Objects," *ACM Transactions on Computer Human Interaction. Sep, 1994. vol. 1, no. 3. pp. 269-294.*

- Perform inverse of selected operation
- Put at end of undo stack
- Almost anything can be undone
- Meaning determined by what is "useful" and appropriate



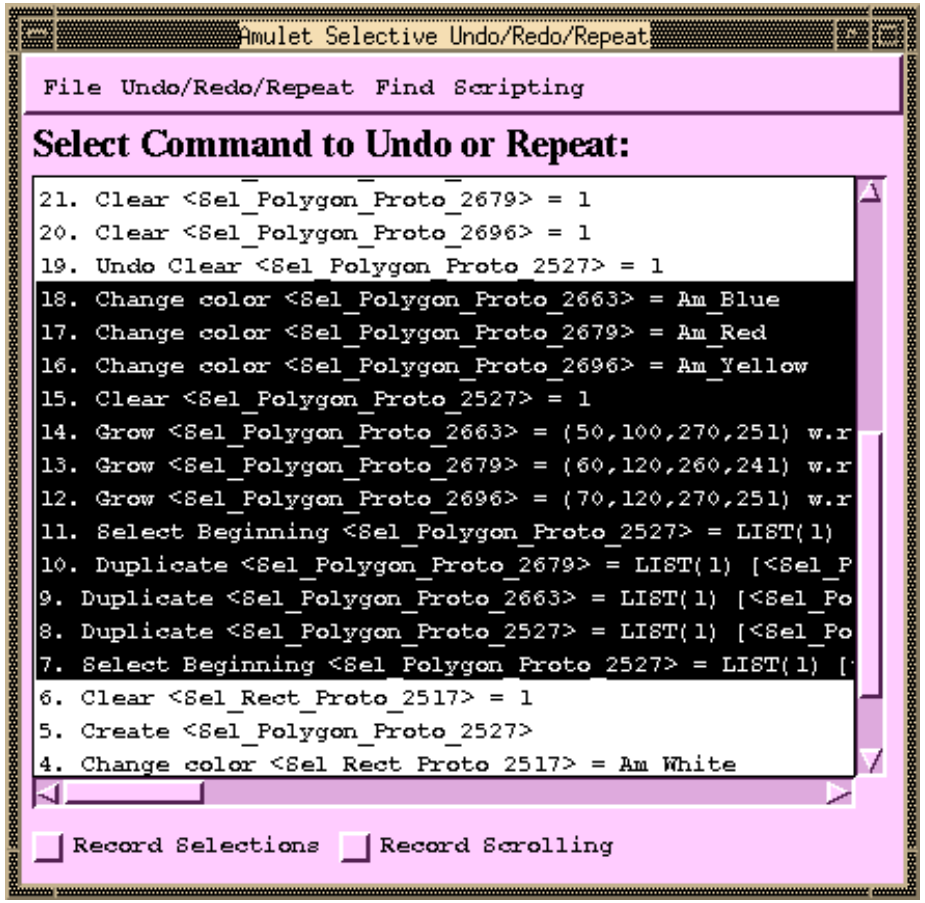
Direct Selective Undo Implementation

- Implementing direct selective undo not much harder than regular undo:
  - Allocates a new command object and adds to end of history list
  - Semantics is based on what the user would want
  - Undo the operation in a new context means to set the object back to its previous value
  - Selective Undo is enabled if object is still available
  - Undo of create is delete
- Redo the operation means to set the value of the object again;
  - redo of create = a new object
- Repeat = redo on new object

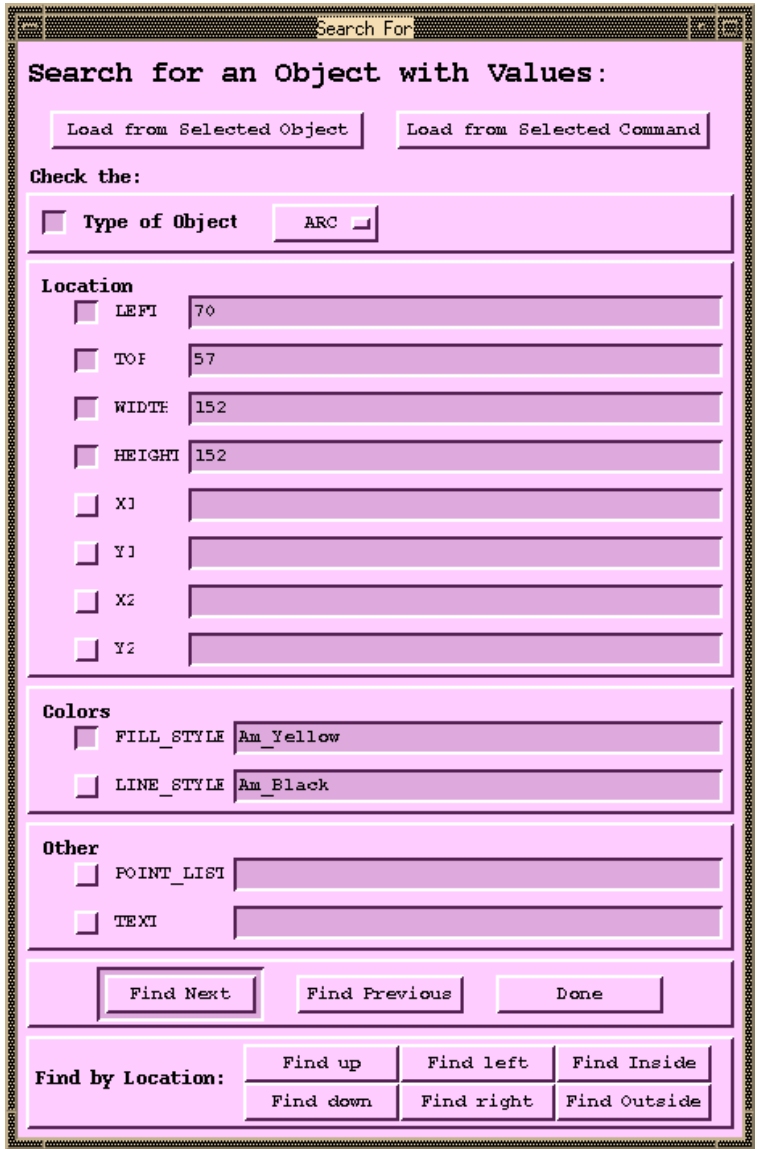
Scripting = “Topaz”

- Brad A. Myers. "Scripting Graphical Applications by Demonstration," *Proceedings CHI'98: Human Factors in Computing Systems*. Los Angeles, CA, April 18-23, 1998. pp. 534-541. ACM DL, or local pdf, and YouTube video or local video (3:09). (Topaz)

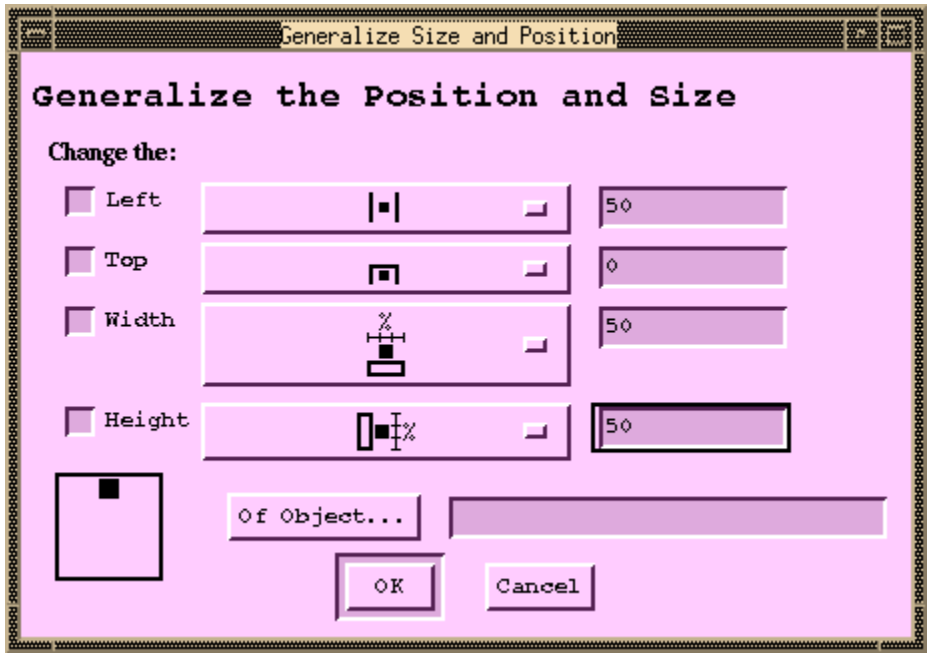
- Select set of commands and specify that in a program
- Uses selective repeat
- Can parameterize actions
- Moving which object selected is recorded
  - Forwards, backwards, left, right, up, down, in, out
  - Search for object of a particular type or value
- Little or no change to application if it supports Selective Repeat



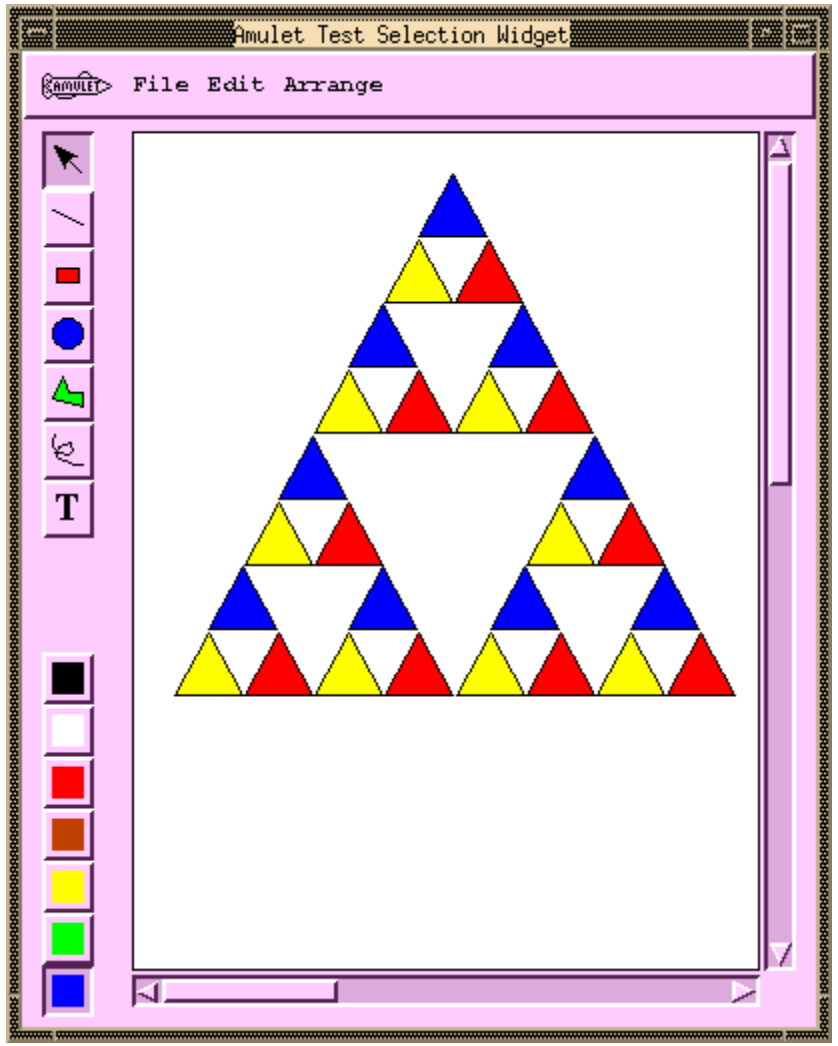
Pictures for Scripting: Object Search

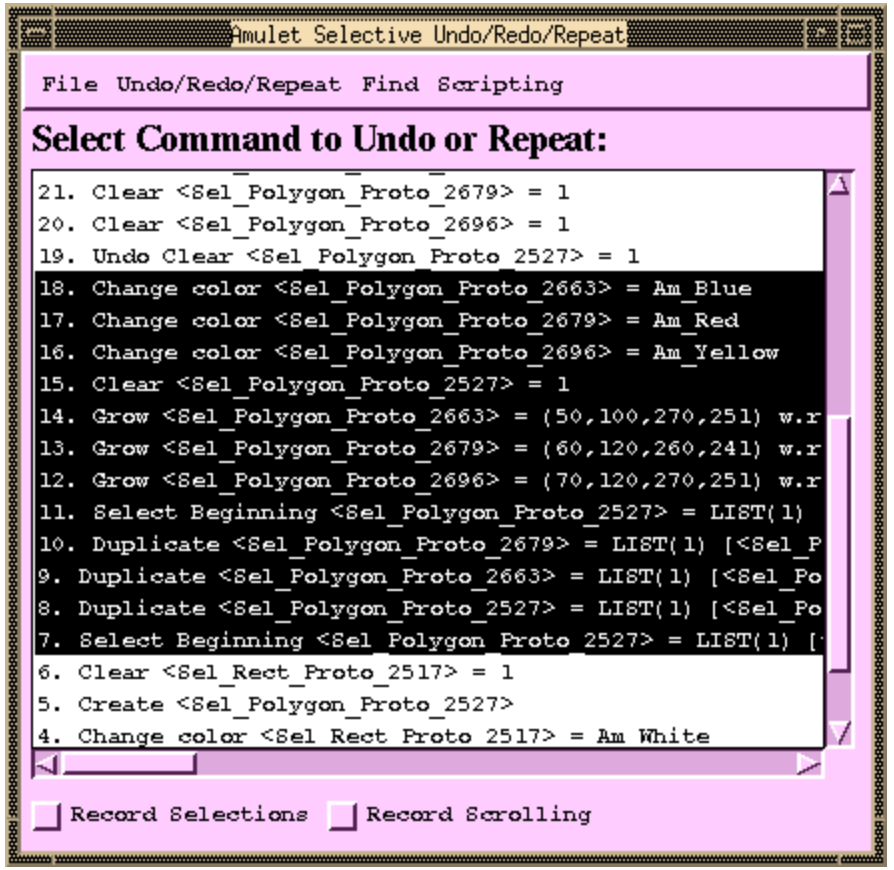


Pictures for Scripting: Generalize Position / Size



Pictures for Scripting: Result





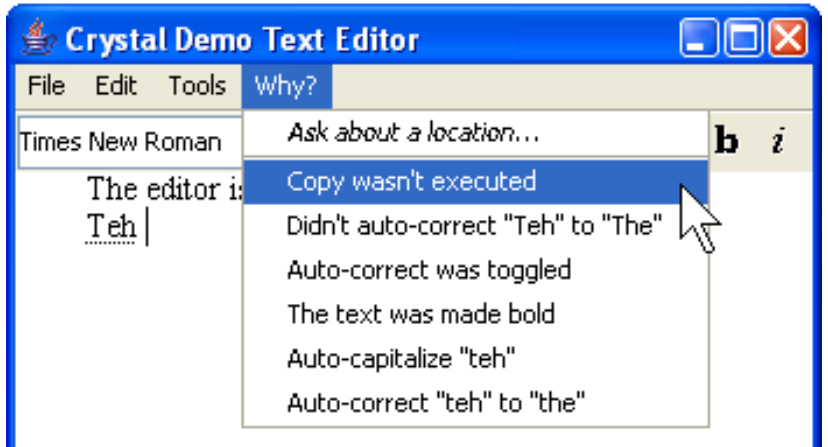
Multi-User Undo

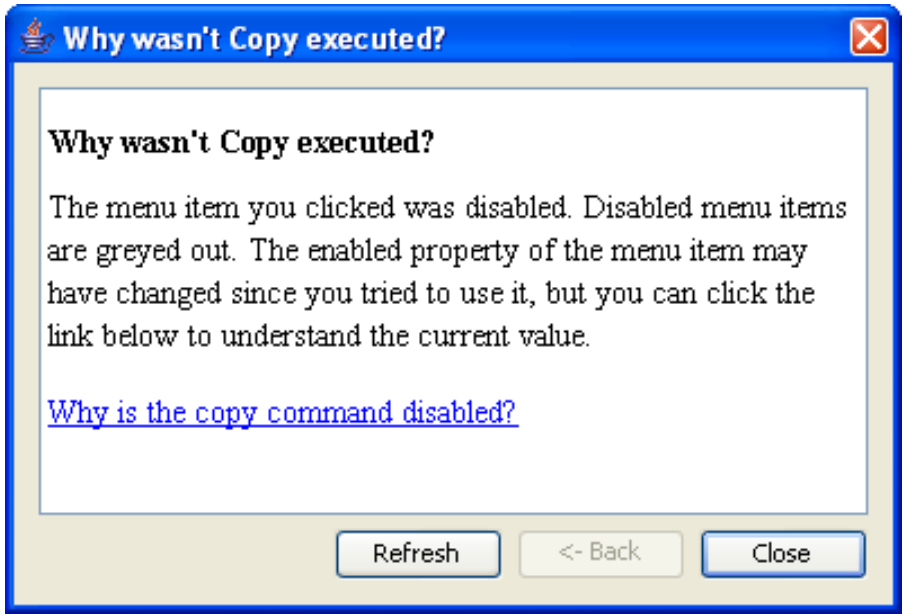
- Required for Google Docs
  - Let's try: https://tinyurl.com/SSUIUndo
- if multiple users have overlapping selection regions and one user does Undo – what should be done?
  1. Undo the globally last operation
  2. Undo that user's last operation
  3. Undo the last operation in the region of the user's cursor
- Google Doc is somewhat random
- Old research on correct ways to handle this
  - Summary: it's complicated for text, easier for graphics

Using Undo History for "Why" Help

Interaction Institute HCII

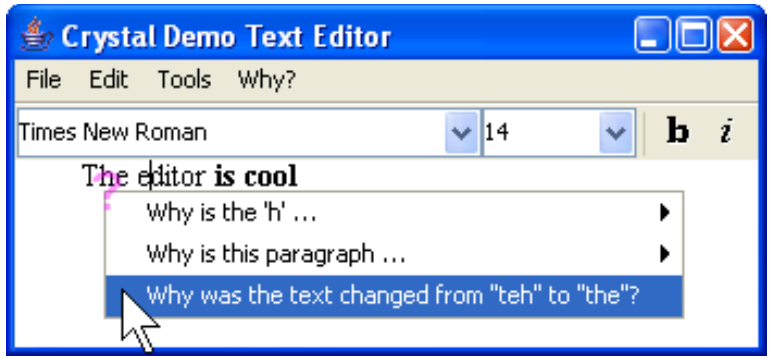
- Crystal: Clarifications Regarding Your Software using Toolkit, Architecture and Language
- Brad Myers, David A. Weitzman, A.J. Ko, and Duen Horng Chau, "Answering Why and Why Not Questions in User Interfaces," *Proceedings CHI'2006: Human Factors in Computing Systems*. Montreal, Canada, April 22-27, 2006. pp. 397-406. pdf. See also YouTube or local video
- Help answer why things happen in regular desktop applications
- Lots of complexity in powerful features that people generally like
- Ask "Why" about what recently happened



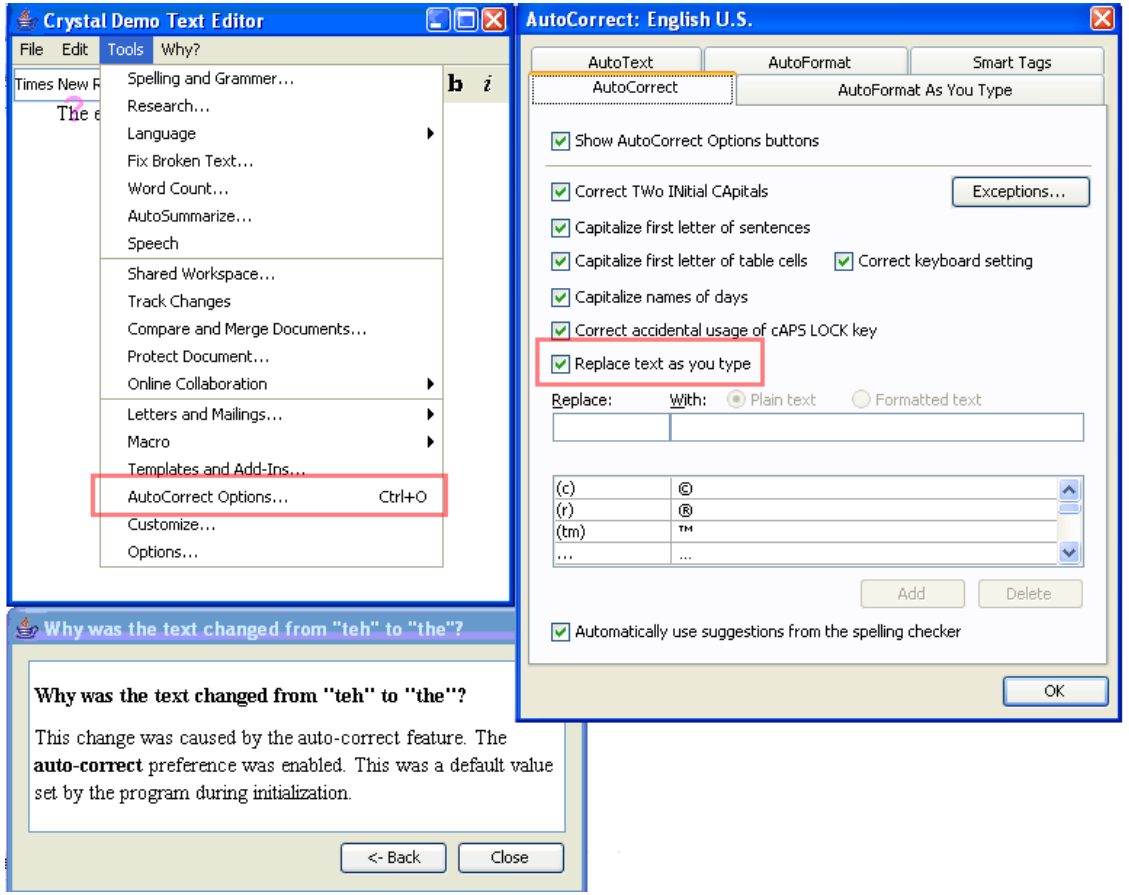


Crystal

- Or, ask Why about a location by clicking on objects, or whitespace

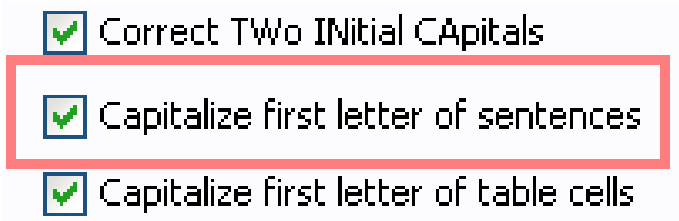


- Also can explain complexities like style inheritance, etc.



Crystal Implementation Overview

- (Full details in the paper)
- *Only a little more work than supporting Undo*
- "Command object" architecture for actions
  - Command objects stored on a list for undo
- Programmer adds back pointers from objects to the commands that changed them
- Add dependency information for mode variables
- Add special commands for actions *not* executed
- Add extra invisible objects for whitespace and deletions



Crystal Implementation, cont.

- Crystal framework then builds Why menus and answers *automatically*
- Crystal finds:
  - Objects under the mouse
  - Commands that affected those objects
  - User interface controls involved in those commands
- Programmer can annotate some commands to *not* include in menus
  - E.g., regular typing
  - Similar to heuristics for granularity of Undo