X Technical Conference 1995

PhotoKit ™

An XIE Toolkit

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About the Speakers...

- **Larry Hare -- AGE Logic**
  - **Chief Architect**
- **Bob Shelley -- AGE Logic**
  - **Imaging Architect -- PhotoKit project architect**
- **AGE Logic**
  - **supplied the XIE SI to the X Consortium**
  - **bringing XIE technology to the market**
  - **high-performance X server products for PCs, MACs, terminals and embedded systems, through direct sales and OEM relationships**

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XIE PhotoKit Intro

- **XIE provides low level mechanism**
  - **XIElib is basically one to one mapping to XIE**
  - **Difficult to use in many cases**
- **Industry Wait and See Attitude**
  - **X Server Providers**
  - **Application Writers**
- **Need an XIE toolkit ===> XIE PhotoKit**
  - **Extensible, Flexible, Object-oriented, Powerful**
- **PhotoKit is innovative, interesting, intense**

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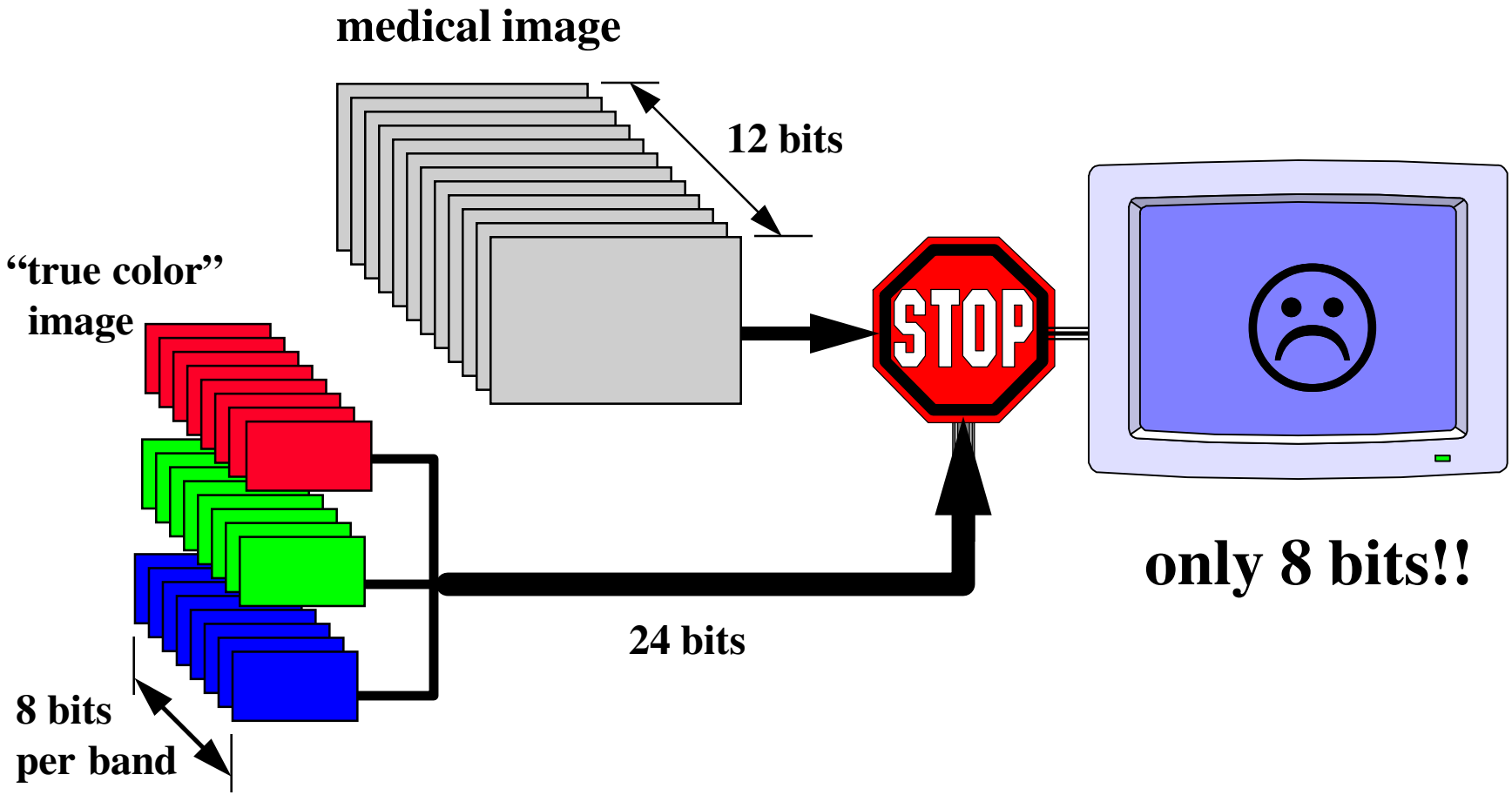
PhotoKit Preview

X needs an “image” data type



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XIE - A Brief History

- Initiated by Joe Mauro at Digital in 1988
  - V1 -- first implementation in 1989
  - V2 -- Photoflos support added in 1990
- Entered Technical Review in March 1991 (V3.0)
- Entered Public Review in Nov 1992 (V4.12)
- AGE awarded Sample Implementation, Jan 1993
- Public Review period ended April, 1993
- AGE released SI to X Consortium, Jan 1994 (V5.0)
- ....

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What does XIE give you?

- **Image transport**
  - what kind of data can we move to and from the X server?
- **Image representation**
  - what kind of data does the X server support?
- **Image rendition**
  - what can we do to display the image on the available hardware?
- **Image enhancement**
  - how can we improve the “viewability” of the image?

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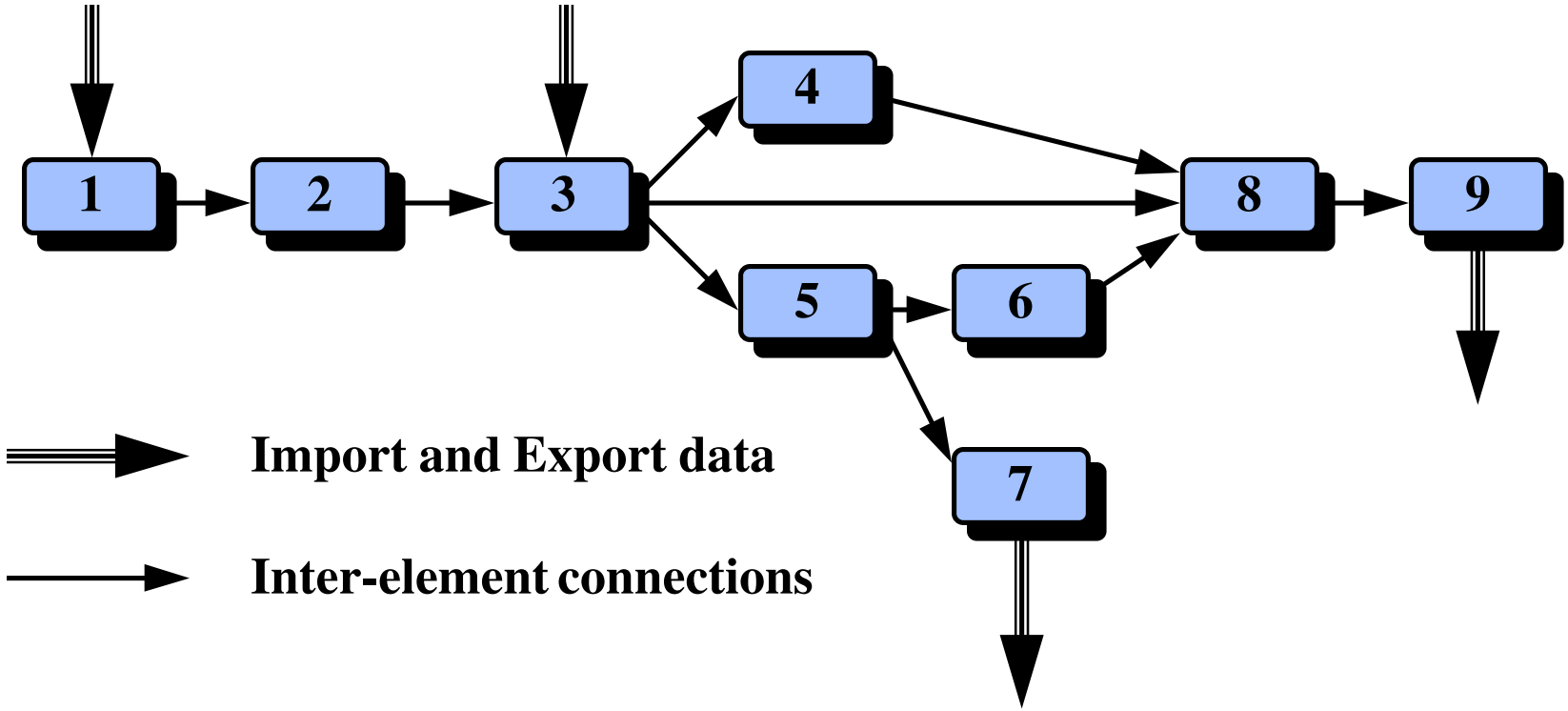
XIE's Programming Model

Photoflo = DAG = array of elements



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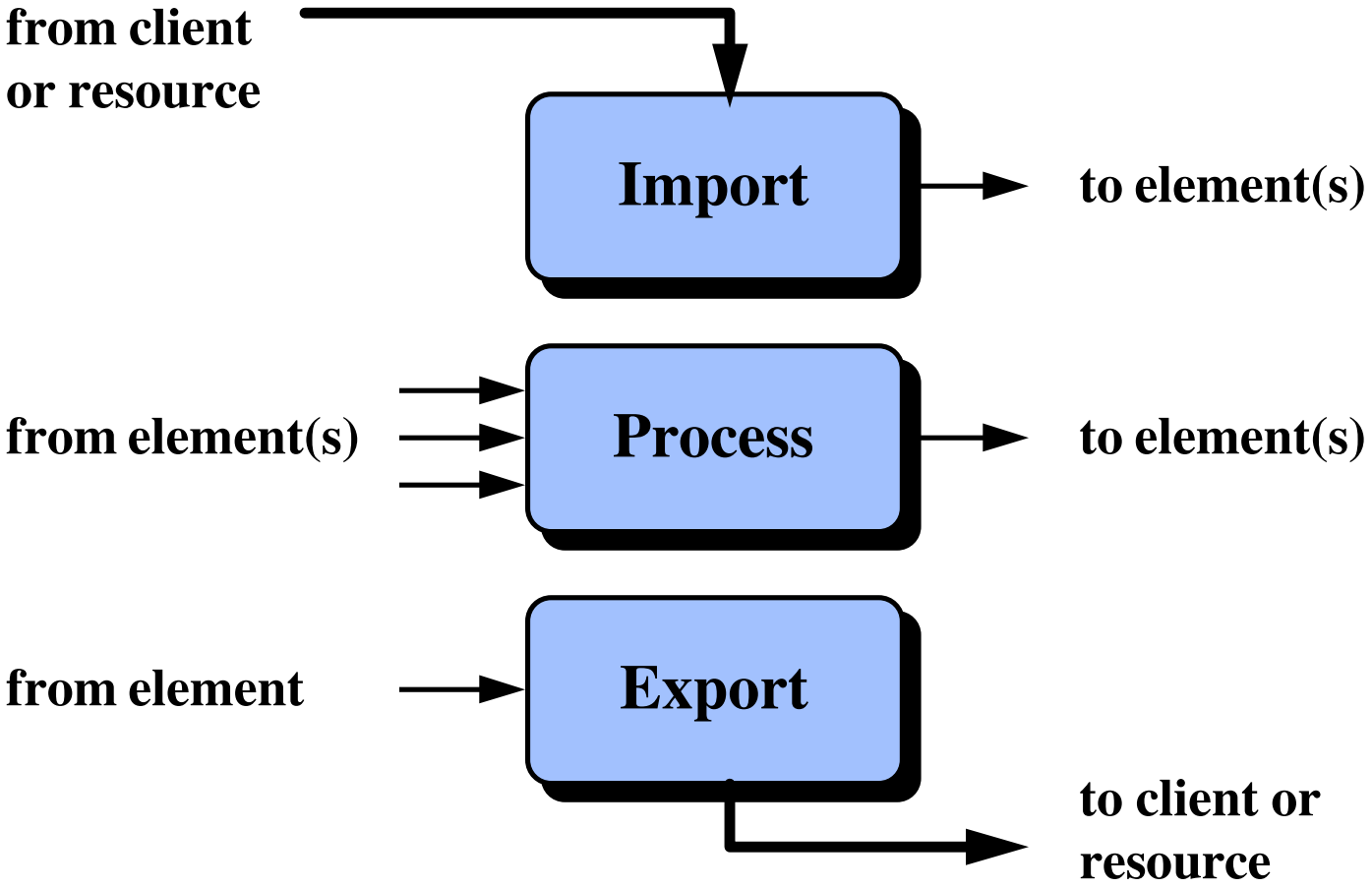
XIE's Element Types & Connections



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XIE Data Attributes

- **DataClass**
  - **SingleBand:** bitonal, grayscale, or index
  - **TripleBand:** color (colorspace unspecified)
- **DataType**
  - **Constrained:** levels is restricted to [0 ... levels-1] (integer data)
  - **Unconstrained:** levels is undefined (may be float)
- **Dimensions*** width and height in pixels
- **Levels*** potential number of quantization levels (if constrained)

* these attributes are per-band

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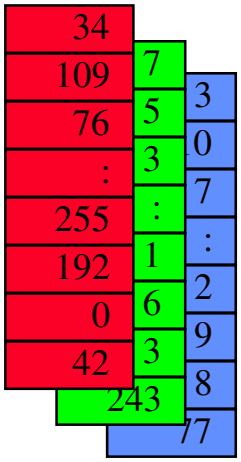
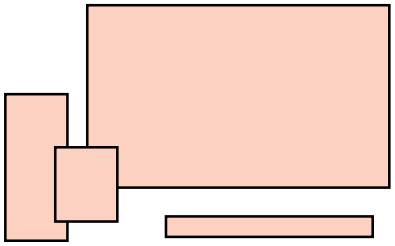
XIE Server Resources

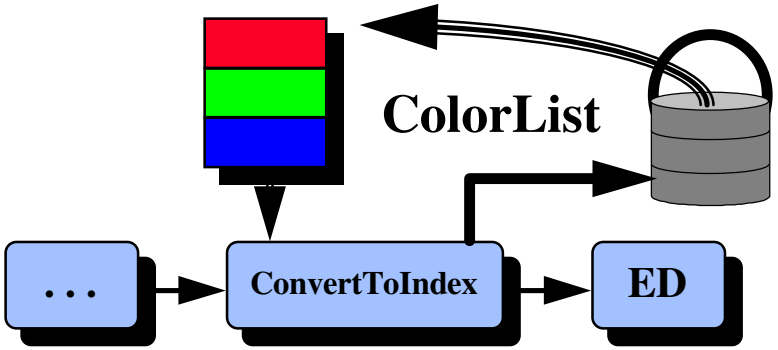


LUT - Lookup Table

Photomap



ROI - Rectangles of Interest



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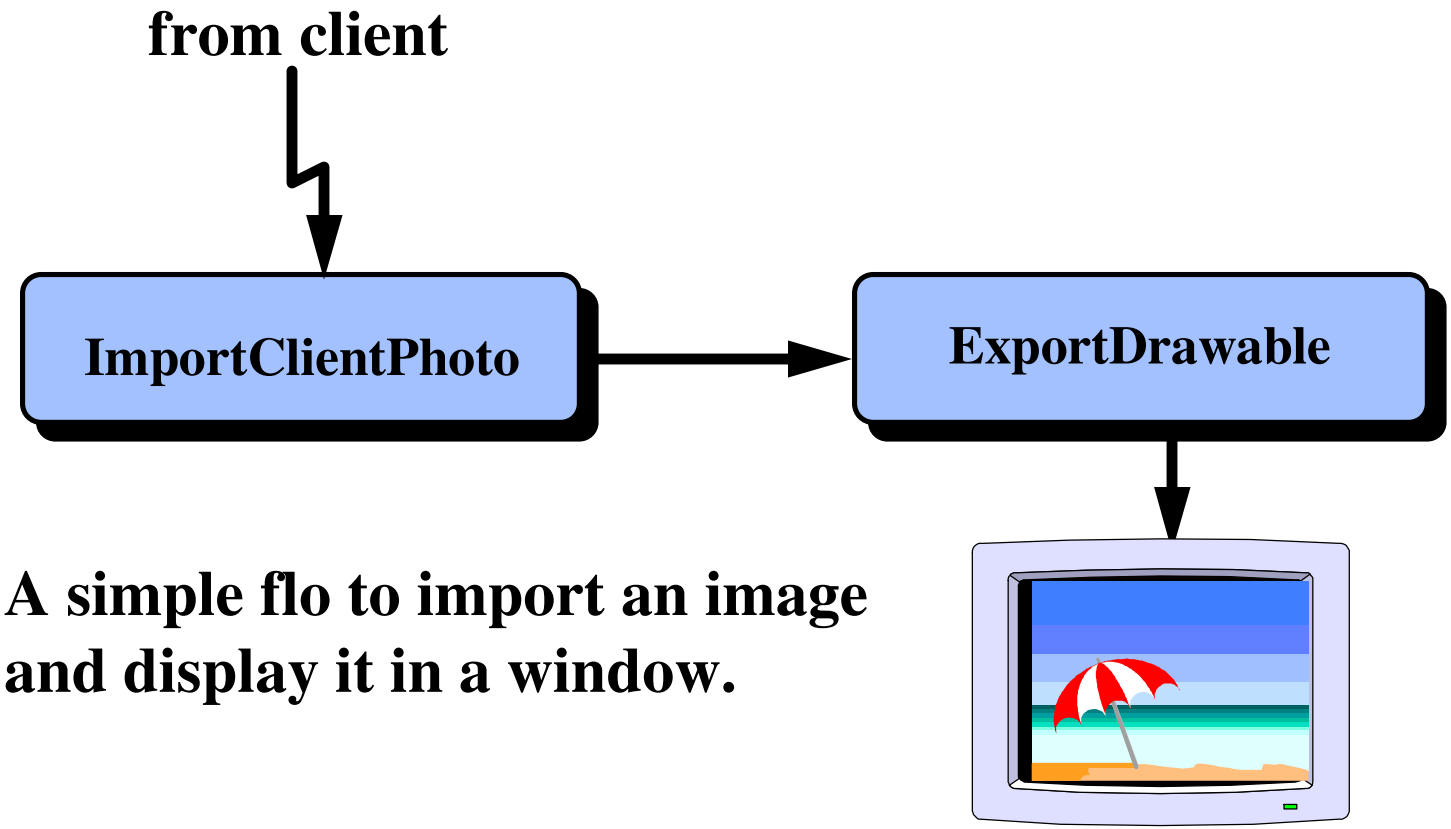
XIElib for the Impatient



A simple flo to import an image and display it in a window.

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XIElib for the Impatient. . .
the basic steps

Initialization

Create X and XIE resources

Allocate a PhotofloGraph (flo)

Define Technique parameters

Define Element parameters

Fill elements into flo

Send the flo definition to the server for execution

Send/retrieve data

Wait for completion

Do cleanup

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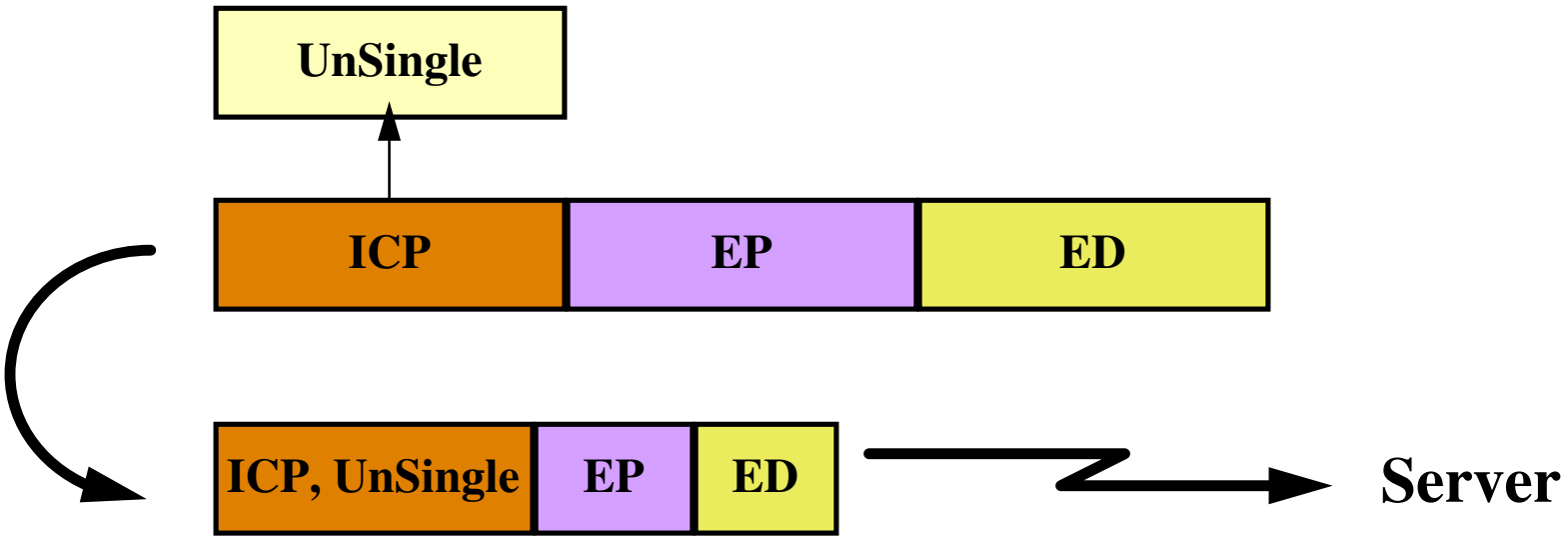
XIElib for the impatient. . .
- 16 slides later -

- Define Photospace, and PhotofloGraph
- Define each Element and Technique
- Send to Server, Execute, Wait, Free, ...



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XIElib for the Impatient. . .
what we did wrong

- We used hard-coded image attributes
- We assumed 8-bit GrayScale or PseudoColor
- We assumed pixel values = Colormap indices
- We were bad citizens of the Colormap
  - we used all the colors
  - we installed a Colormap -- the ICCCM will get us :-)
- We skipped some error checking
- We didn't check to see if the flo finished
- Not oriented to event loop and callback paradigm !
- Overkill -- we could have used XPutImage ☺

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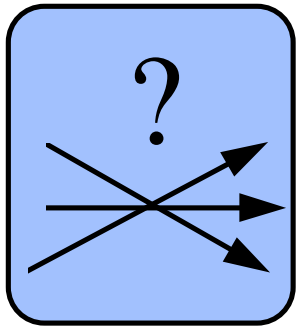
XIE Backend Display
the general problem

Image Type

- Bitonal
- GrayScale
- TripleBand
  - RGB
  - YCC, ...
- Color Palette
- Indexed



Display or Visual

- StaticGray
  - bitonal
- GrayScale
- StaticColor
- TrueColor
- DirectColor
- PseudoColor
  - standard Cmap
  - default Cmap
  - new Cmap

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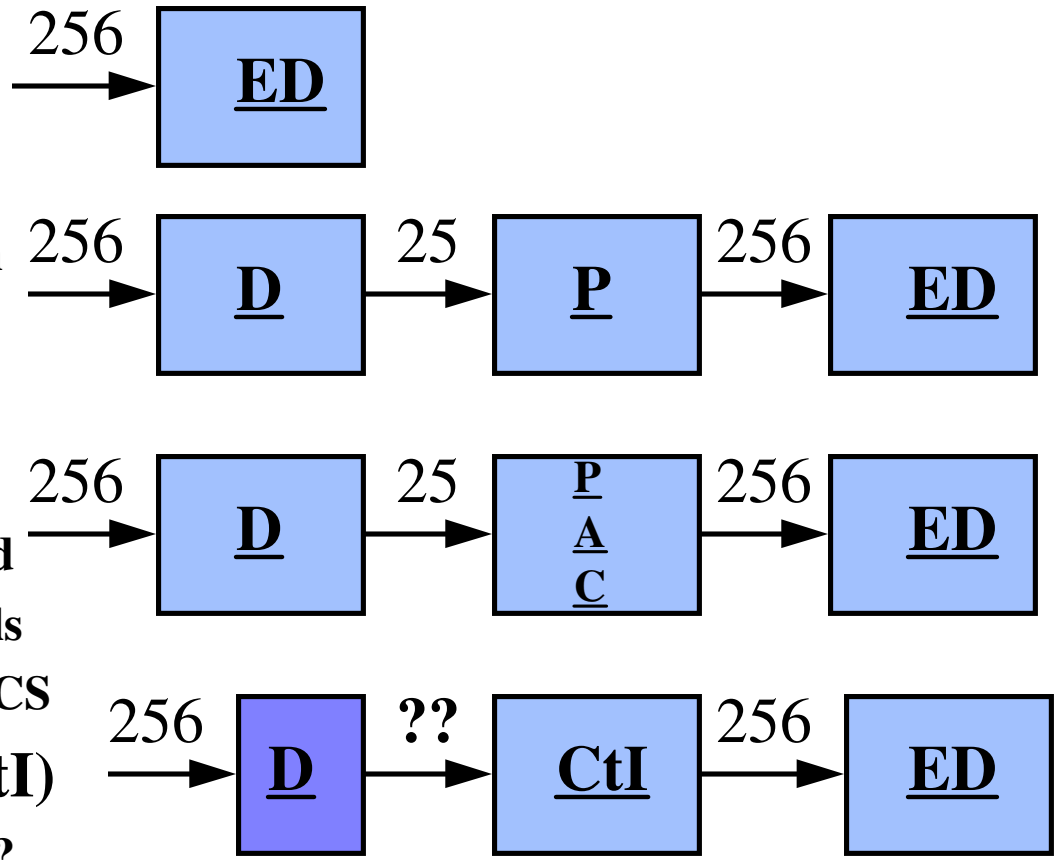
XIE Backend Display
gray image to PseudoColor

- **Use all 256 levels**
  - Colormap with 256 grays
- **Use fewer levels**
  - allocate N gray cells, random
  - Dither to N levels
  - map thru Point
- **Use fewer levels**
  - allocate N gray cells, ordered
  - Dither to N levels, offset levels
    - » Arith, Point, Constrain CS
- **Use Convert to Index (CtI)**
  - Dither to N levels, optional ??
  - use magic element CtI



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XIElib for the impatient. . . Summary

- What about different image formats?
- Procedural Programming model
  - does not meld with typical Widget, Event, Callback models
- No event or error handlers
- Formidable learning curve
  - unfamiliar programming model
  - protocol level imaging expertise
- Low-level interface increases programming costs
  - discourages modular programming
  - large number of permutations lead to complex design, test
  - many opportunities for errors

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PhotoKit to the Rescue

- AGE decided a toolkit for XIE was necessary
- PhotoKit Goals
  - Consistent with current X programming practice (widgets)
  - Not a large monolithic kitchen sink viewing element
  - Flexibility - eg support multiple images
  - Extensibility - by us, or the customer
  - Pure Mechanism and/or a variety of Policies
  - Embed significant XIE knowledge and tricks
  - Potential to optimize typical flos while maintaining generality
  - Compatible with potential XIE Server improvements

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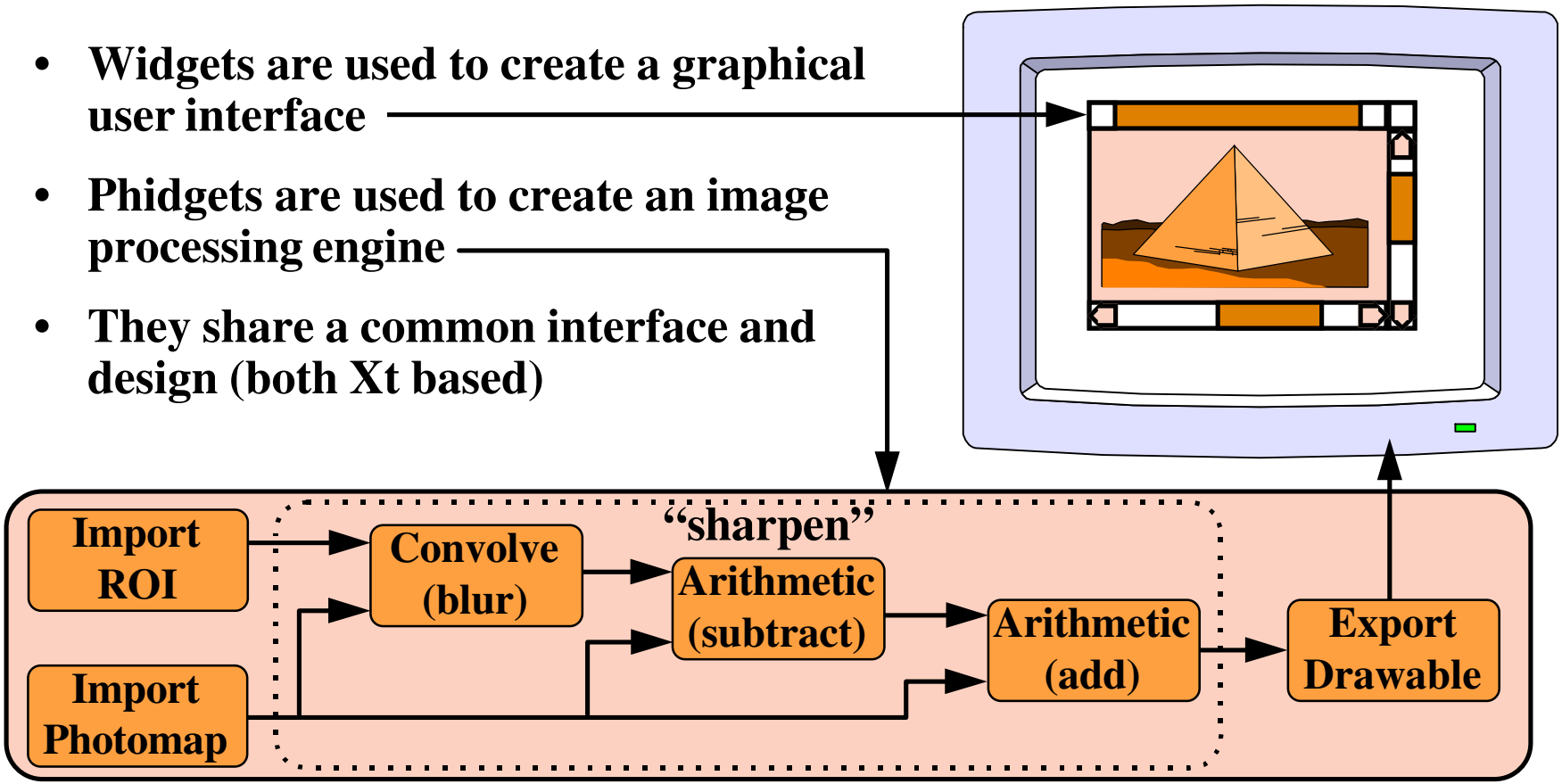
Widgets vs. Phidgets

- Widgets are used to create a graphical user interface
- Phidgets are used to create an image processing engine
- They share a common interface and design (both Xt based)



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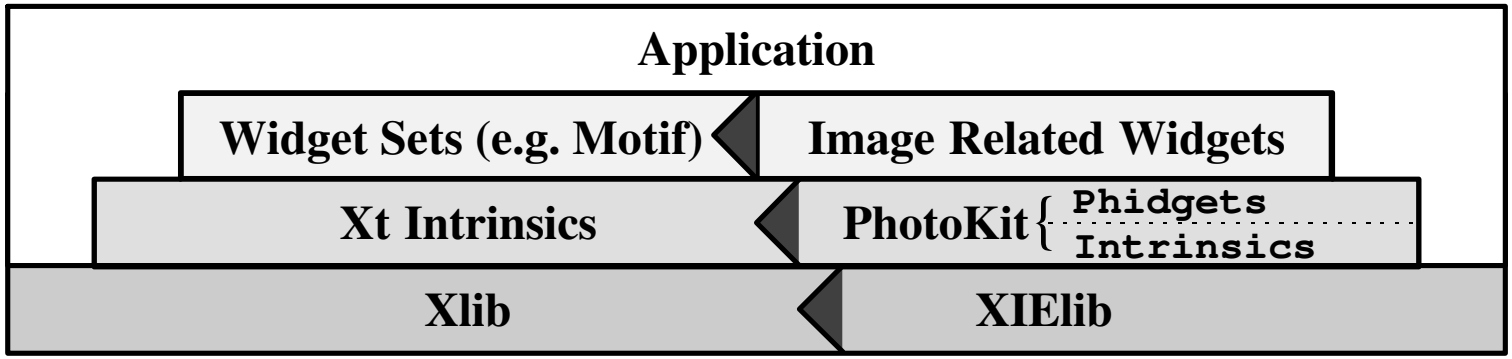
Widgets and Phidgets

An "Xt compliant extension"

- PhotoKit is based on Xt Intrinsics
- Provides familiar programming paradigm



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PhotoKit Object Classes "Phidgets"

- **Phidget**
  - **the Super Class of all PhotoKit classes**
- **PhotoShell**
  - **the Super Object of all PhotoKit Instances**
- **Element**
  - **Simple Elements - map closely to XIE Pipeline Elements**
  - **Abstract Elements - a group of simpler elements**
  - **Execute Elements - an executable pipeline**
- **Connect**
  - **holds image attributes at element connections**
  - **can represent XIE resources**

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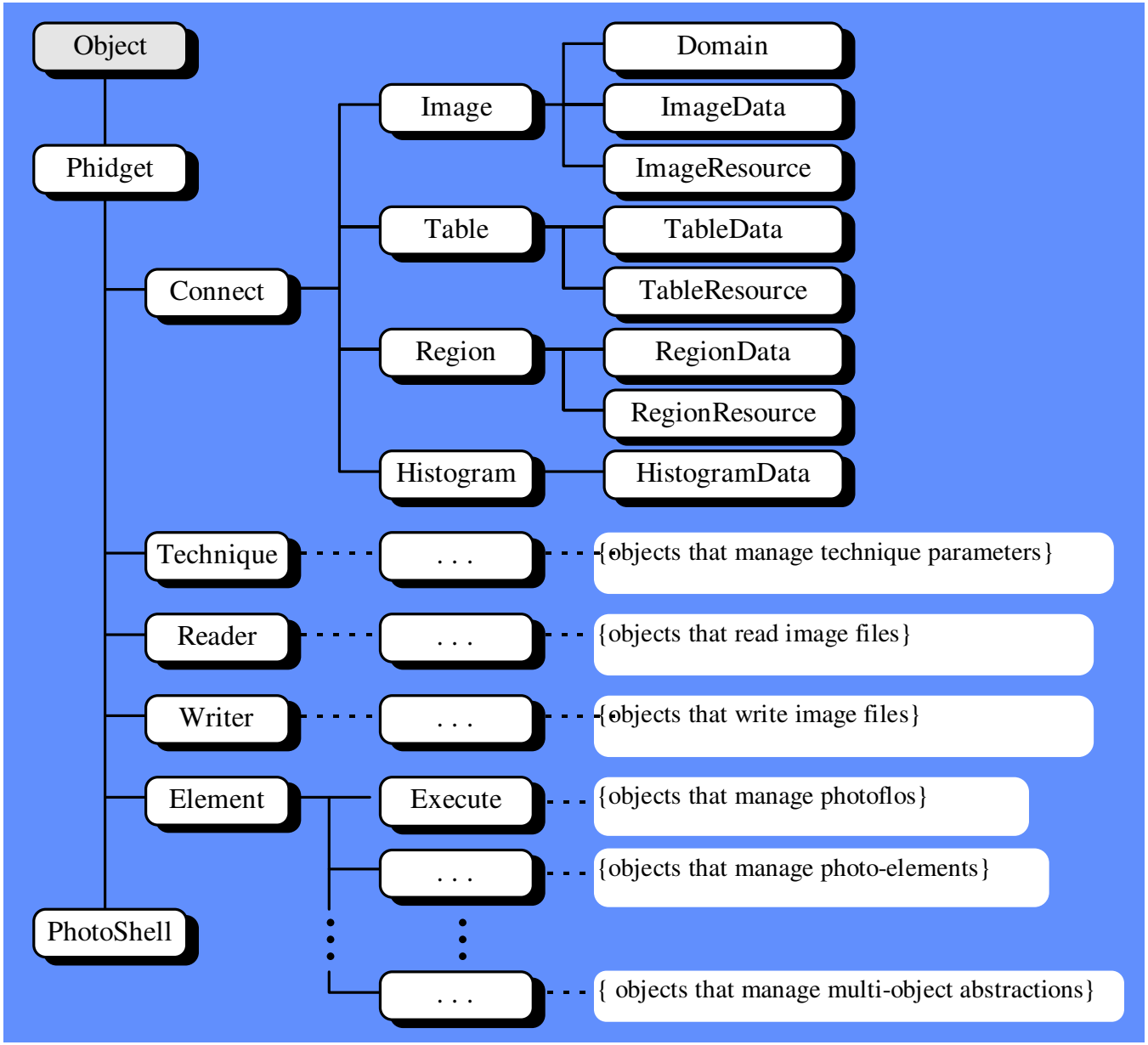
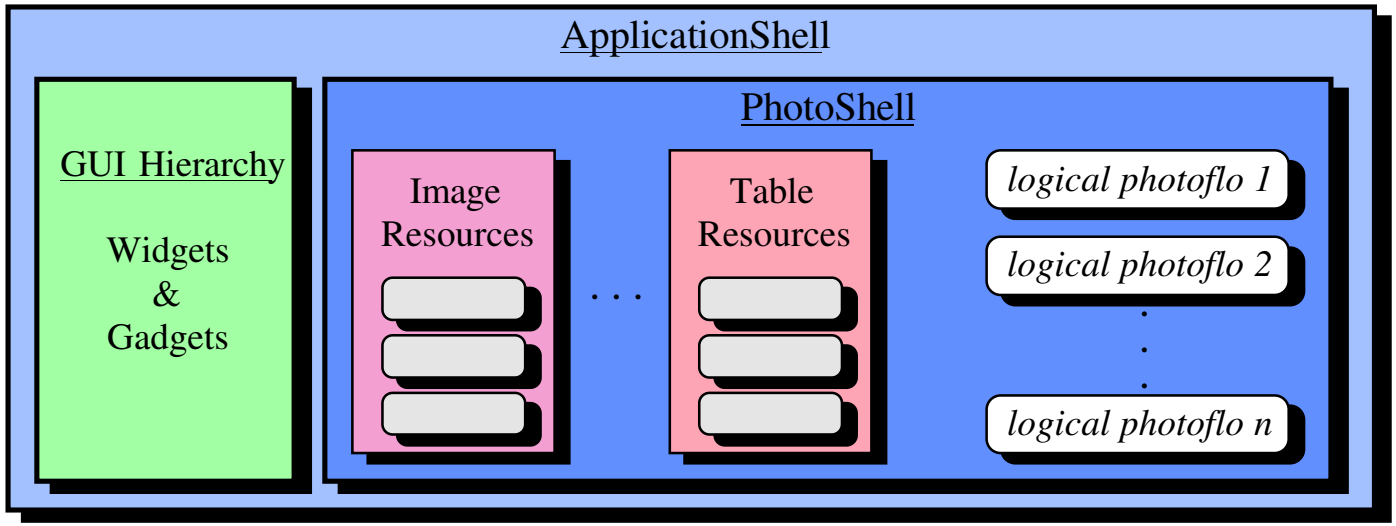
PhotoKit Object Class Hierarchy



PhotoShell Class

- **PhotoShell serves as PhotoKit GodMother**
  - **all other PhotoKit kit objects (instances) descend from PhotoShell**
  - **performs XIE server resource book-keeping**
  - **also directly owns all photoflo Execute class instances**



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Simple Elements - Mechanism

- A subclass of Element exists for each XIE element
- A subclass of Technique exists for each XIE technique
  - can add new technique classes or subclasses
- Allows access to all details of XIE or XIElib
- Can create Element and Technique in one call

```
XpkVaCreateObject("Constrain", xpkConstrainPhidgeClass, flo,
                  XpkNconstrainTechnique, XpkSConstrainClipScale,
                  XpkNoutHigh, cnstrn_levels - 1,
                  XpkNlevels, cnstrn_levels, NULL);
```

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Create a “logical photoflo”

- PhotoKit elements can be connected to represent all possible XIE directed acyclic graphs
- Abstract elements are made of simpler elements
- PhotoKit elements have connector taps
  - by default, connections are made in pipeline order
- Can make explicit connections, dynamically
  - utilize “ascii” connector names
- Eventually, the logical photoflo is “realized” as physical XIE photoflo

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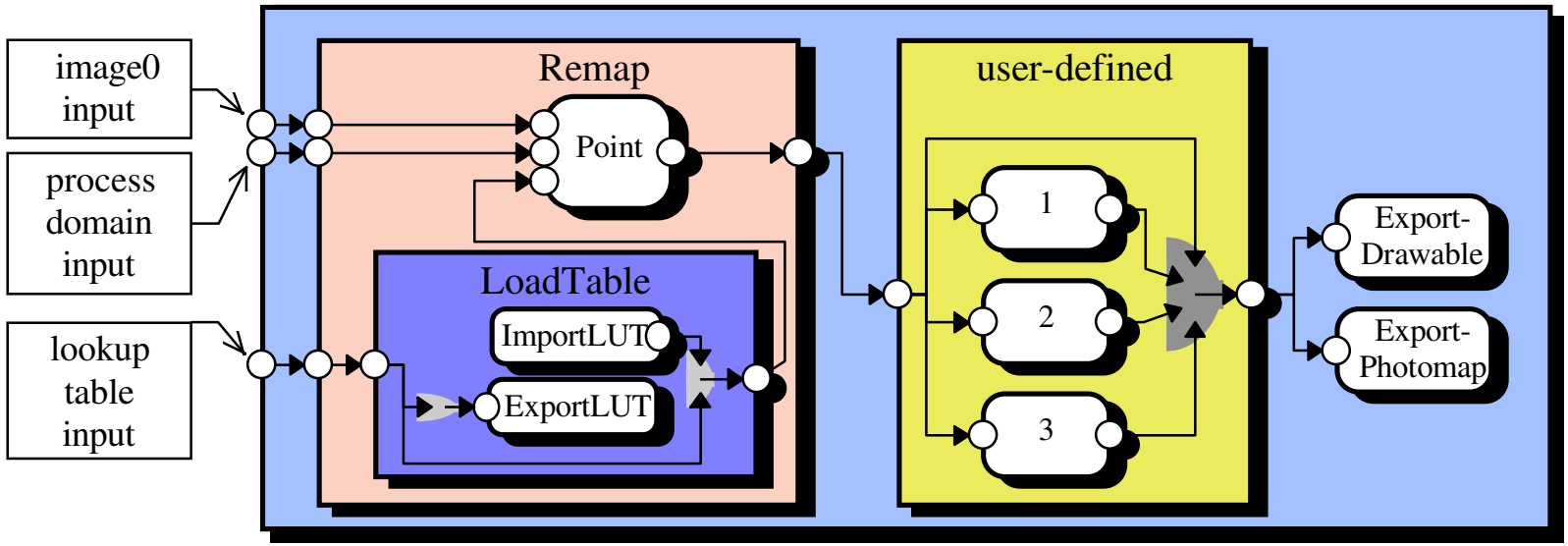
PhotoKit Element Topology

- Circles represent Connect objects
  - have ascii names like “image0”, or “domain”, or “table”
- Color boxes represent Abstract Elements
- Gray areas represent “Muxes” or dynamic connections



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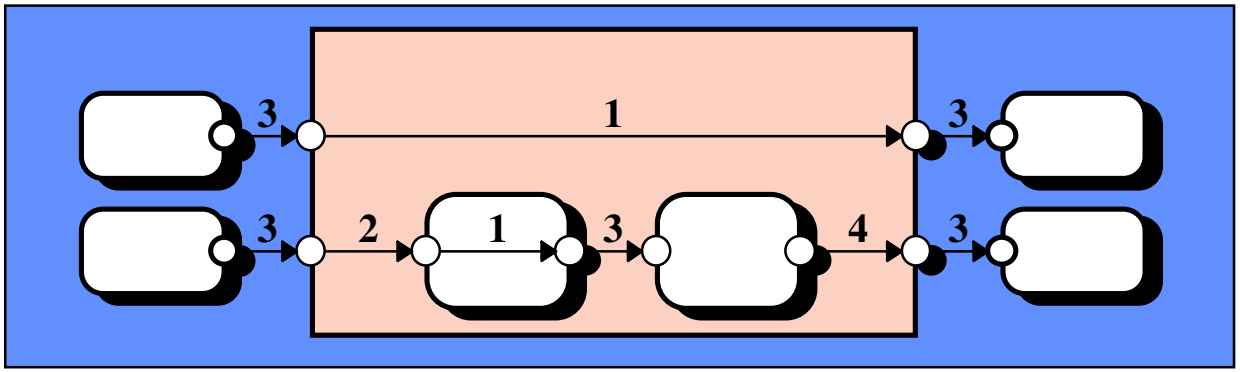
Abstract Elements
legal connections



1) from an element's input to its output (bypass)
2) from an element's input to a child's input
3) from an element's output to a sibling's input
4) from a child's output to the element's output

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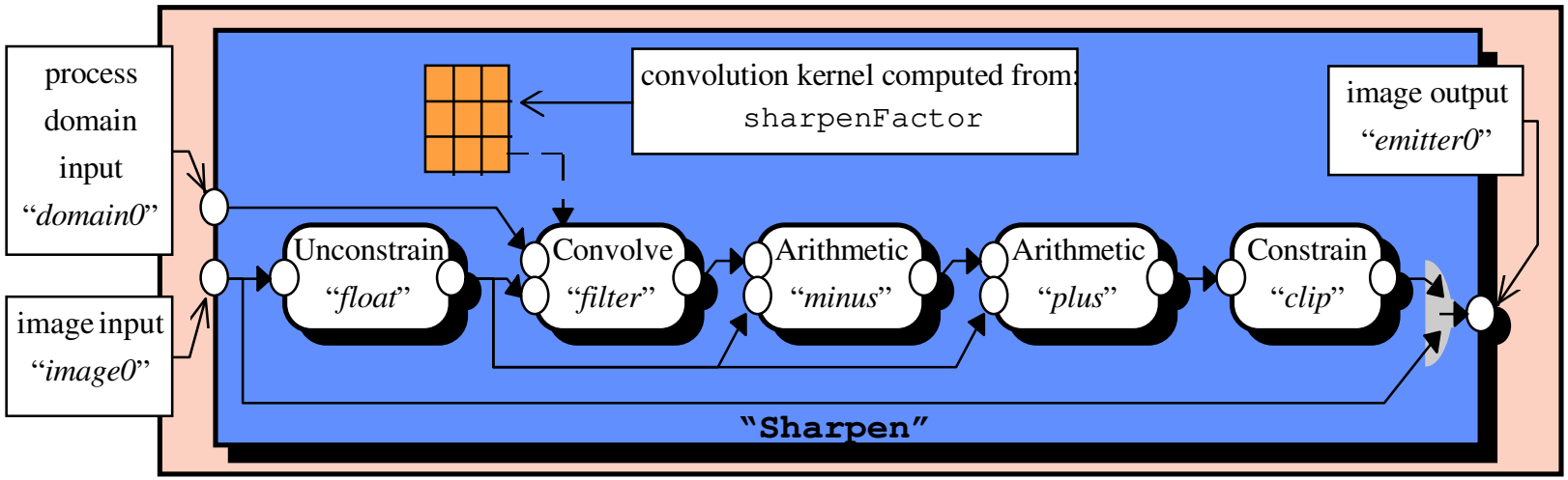
Abstract Elements knowledge and policy

- **Sharpen** Element constructed from simpler parts
  - even supports Process Domain (ROI) input
- Requires image processing knowledge to write
- Easy to use, controlled by single parameter

```
XtVaSetValues(sharp, XpkNsharpenFactor, XpkFloatArg(factor), NULL);
```



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Connector Characteristics

XIE Characteristics

- DataClass
  - SingleBand
  - TripleBand
- DataType
  - Constrained (“integer”)
  - Unconstrained (“float”)
- Dimensions
  - width, height
- Levels
  - “pixel depth”

+ PhotoKit Characteristics

- ColorSpace
  - RGB, YCC, ...
  - Indexed, Palette, ...
  - ?? PaletteHandle ??
- potentialColors
  - helps with optimal display
- pixelPolarity
- also LUT, ROI

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Characteristic Propagation "Prepping"

- Import Connectors "seed" the logical flo
  - Reader class, or callbacks may parse input files
  - determines initial values of characteristics
- Characteristics are propagated thru logical flo
  - passed via connected Connector instances
  - Simple Elements transform values with XIE element rules
  - Simple Element subclasses might alter techniques ...
- Abstract Elements examine characteristic values
  - may decide to instantiate, bypass, or re-plumb internal objects
  - propagation by depth then breadth
- Logical flo "adapts" to its inputs
  - determined by characteristics and/or current object values

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Simple Geometry Subclass

- Direct subclass of Geometry Element
- Augments Geometry's cryptic transforms
- Looks at incoming image size in connector
- Supports options like
  - Scale-to-Fit or Stretch-to-Fit,
  - Mirror in X and/or Y
- Can be used in place of Geometry Element

- Also consider Scale to Gray variants

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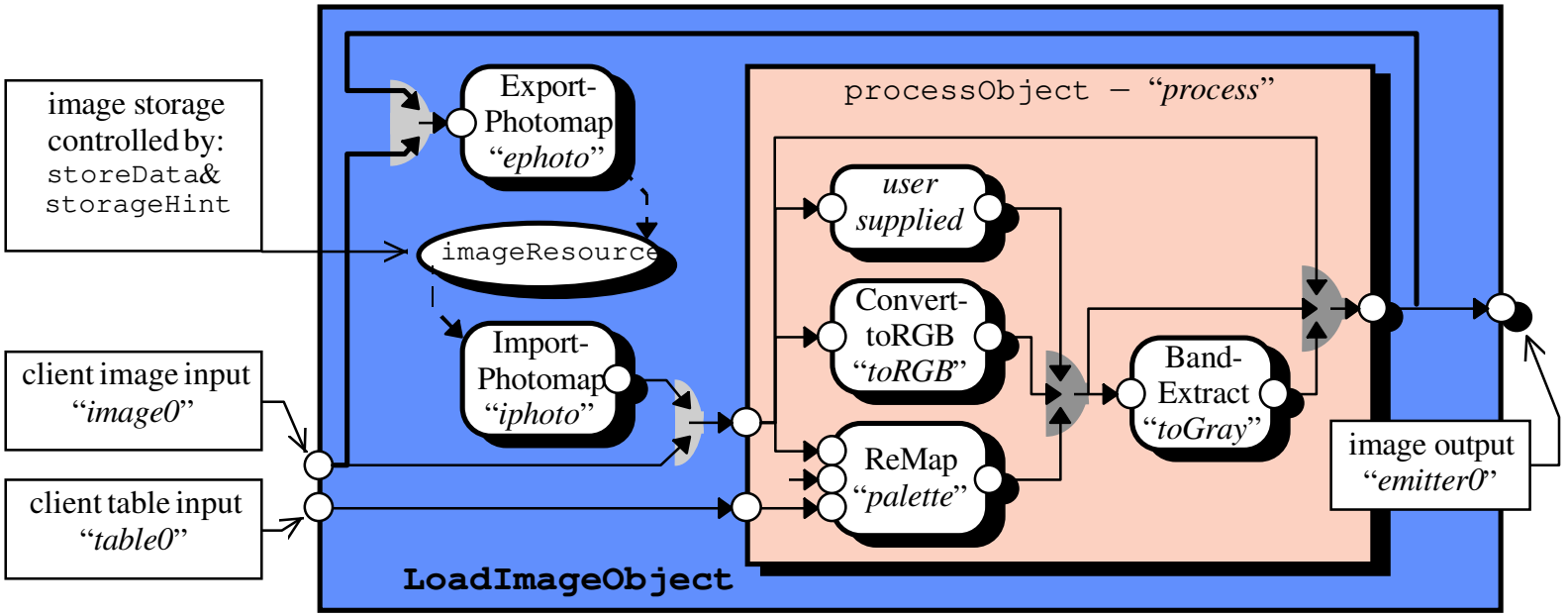
Simple Geometry Example

Abstract Elements knowledge and policy

- **StorageHint policy used by several elements**
  - **LoadImage captures import data before or after initial processing**
  - **also controls compression in Photomaps**
  - **also passes into ReMap Element**



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pkview Sample Application

- Prototype viewing application
  - testbed for many integration ideas
- Provides Simple Conceptual 6 Element PipeLine
  - actual DAG generated can be more complex
- GUI area is poor man's Visual Programmer
  - up / down arrows alter pipeline order
- Downloads image once, allows repeated changes
  - image at beginning of pipe remains intact

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Minor Image Enhancement

pkview Sample Application

- **Actual realized photoflo varies depending on:**
  - **input file type, GUI settings, resources**
  - **Flo2 is used for expose and panning**

```
(elemType  7) pkview.photo_shell.Flo1.Import.iphoto
(elemType  6) pkview.photo_shell.Flo1.Import.process.palette.table.ilut
(elemType 27) pkview.photo_shell.Flo1.Import.process.palette.point
(elemType 22) pkview.photo_shell.Flo1.Geom
(elemType 21) pkview.photo_shell.Flo1.RenderForWindow.Dither
(elemType 18) pkview.photo_shell.Flo1.RenderForWindow.CtoI
(elemType 36) pkview.photo_shell.Flo1.EPhoto
(elemType 33) pkview.photo_shell.Flo1.EDraw

(elemType  7) pkview.photo_shell.Flo2.IPhoto
(elemType 33) pkview.photo_shell.Flo2.EDraw2
```

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Sharpen in Action

Pipeline Order

Extend the PhotoKit write your own abstractions

- PhotoKit is fully extensible
- Subclass existing Simple or Abstract elements
  - to extend or modify their behavior
- Add Soft Techniques
- Add your own Abstract elements
  - examples provided in release.
- File Reader class has specific provisions for subclassing
  - also includes callback hooks
- Elements provide “prep” callbacks
  - last minute adjustments to Policy based on characteristics

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Attention to Details

- Double buffering of ColorLists
  - avoids color twinkle normally seen in palette loads
- Clearing view area
  - knows when to clear colorList and drawing area
- Clearing Image resources before re-use

- Consistent policy hints
- Full Xt integration
- Object cleanup, no user mallocs and free

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Events, Errors, and Editres

- Interfaces to Xt to catch events and errors
  - Solves several hard R5 vs R6 Xt portability issues
- Utilizes XIE event facilities to help schedule data transport automatically with callbacks
- Filters errors and events in useful way
- Provides useful error messages

```
Warning: decodeNotify (ImgDataEvent) image band 0
  declared dimen of 738 x 521 vs. decoded dimen 738 x 512
  at pkview.photo_shell.Flo1.Import.image0
```

- Adds editres support for PhotoKit Phidget classes

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Editres Example

```
LoadImage  Import
        DecodeJPEGBaseline  JPEG-BASELINE
    Element  process
        Remap  palette
            LoadTable  table
                ExportLut  elut
                ImportLut  ilut
            Point  point
        ConvertToRGB  toRGB
            YCbCrToRGB  YCbCr
                Technique  CLIP-RGB
    ExportPhotomap  ephoto
        EncodeServerChoice  SERVER-CHOICE
    ImportPhotomap  iphoto
    Reader  reader
        JFIFReader  JFIFReader
```

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EditRes Example

- Change ditherTechnique to ORDERED in editres
- Note dither pattern on giraffe skin

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File Input and Output

- Reader and Writer Class
- Base Reader class can iterate over known subclasses
  - to perform detection of image type
- Or can explicitly instantiate correct class
  - TIFF (fax, rgb, palette, ...) , JPEG (JFIF) formats supported
- Can extend PhotoKit
  - code samples for several readers supplied
- Plumbing is automated, via method callbacks
  - LoadImage calls when "filename" changes
  - data retrieved "as needed" by Execute object

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Super Phidget

- PhotoKit has intentionally grown from ground up
  - to avoid the "Kitchen Sink" problem
  - to allow full access to XIE mechanisms
  - initial goal is powerful toolkit, not a viewing widget
- Goal is modular pieces, with various policy conventions
- Possible to construct flexible viewing widgets
  - could tune for specific image types or policies
  - could provide general purpose viewer (pkview)
  - could provide multi-image viewer
- Good match for visual programming

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Coming (Soon) in Release 2

- New File Reader Classes
- Completed ShowImage class (display backend)
- Additional Characteristic Data, Policy Hints
- Additional Abstract Elements
- More sample programs and documentation
  - including sample Abstract Elements and File Readers
- Release 1 available now:
  - Early Adopters version
  - supports major workstations
  - ships on CD-ROM

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Future Work

- SuperPhidgets (complete viewing widgets)
  - for several application domains
- Integration with GUI builder tools
- Integration with CDE?, OPENDOC?, ...
- Visual programming environment
- Mixing local and remote processing
- Base architecture may be good fit for other pipeline processing systems (XIL, NAS, ...)
  - can modify PhotoKit to support eg N-band data
  - PhotoKit API over XIL? or HPIL?

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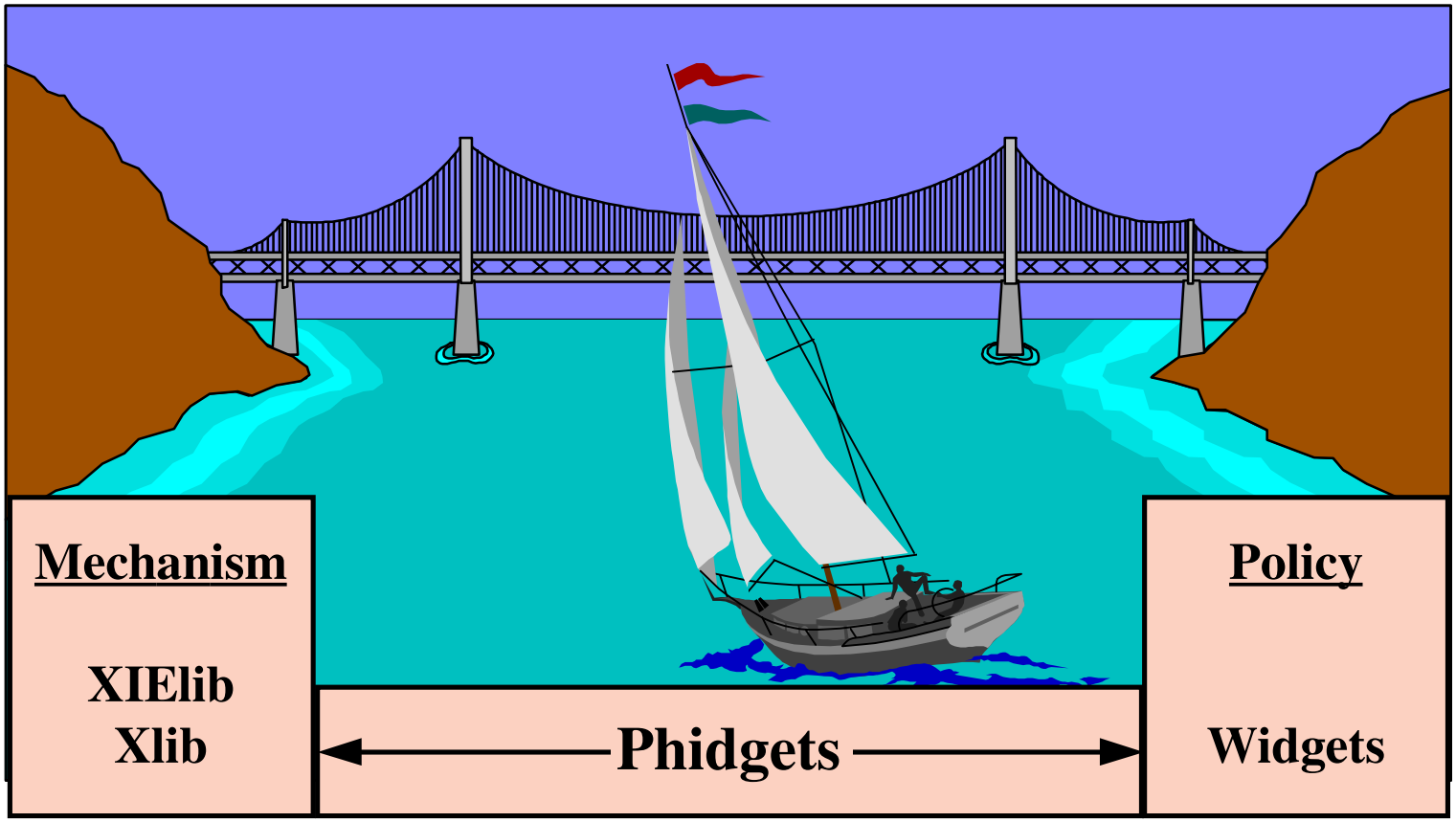
Mechanism vs. Policy
Phidgets bridge the gap



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PhotoKit Summary

- XIE attacks practical problems in X Image Display
- The PhotoKit makes XIE practical to use
- The PhotoKit is “cool stuff”
- Send email to xie@age.com

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