Introduction to ImgLib2

Stephan Preibisch, Tobias Pietzsch, Stephan Saalfeld

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MPI-CBG, Dresden, Germany
HHMI Janelia Farm Research Campus, Virginia

Albert Einstein College of Medicine OF YESHIVA UNIVERSITY

janelia farm research campus

CBG Max Planck Institute of Molecular Cell Biology and Genetics

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- <u>Stephan Saalfeld (MPI-CBG)</u>

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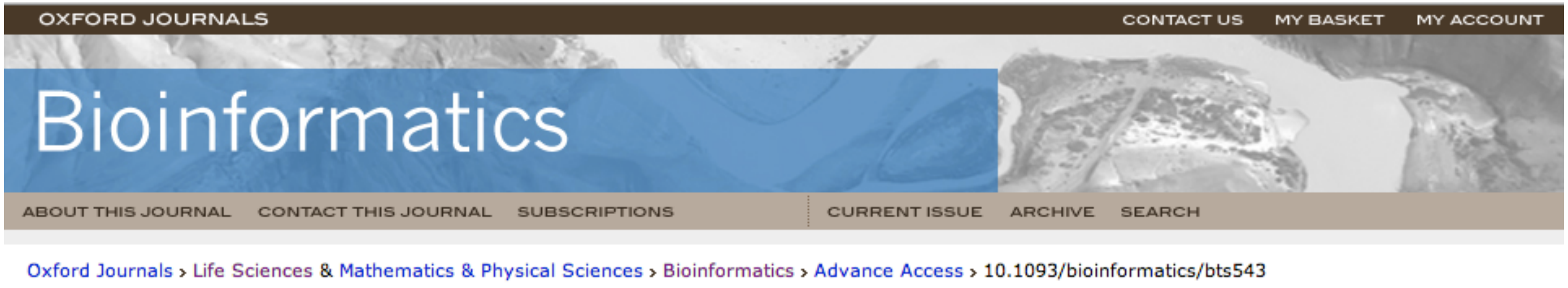
  - Curtis Rueden
  - Barry DeZonia
  - Kevin Eliceiri
- Albert Cardona
- KNIME guys
  - Christian Dietz
  - Martin Horn

HFSP

ImgLib2



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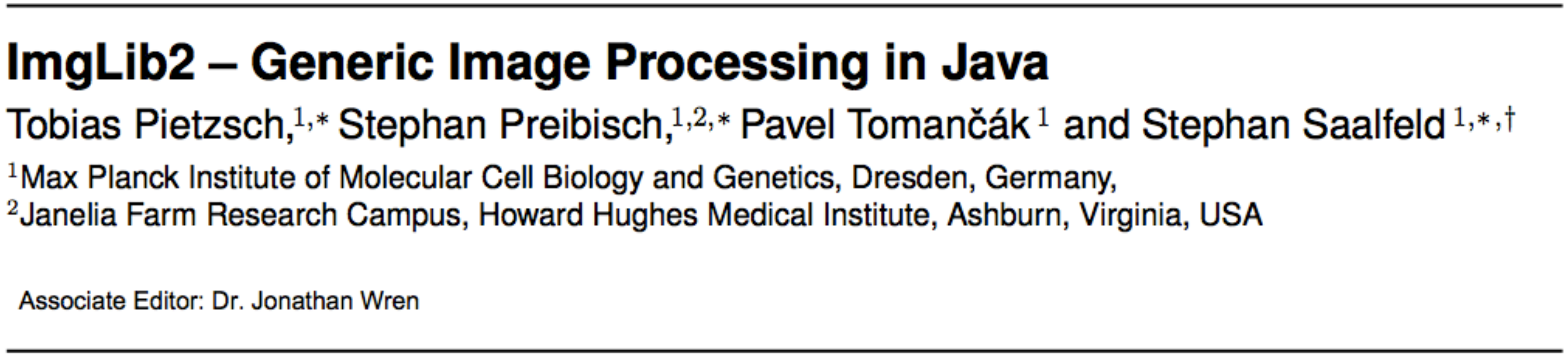
ImgLib2 paper is finally out …



ImgLib2 – Generic Image Processing in Java

Tobias Pietzsch,[1,*] Stephan Preibisch,[1,2,*] Pavel Tomančák[1] and Stephan Saalfeld[1,*,†]

[1]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany,
[2]Janelia Farm Research Campus, Howard Hughes Medical Institute, Ashburn, Virginia, USA

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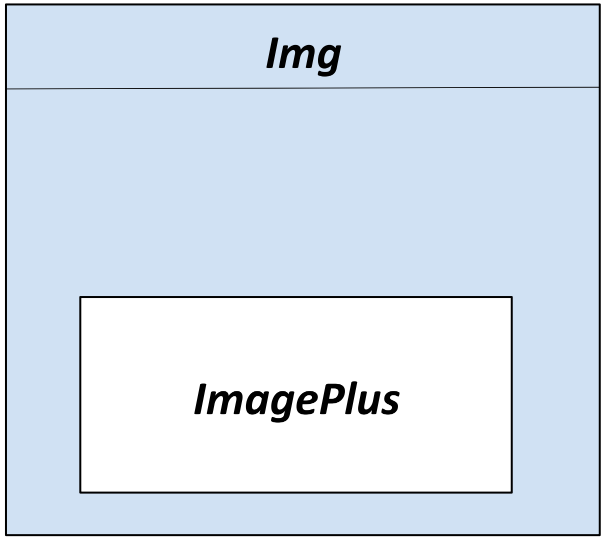
ImgLib2

Why using ImgLib2?

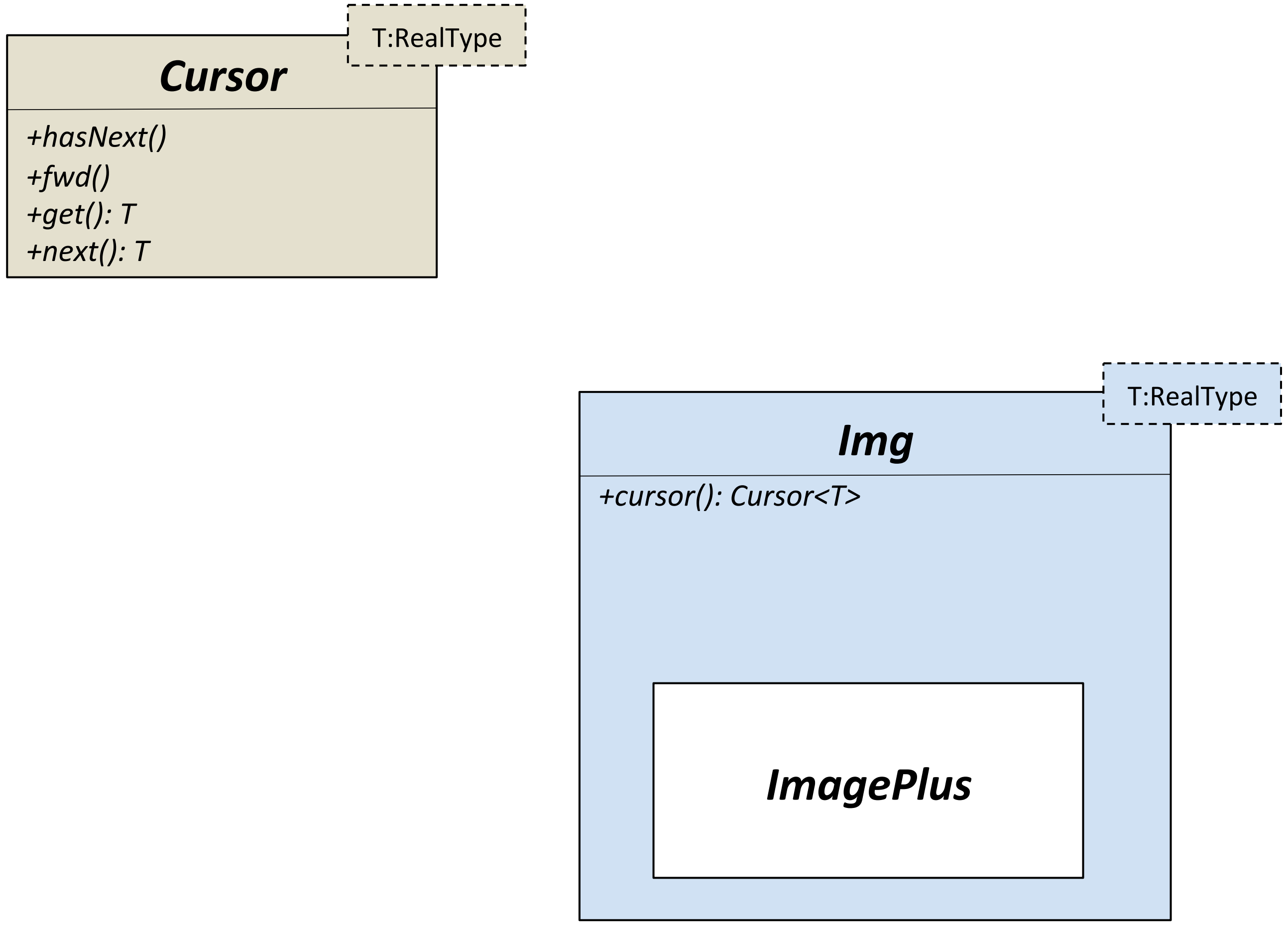
- Generic programming – Write it once!
- Directly applicable to very large datasets, different dimensionality or pixel type
- ImgLib2 does not force you to implement type independent or n-dimensional – it is still applicable to very large datasets
- More algorithm-like programming
- Fewer simple programming mistakes
- Easier exchange of code
- Smaller source code

ImgLib2

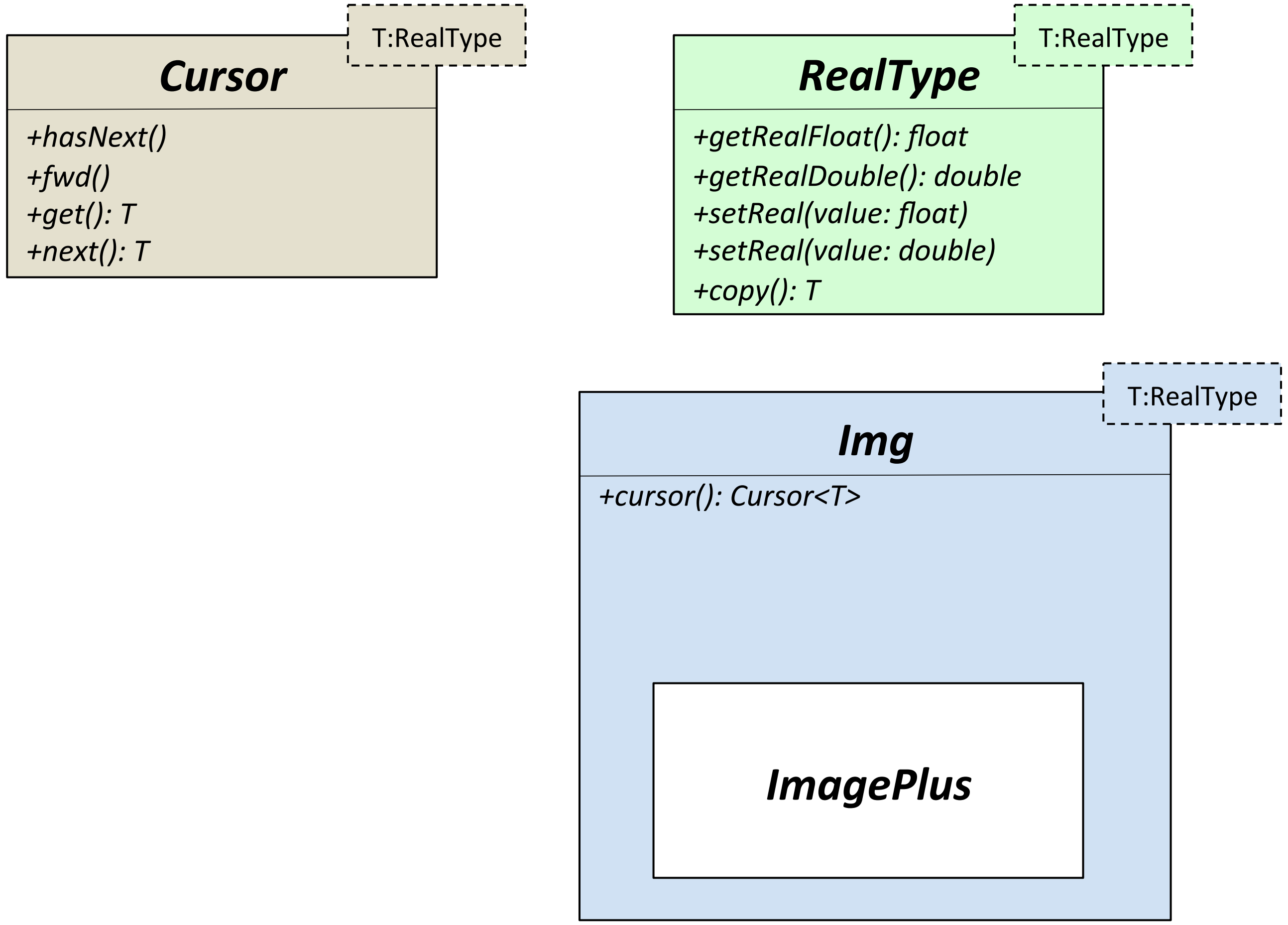
ImagePlus



ImgLib2


T:RealType
Cursor
+hasNext()
+fwd()
+get(): T
+next(): T
T:RealType
Img
+cursor(): Cursor<T>
ImagePlus

ImgLib2


Cursor
T:RealType
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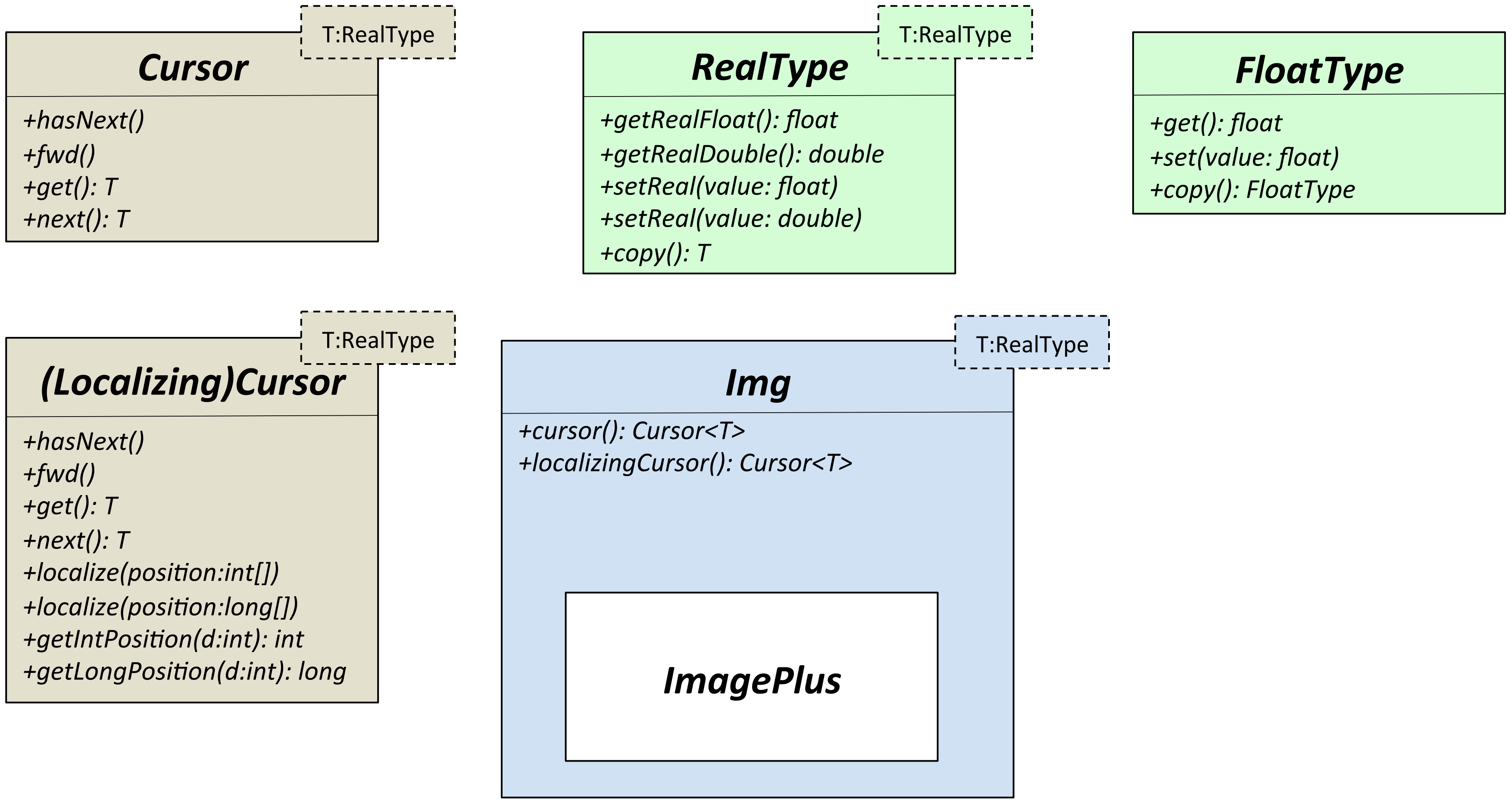
+fwd()
+get(): T
+next(): T
RealType
T:RealType
+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T
FloatType
+get(): float
+set(value: float)
+copy(): FloatType
Img
T:RealType
+cursor(): Cursor<T>
ImagePlus

ImgLib2


T:RealType
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+next(): T
T:RealType
RealType
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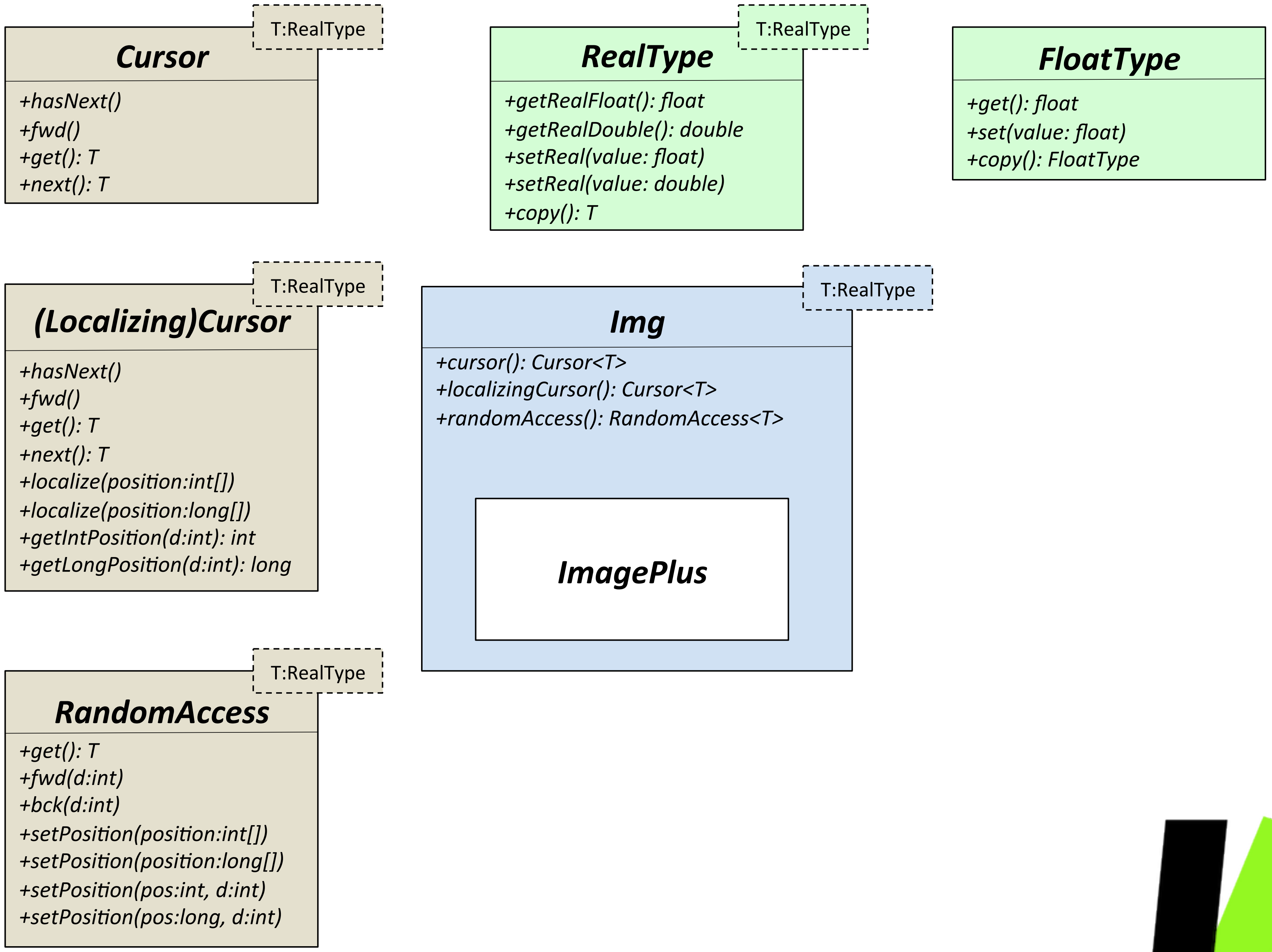
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T
FloatType
+get(): float
+set(value: float)
+copy(): FloatType
T:RealType
(Localizing)Cursor
+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long
T:RealType
Img
+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
ImagePlus

ImgLib2



T:RealType
Cursor
- _+hasNext()_
- _+fwd()_
- _+get(): T_
- _+next(): T_

T:RealType
RealType
- _+getRealFloat(): float_
- _+getRealDouble(): double_
- _+setReal(value: float)_
- _+setReal(value: double)_
- _+copy(): T_

FloatType
- _+get(): float_
- _+set(value: float)_
- _+copy(): FloatType_

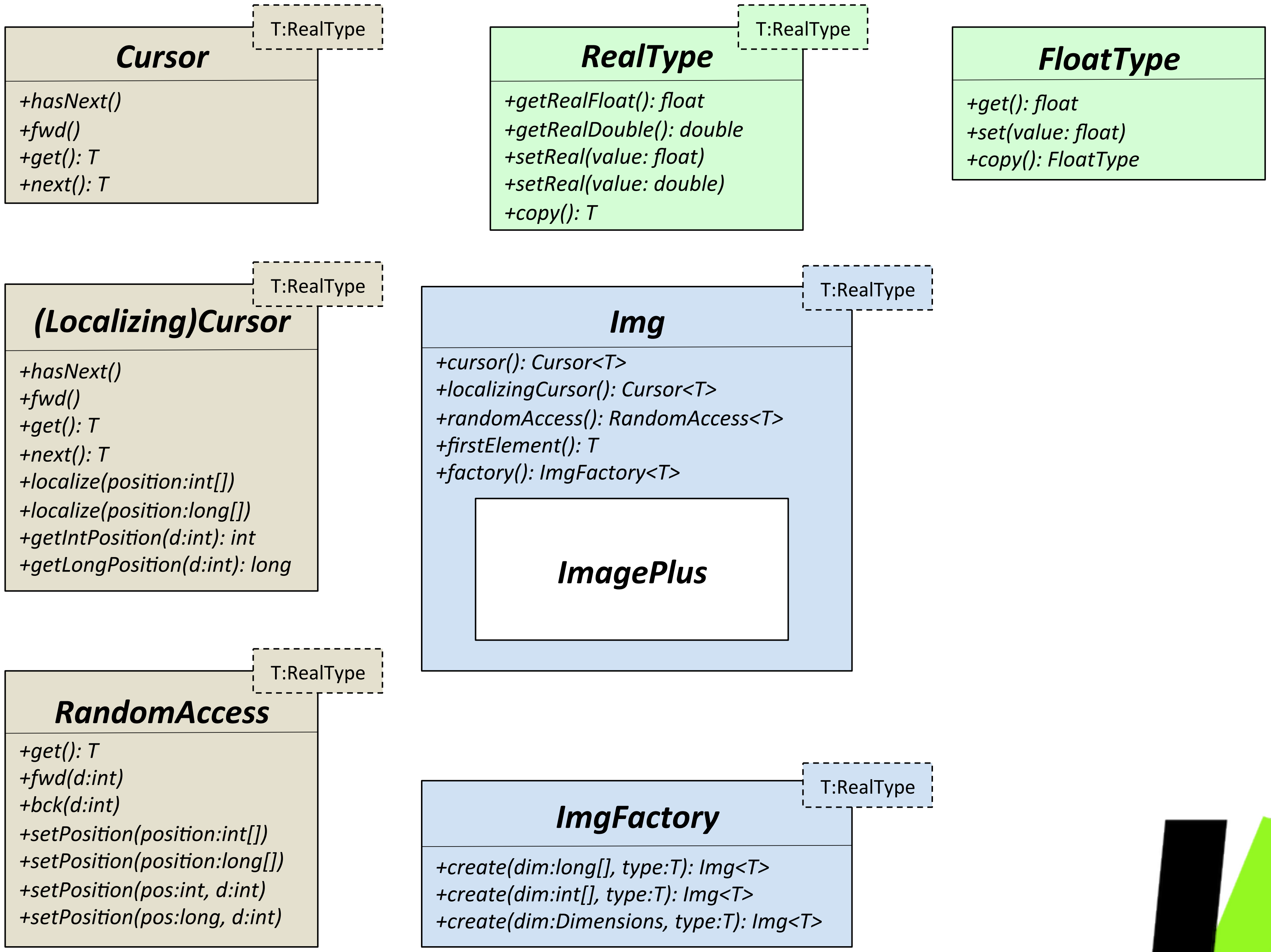
T:RealType
(Localizing)Cursor
- _+hasNext()_
- _+fwd()_
- _+get(): T_
- _+next(): T_
- _+localize(position:int[])_
- _+localize(position:long[])_
- _+getIntPosition(d:int): int_
- _+getLongPosition(d:int): long_

T:RealType
Img
- _+cursor(): Cursor<T>_
- _+localizingCursor(): Cursor<T>_
- _+randomAccess(): RandomAccess<T>_

ImagePlus

T:RealType
RandomAccess
- _+get(): T_
- _+fwd(d:int)_
- _+bck(d:int)_
- _+setPosition(position:int[])_
- _+setPosition(position:long[])_
- _+setPosition(pos:int, d:int)_
- _+setPosition(pos:long, d:int)_

ImgLib2



Cursor T:RealType

```
+hasNext()
+fwd()
+get(): T
+next(): T
```

RealType T:RealType

```
+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T
```

FloatType

```
+get(): float
+set(value: float)
+copy(): FloatType
```

(Localizing)Cursor T:RealType

```
+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long
```

Img T:RealType

```
+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
```

ImagePlus

RandomAccess T:RealType

```
+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:int[])
+setPosition(position:long[])
+setPosition(pos:int, d:int)
+setPosition(pos:long, d:int)
```

ImgFactory T:RealType

```
+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>
```

ImgLib2

T:RealType

Cursor

+hasNext()
+fwd()
+get(): T
+next(): T

T:RealType

(Localizing)Cursor

+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long

T:RealType

RandomAccess

+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:int[])
+setPosition(position:long[])
+setPosition(pos:int, d:int)
+setPosition(pos:long, d:int)

T:RealType

RealType

+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T

T:RealType

Img

+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>

ImagePlus

T:RealType

ImgFactory

+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

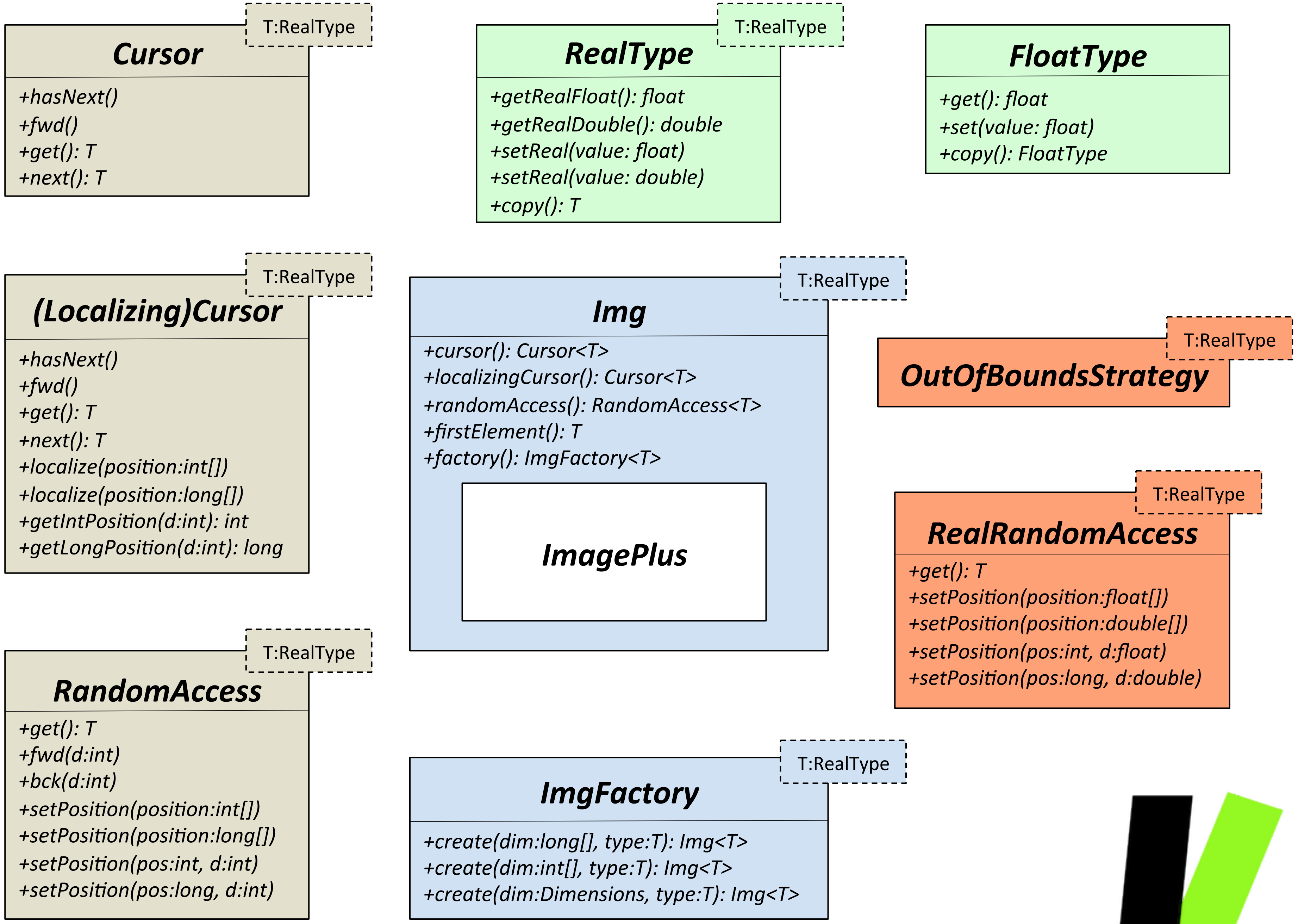
FloatType

+get(): float
+set(value: float)
+copy(): FloatType

T:RealType

OutOfBoundsStrategy

ImgLib2



Cursor (T:RealType)
- +hasNext()
- +fwd()
- +get(): T
- +next(): T

RealType (T:RealType)
- +getRealFloat(): float
- +getRealDouble(): double
- +setReal(value: float)
- +setReal(value: double)
- +copy(): T

FloatType
- +get(): float
- +set(value: float)
- +copy(): FloatType

(Localizing)Cursor (T:RealType)
- +hasNext()
- +fwd()
- +get(): T
- +next(): T
- +localize(position:int[])
- +localize(position:long[])
- +getIntPosition(d:int): int
- +getLongPosition(d:int): long

Img (T:RealType)
- +cursor(): Cursor<T>
- +localizingCursor(): Cursor<T>
- +randomAccess(): RandomAccess<T>
- +firstElement(): T
- +factory(): ImgFactory<T>

ImagePlus

OutOfBoundsStrategy (T:RealType)

RealRandomAccess (T:RealType)
- +get(): T
- +setPosition(position:float[])
- +setPosition(position:double[])
- +setPosition(pos:int, d:float)
- +setPosition(pos:long, d:double)

RandomAccess (T:RealType)
- +get(): T
- +fwd(d:int)
- +bck(d:int)
- +setPosition(position:int[])
- +setPosition(position:long[])
- +setPosition(pos:int, d:int)
- +setPosition(pos:long, d:int)

ImgFactory (T:RealType)
- +create(dim:long[], type:T): Img<T>
- +create(dim:int[], type:T): Img<T>
- +create(dim:Dimensions, type:T): Img<T>

ImgLib2

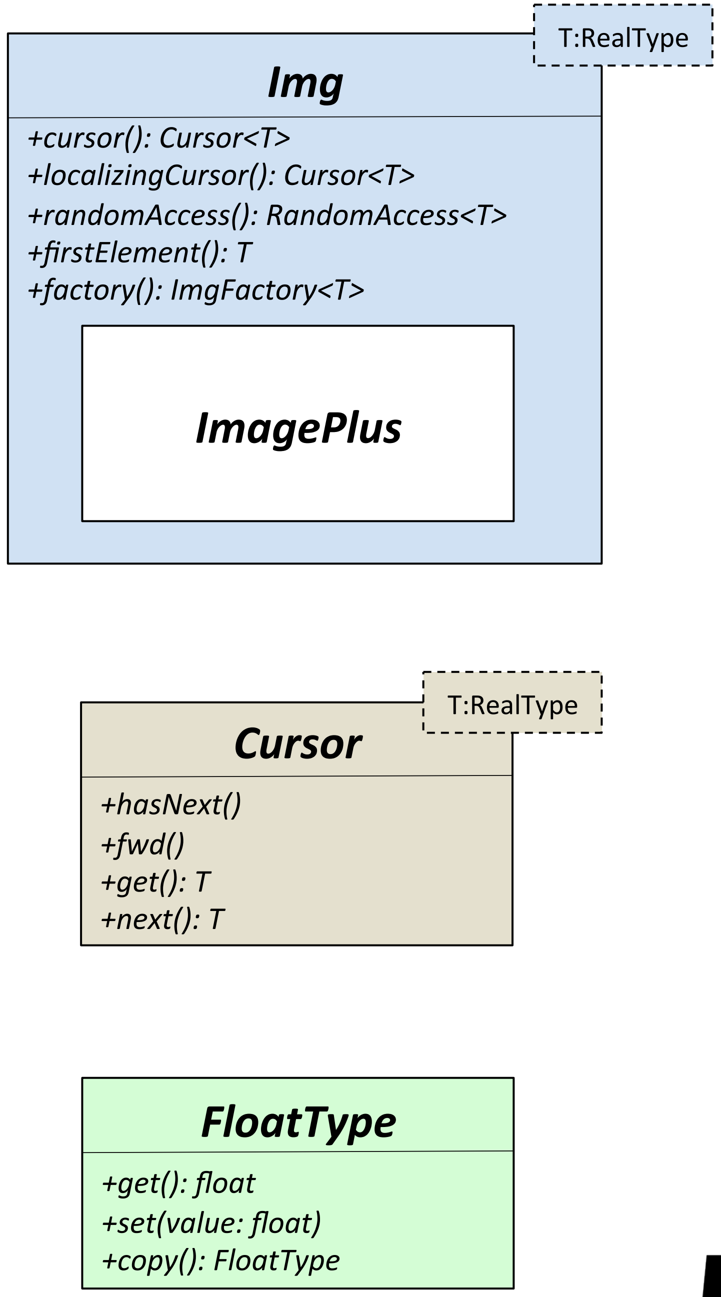
Hands on Programming

① Threshold on an image
② Center of mass of an image
③ Gradient of an image
④ Rigid transformation of an image

ImgLib2

Thresholding 1

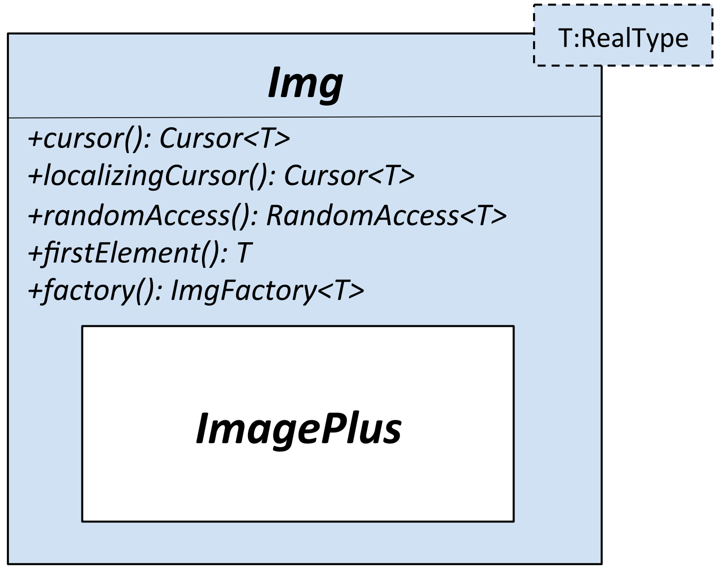
- Wrap a float image
- Compute threshold for each pixel
- Overwrite the original data
- ImgLib2_Threshold1.java

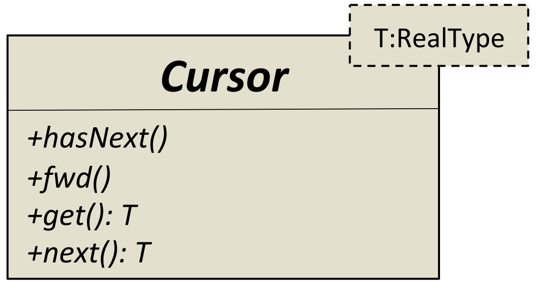


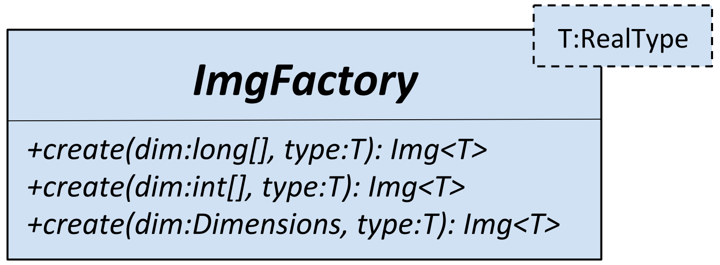
ImgLib2

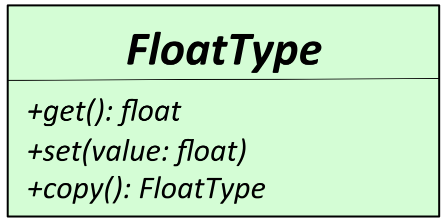
Thresholding 2

- Wrap a float image
- Create a new Img
- Compute threshold for each pixel
- Write threshold into the new Img
- ImgLib2_Threshold2.java


T:RealType
Img
+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
ImagePlus



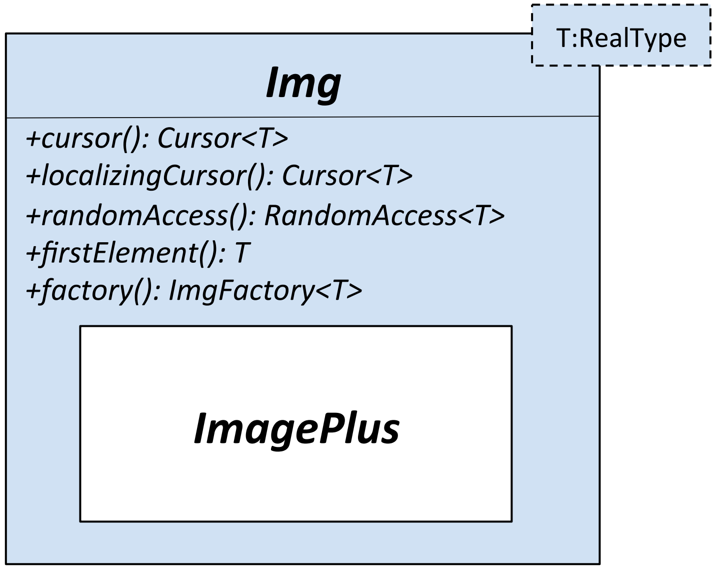

T:RealType
ImgFactory
+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

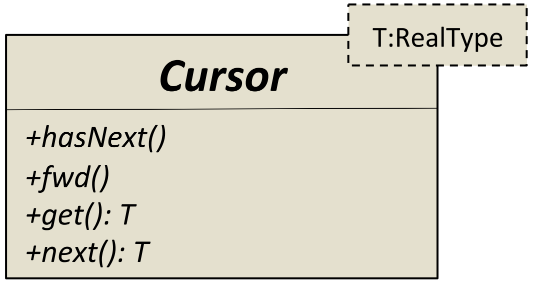


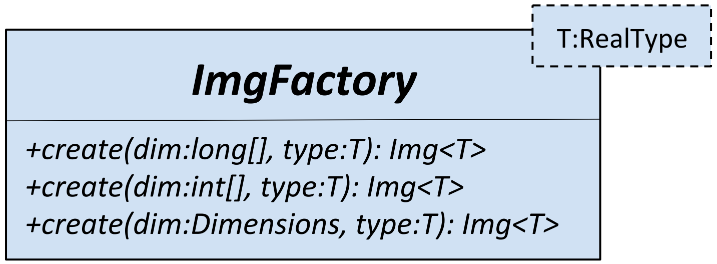
ImgLib2

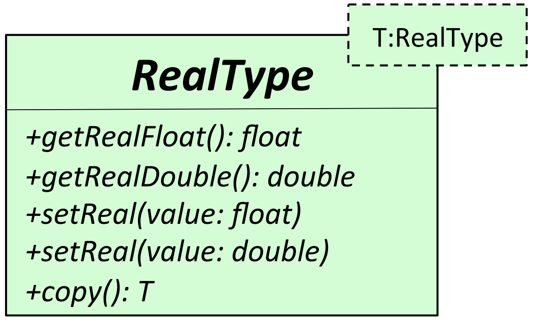
Thresholding 3

- Wrap <u>any real valued</u> image
- Create a new Img
- Compute threshold for each pixel
- Write threshold into the new Img
- ImgLib2_Threshold3.java


T:RealType
Img
+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
ImagePlus

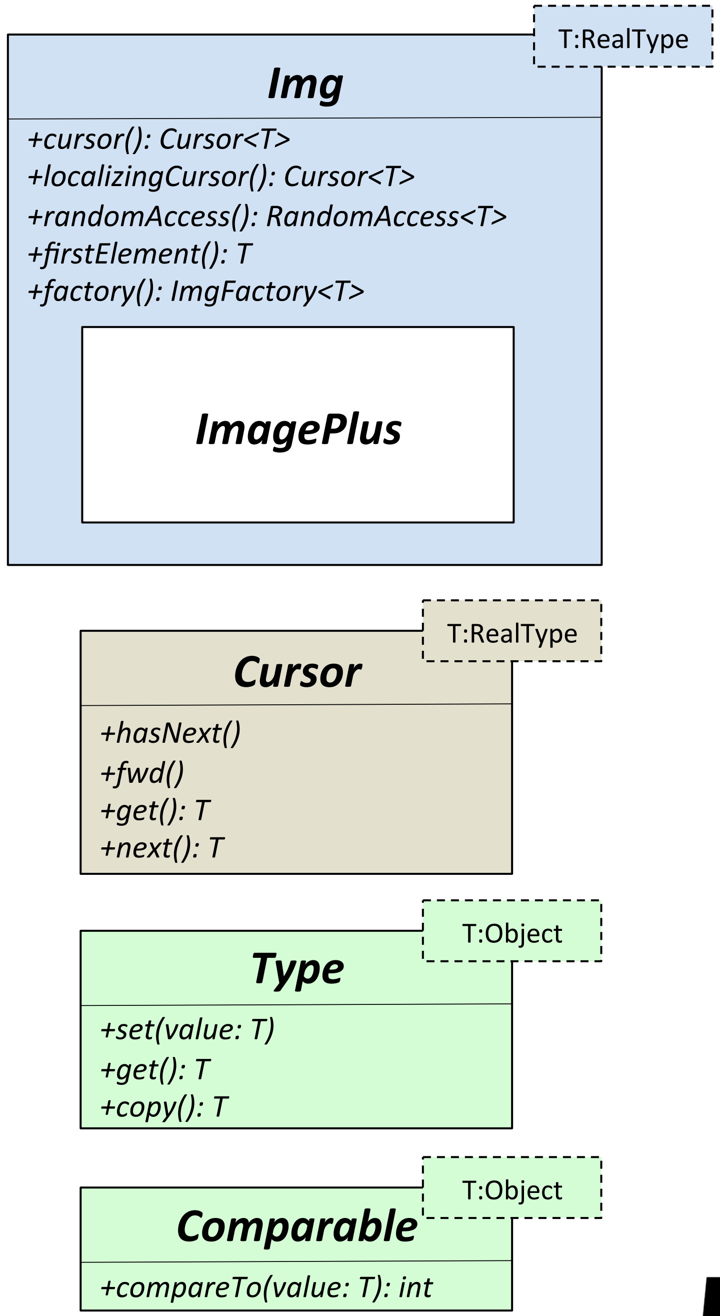


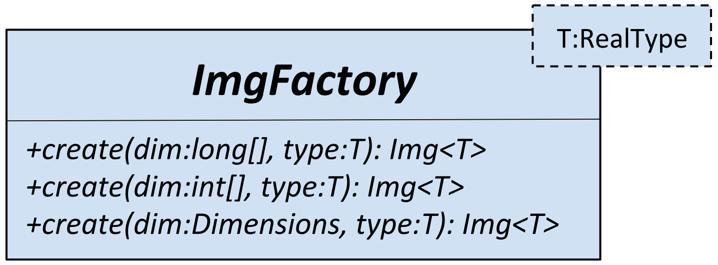

T:RealType
ImgFactory
+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>



Thresholding 4

- Wrap any real valued image
- Create a new Img
- Compute threshold for each pixel for all <u>Comparable</u>
- Write threshold into the new <u>Img of BitType (1 bit per pixel)</u>
- ImgLib2_Threshold4.java

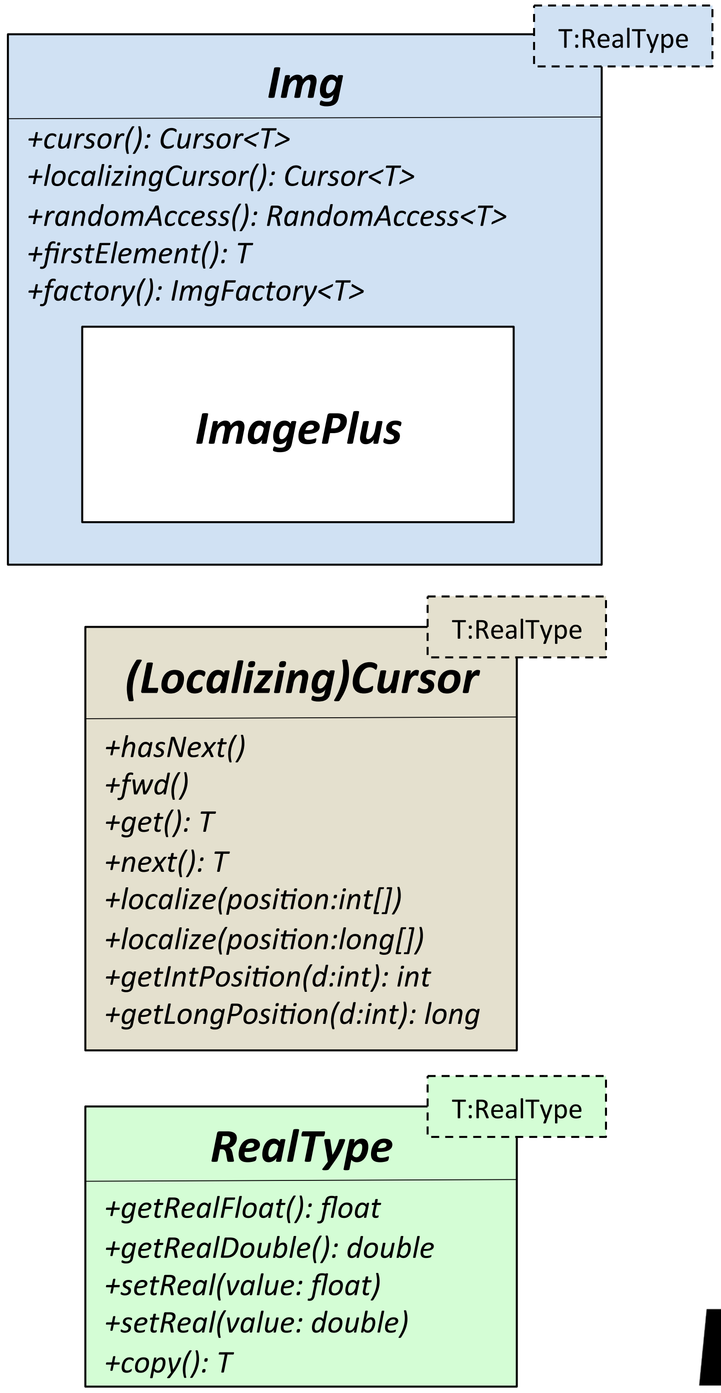



T:RealType
ImgFactory
+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

ImgLib2

Center of Mass 1

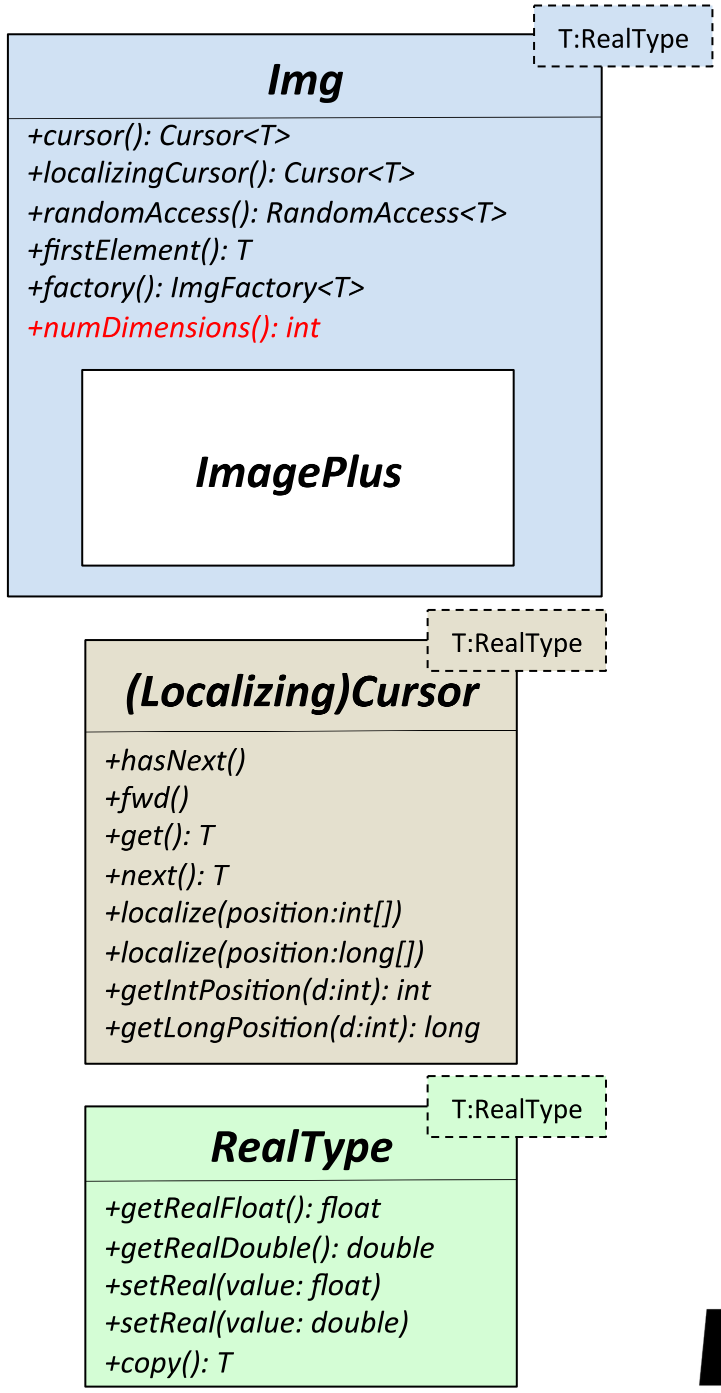
- Wrap any real valued image
- Use a localizing Cursor to Compute the center of mass in two dimensions (x,y)
- Write the result to the log window
- ImgLib2_CenterOfMass1.java



ImgLib2

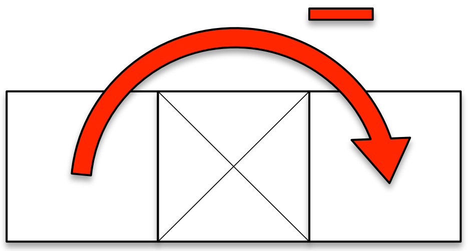
Center of Mass 2

- Wrap any real valued image
- Use a localizing Cursor to Compute the center of mass in <u>n dimensions</u>
- Write the result to the log window
- ImgLib2_CenterOfMass2.java



Gradient 1

- Wrap any real valued image
- Approximate the magnitude of the gradient for each pixel using a localizing Cursor on the output and a RandomAccess on the input



$$\nabla f_x = \frac{I(x+1,y,\ldots) - I(x-1,y,\ldots)}{2}$$

$$\nabla f_y = \frac{I(x,y+1,\ldots) - I(x,y-1,\ldots)}{2}$$

$$|\nabla f| = \sqrt{\nabla f_x^2 + \nabla f_y^2 + \ldots}$$

- ImgLib2_Gradient1.java

T:RealType

Img

+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
+numDimensions(): int
+dimension(d:int): long
+min(d:int): long
+max(d:int): long

ImagePlus

T:RealType

RealType

+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T

T:RealType

(Localizing)Cursor

+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long

T:RealType

RandomAccess

+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:int[])
+setPosition(position:long[])
+setPosition(pos:int, d:int)
+setPosition(pos:long, d:int)

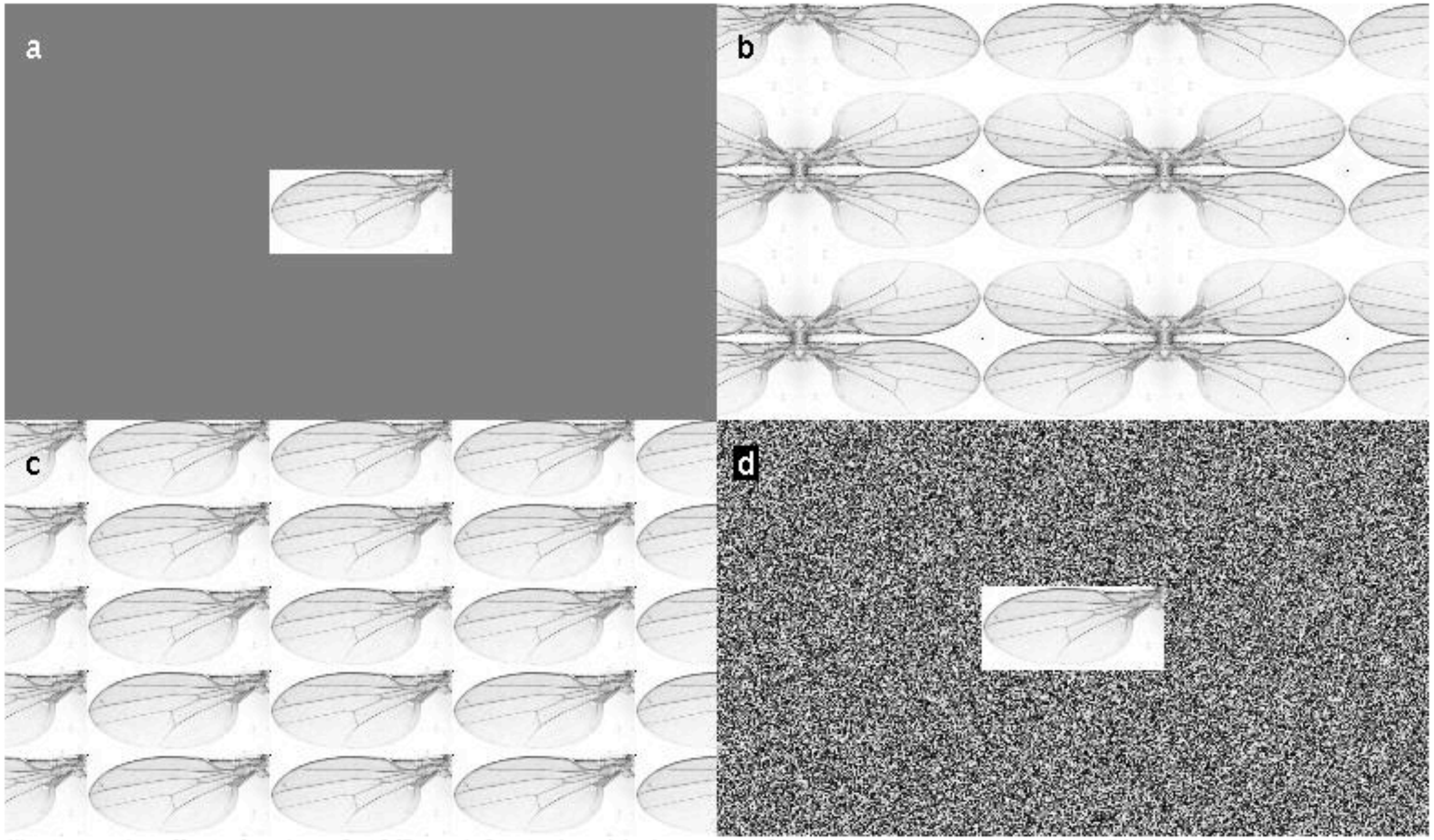
T:RealType

ImgFactory

+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

ImgLib2

OutOfBoundsStrategies

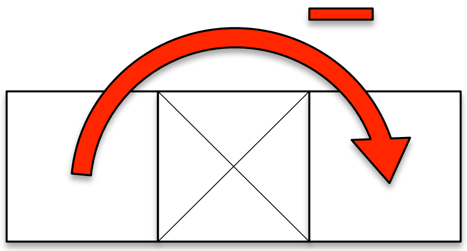


Illustrates the effect of various OutOfBoundsStrategies. (a) shows out of bounds with a constant value, (b) shows a mirroring strategy, (c) shows the periodic strategy, and (d) shows a strategy that uses random values.

ImgLib2

Gradient 2

- Use OutOfBoundsStrategy to compute gradient for all pixels
- Approximate the magnitude of the gradient for each pixel using a localizing Cursor on the output and a RandomAccess on the input



$$\nabla f_x = \frac{I(x+1,y,\ldots) - I(x-1,y,\ldots)}{2}$$

$$\nabla f_y = \frac{I(x,y+1,\ldots) - I(x,y-1,\ldots)}{2}$$

$$|\nabla f| = \sqrt{\nabla f_x^2 + \nabla f_y^2 + \ldots}$$

- ImgLib2_Gradient2.java

T:RealType

Img

+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
+numDimensions(): int
+dimension(d:int): long
+min(d:int): long
+max(d:int): long

ImagePlus

T:RealType

RealType

+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T

T:RealType

(Localizing)Cursor

+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long

T:RealType

RandomAccess

+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:int[])
+setPosition(position:long[])
+setPosition(pos:int, d:int)
+setPosition(pos:long, d:int)

T:RealType

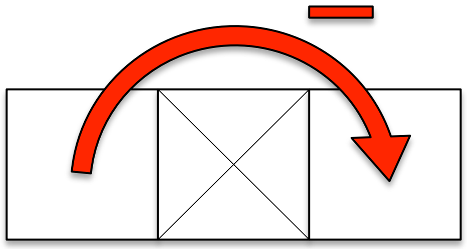
ImgFactory

+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

ImgLib2

Gradient 3

- Always return an Img<FloatType> to prevent overflows
- Approximate the magnitude of the gradient for each pixel using a localizing Cursor on the output and a RandomAccess on the input



$$\nabla f_x = \frac{I(x+1,y,\dots) - I(x-1,y,\dots)}{2}$$

$$\nabla f_y = \frac{I(x,y+1,\dots) - I(x,y-1,\dots)}{2}$$

$$|\nabla f| = \sqrt{\nabla f_x^2 + \nabla f_y^2 + \dots}$$

- ImgLib2_Gradient3.java

Img (T:RealType)

+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
+numDimensions(): int
+dimension(d:int): long
+min(d:int): long
+max(d:int): long

ImagePlus

RealType (T:RealType)

+getRealFloat(): float
+getRealDouble(): double
+setReal(value: float)
+setReal(value: double)
+copy(): T

PlanarImgFactory (T:RealType)

+create(dim:long[], type:T): Img<T>
+create(dim:int[], type:T): Img<T>
+create(dim:Dimensions, type:T): Img<T>

(Localizing)Cursor (T:RealType)

+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long

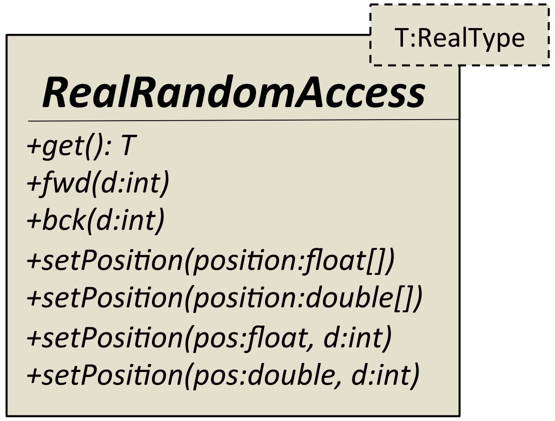
RandomAccess (T:RealType)

+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:int[])
+setPosition(position:long[])
+setPosition(pos:int, d:int)
+setPosition(pos:long, d:int)

ImgLib2

Interpolation

- Transform an Img (RandomAccessible) into a RealRandomAccessible that can return values at any real-valued location in space
- First extend by OutOfBounds



T:RealType

RealRandomAccess

+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:float[])
+setPosition(position:double[])
+setPosition(pos:float, d:int)
+setPosition(pos:double, d:int)

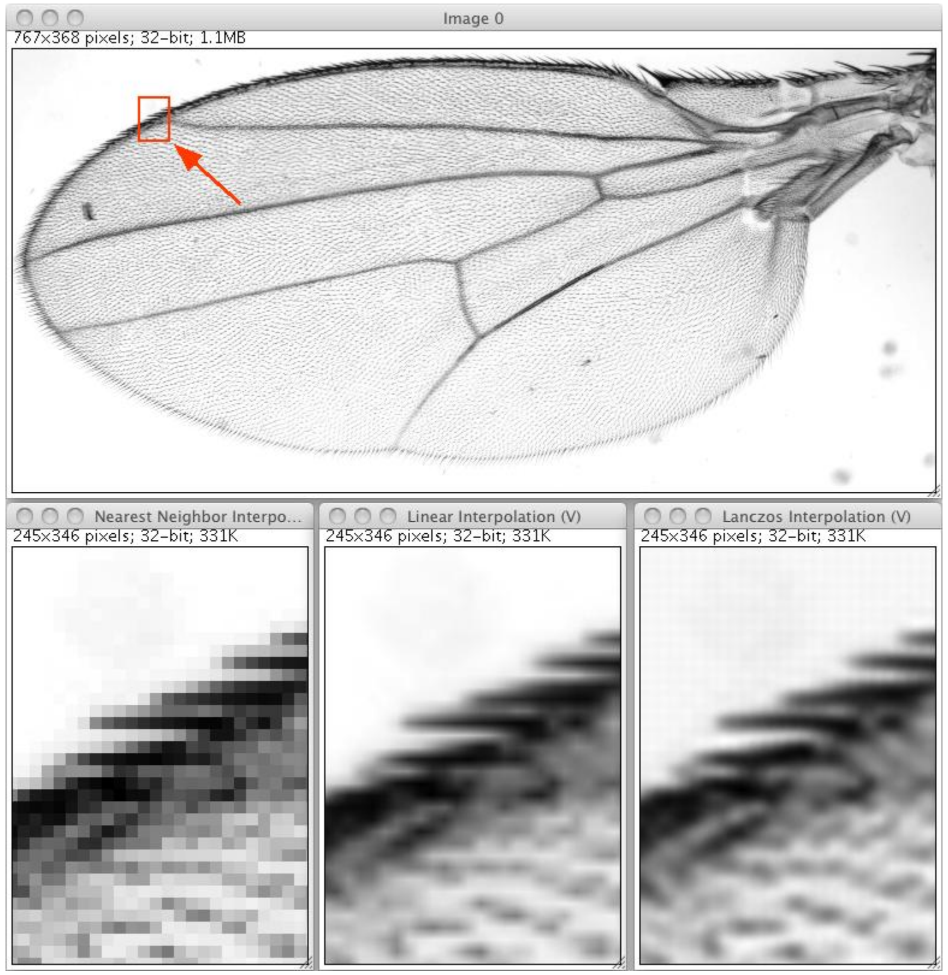
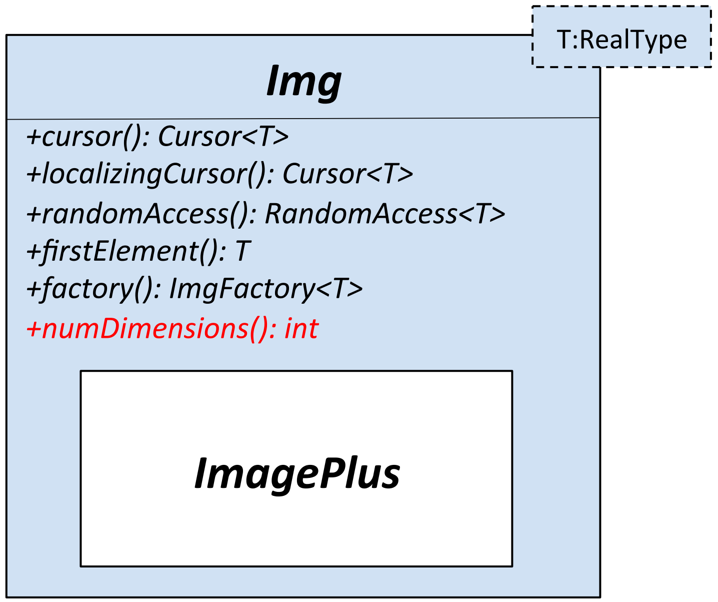


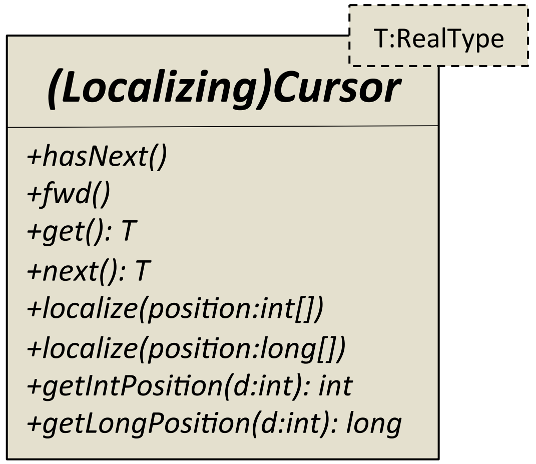
Image 0
767x368 pixels; 32-bit; 1.1MB
Nearest Neighbor Interpo...
245x346 pixels; 32-bit; 331K
Linear Interpolation (V)
245x346 pixels; 32-bit; 331K
Lanczos Interpolation (V)
245x346 pixels; 32-bit; 331K

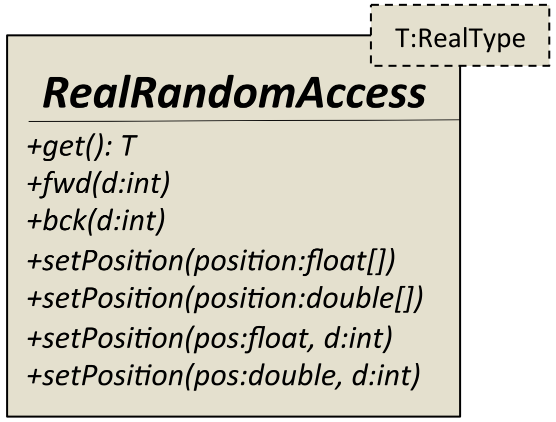
ImgLib2

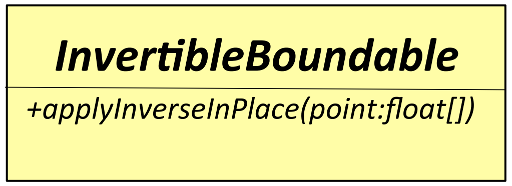
Image Transform

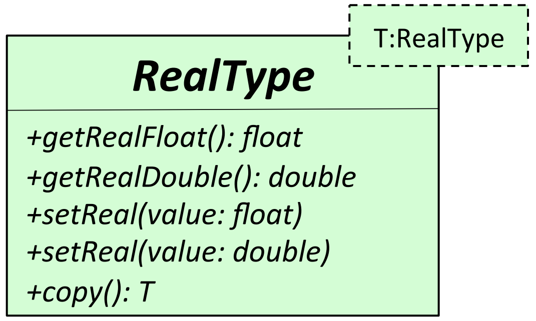
- Wrap any real valued image
- Use a localizing Cursor on the output image and a RealRandomAccess on the input to transform the image
- Each pixel location in the output needs to be transformed and the respective value read from the interpolated image
- ImgLib2_Transform.java


T:RealType
Img
+cursor(): Cursor<T>
+localizingCursor(): Cursor<T>
+randomAccess(): RandomAccess<T>
+firstElement(): T
+factory(): ImgFactory<T>
+numDimensions(): int
ImagePlus


T:RealType
(Localizing)Cursor
+hasNext()
+fwd()
+get(): T
+next(): T
+localize(position:int[])
+localize(position:long[])
+getIntPosition(d:int): int
+getLongPosition(d:int): long


T:RealType
RealRandomAccess
+get(): T
+fwd(d:int)
+bck(d:int)
+setPosition(position:float[])
+setPosition(position:double[])
+setPosition(pos:float, d:int)
+setPosition(pos:double, d:int)





ImgLib2

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http://fiji.sc/~preibisch/ImgLib2_presentation.pdf

(this presentation as PDF)

http://fiji.sc/~preibisch/ImgLib2_Introduction_src.zip

(the sources for this workshop and completed examples)

http://fiji.sc/~preibisch/ImgLib2_Introduction.zip

(the sources for this workshop, completed examples and pictures)