

Hi,

I've been trying for a very long time now to implement a principle axes transformation for the coregistration of MR image volumes. My rather simplistic understanding of how this should work is:

Find centre of mass

Calculate inertia matrix of image in centre of mass coordinate system

Find eigenvalues and eigenvectors of inertia matrix

Matrix multiply centre of mass coordinates by eigenvectors then transform back to cartesian coordinates

Voila image is rotated onto it's principle axes!

I should mention that I have no natural feel for maths and my 'play with it till it works' approach to life has proved to be a dismal failure in this project. I've tried many variations of code in the last months to try to get the principle axes transform to work for 3D matrices. Including a hack of Martin Downing's stunning `transform_volume`. I've included the inertia matrix code, and principle axes code (minus all the widget state variable stuff). These are loop versions as it may be easier for someone to spot any obvious screw ups on my part, and the matrix multiplication is (I think) quaternion, as playing with that seemed to give something close to registration.

If anyone has any hints or observations (give up is acceptable, and very close :) I'd be more than happy to hear them.

Thanks

Marc O'Brien

```
function Inertia3D, imagearray, com
```

```
  ; Calculate inertia matrix for image
```

```
  sarr = size(imagearray)
```

```
  x = sarr[1]
```

```
  y = sarr[2]
```

```
  z = sarr[3]
```

```
  npix = x * y * z
```

```
  inertia = dblarr(3,3)
```

```
  for i=-com[0], (x-com[0])-1 do begin
```

```

for j=-com[1], (y-com[1])-1 do begin
for k=-com[2], (z-com[2])-1 do begin
  pixelval = getpix_3dcom(i,j,k,com,imagearray)

```

```

; Moment of inertia = mass * distance ^ 2

```

```

; xx

```

```

temp = pixelval * (j^2 + k^2)

```

```

inertia[0,0] = inertia[0,0] + temp

```

```

; yy

```

```

temp = pixelval * (k^2 + i^2)

```

```

inertia[1,1] = inertia[1,1] + temp

```

```

; zz

```

```

temp = pixelval * (i^2 + j^2)

```

```

inertia[2,2] = inertia[2,2] + temp

```

```

; Products of inertia

```

```

; xy

```

```

temp = (pixelval * i * j)

```

```

inertia[0,1] = inertia[0,1] + temp

```

```

; xz

```

```

temp = (pixelval * i * k)

```

```

inertia[0,2] = inertia[0,2] + temp

```

```

; yz

```

```

temp = (pixelval * j * k)

```

```

inertia[1,2] = inertia[1,2] + temp

```

```

endfor

```

```

endfor

```

```

endfor

```

```

; Get mean

```

```

inertia[0,0] = inertia[0,0] / npix

```

```

inertia[1,1] = inertia[1,1] / npix

```

```

inertia[2,2] = inertia[2,2] / npix

```

```

inertia[0,1] = (inertia[0,1]) / npix

```

```

inertia[0,2] = (inertia[0,2]) / npix

```

```

inertia[2,1] = (inertia[2,1]) / npix

```

```

; ZX

```

```

inertia[2,0] = inertia[0,2]

```

```

; YX

```

```

inertia[1,0] = inertia[0,1]

```

```

; ZY

```

```
inertia[1,2] = inertia[2,1]
```

```
return, inertia  
end
```

```
pro OnPax3D, event
```

```
<snip>
```

```
; Volumes are vol and nc although for testing both volumes have  
; been the same with one rotated
```

```
; Get volume data
```

```
ivol = volarray[*,*,*]
```

```
inc = nccarray[*,*,*]
```

```
sizevol = size(ivol)
```

```
sizenc = size(inc)
```

```
; Get centers of mass
```

```
volcom=dblarr(3)
```

```
ncccom=dblarr(3)
```

```
ncccom=ROUND(COM_n(inc, /DOUBLE))-1
```

```
volcom=ROUND(COM_n(ivol,/DOUBLE))-1
```

```
; Calculate inertia matrix for vol image
```

```
I1 = Inertia3D(ivol,volcom)
```

```
; Calculate inertia matrix for nc image
```

```
I2 = Inertia3D(inc,ncccom)
```

```
; Get eigencolumns for volume image
```

```
S1 = I1
```

```
TRIRED, S1, D1, E, /DOUBLE
```

```
TRIQL, D1, E, S1, /DOUBLE
```

```
; Get eigencolumns for non contrast volume
```

```
S2 = I2
```

```
TRIRED, S2, D2, F, /DOUBLE
```

```
TRIQL, D2, F, S2, /DOUBLE
```

```
; Create the rotation matrices
```

```
;R1 = S1 ## TRANSPOSE(S2)
```

```
;R2 = S2 ## TRANSPOSE(S1)
```

```
R1 = TRANSPOSE(S1)
```

```
R2 = TRANSPOSE(S2)
```

```
; Create arrays to store transformed images
```

```
newvol = dblarr(sizevol[1],sizevol[2],sizevol[3])
```

```
newnc = dblarr(sizenc[1],sizenc[2],sizenc[3])
```

```

; Get array dimension sizes
sxvol = sizevol[1]
syvol = sizevol[2]
szvol = sizevol[3]
sxnc = sizenc[1]
sync = sizenc[2]
sznc = sizenc[3]

quartmat1 = dblarr(4,4)
quartmat1[3,*] = 0
quartmat1[* ,3] = 0
quartmat1[3,3] = 1
quartmat1[0:2,0:2] = R1
quartmat2 = dblarr(4,4)
quartmat2[3,*] = 0
quartmat2[* ,3] = 0
quartmat2[3,3] = 1
quartmat2[0:2,0:2] = R2

print, quartmat1
print
print, quartmat2

quartvec = TRANSPOSE([1,1,1,1])
newquartvec = TRANSPOSE([1,1,1,1])

; Back to the loops
for z=0, szvol-1 do begin
  for y=0, syvol-1 do begin
    for x=0, sxvol-1 do begin
      curpix = [x,y,z]

      ; Convert to centre of mass coordinates
      curpix = curpix - volcom
      quartvec[0:2] = curpix
      newquartvec = quartmat1 ## quartvec
      ; Convert back to cartesian
      newquartvec[0:2] = newquartvec[0:2] + volcom
      newquartvec = ABS(FIX(newquartvec))
      ; Check for outliers
      if newquartvec[0] GE sxvol then newquartvec[0] = sxvol -1
      if newquartvec[1] GE syvol then newquartvec[1] = syvol -1
      if newquartvec[2] GE szvol then newquartvec[2] = szvol -1
      ; Copy pixel location
      newvol[x,y,z] = ivol[newquartvec[0],newquartvec[1],newquartvec[2]]

      ; Repeat for second image

```

```

curpix = [x,y,z]
curpix = curpix - nccom
quartvec[0:2] = curpix
newquartvec = quartmat2 ## quartvec
newquartvec[0:2] = newquartvec[0:2] + nccom
newquartvec = ABS(FIX(newquartvec))
if newquartvec[0] GE sxnc then newquartvec[0] = sxnc -1
if newquartvec[1] GE sync then newquartvec[1] = sync -1
if newquartvec[2] GE sznc then newquartvec[2] = sznc -1
newnc[x,y,z] = inc[newquartvec[0],newquartvec[1],newquartvec[2]]
endfor ; x
endfor ; y
endfor ; z
<snip>
end

```

--
Tel: 0208 725 2857
Fax: 0208 725 2992

St George's Hospital Medical School
Department of Biochemistry and Immunology
Cranmer Terrace
Tooting
London SW17 0RE

Subject: Re: Principle axes transform of image volumes
Posted by [Martin Downing](#) on Thu, 14 Nov 2002 22:38:31 GMT
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Hi Marc,

I just came across this posting of yours in the archive while doing some work writing a routine for principle moments of inertia for point masses. It appeared as though you never got any replies, and I noticed that in Inertia3D you have the wrong sign for your products of inertia (they should be negative)

I.E should be:
; Products of inertia
; xy
temp = (pixelval * i * j)
inertia[0,1] = inertia[0,1] - temp

NOT:
inertia[0,1] = inertia[0,1] + temp

Hope this is of help. (but probably not anymore!).

regards

Martin

ps. Cant remember how to reply to a message on the google archive - hence this mess. And yes I have been in hiding!

Marc's original posting on 7/6/2002 follows:

From: m.obrien@sghms.ac.uk (m.obrien@sghms.ac.uk)

Subject: Principle axes transform of image volumes

This is the only article in this thread

View: Original Format

Newsgroups: comp.lang.idl-pvwave

Date: 2002-06-07 03:25:47 PST

Hi,

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If anyone has any hints or observations (give up is acceptable, and very close :) I'd be more than happy to hear them.

Thanks

Marc O'Brien

```
function Inertia3D, imagearray, com

; Calculate inertia matrix for image
sarr = size(imagearray)
x = sarr[1]
y = sarr[2]
z = sarr[3]
npix = x * y * z

inertia = dblarr(3,3)

for i=-com[0], (x-com[0])-1 do begin
for j=-com[1], (y-com[1])-1 do begin
for k=-com[2], (z-com[2])-1 do begin
pixelval = getpix_3dcom(i,j,k,com,imagearray)

; Moment of inertia = mass * distance ^ 2
; xx
temp = pixelval * (j^2 + k^2)
inertia[0,0] = inertia[0,0] + temp

; yy
temp = pixelval * (k^2 + i^2)
inertia[1,1] = inertia[1,1] + temp

; zz
temp = pixelval * (i^2 + j^2)
inertia[2,2] = inertia[2,2] + temp

; Products of inertia
; xy
temp = (pixelval * i * j)
inertia[0,1] = inertia[0,1] + temp

; xz
temp = (pixelval * i * k)
inertia[0,2] = inertia[0,2] + temp

; yz
temp = (pixelval * j * k)
inertia[1,2] = inertia[1,2] + temp
endfor
```

```
endfor
endfor
```

```
; Get mean
inertia[0,0] = inertia[0,0] / npix
inertia[1,1] = inertia[1,1] / npix
inertia[2,2] = inertia[2,2] / npix
inertia[0,1] = (inertia[0,1]) / npix
inertia[0,2] = (inertia[0,2]) / npix
inertia[2,1] = (inertia[2,1]) / npix
```

```
; ZX
inertia[2,0] = inertia[0,2]
; yx
inertia[1,0] = inertia[0,1]
; zy
inertia[1,2] = inertia[2,1]
```

```
return, inertia
end
```

```
pro OnPax3D, event
```

```
<snip>
```

```
; Volumes are vol and nc although for testing both volumes have
; been the same with one rotated
```

```
; Get volume data
ivol = volarray[*,*,*]
inc = narray[*,*,*]
sizevol = size(ivol)
sizenc = size(inc)
```

```
; Get centers of mass
volcom=dblarr(3)
nccom=dblarr(3)
nccom=ROUND(COM_n(inc, /DOUBLE))-1
volcom=ROUND(COM_n(ivol,/DOUBLE))-1
```

```
; Calculate inertia matrix for vol image
I1 = Inertia3D(ivol,volcom)
; Calculate inertia matrix for nc image
I2 = Inertia3D(inc,nccom)
```

```
; Get eigencolumns for volume image
S1 = I1
```

```

TRIRED, S1, D1, E, /DOUBLE
TRIQL, D1, E, S1, /DOUBLE

; Get eigencolumns for non contrast volume
S2 = I2
TRIRED, S2, D2, F, /DOUBLE
TRIQL, D2, F, S2, /DOUBLE

; Create the rotation matrices
;R1 = S1 ## TRANSPOSE(S2)
;R2 = S2 ## TRANSPOSE(S1)
R1 = TRANSPOSE(S1)
R2 = TRANSPOSE(S2)

; Create arrays to store transformed images
newvol = dblarr(sizevol[1],sizevol[2],sizevol[3])
newnc = dblarr(sizenc[1],sizenc[2],sizenc[3])

; Get array dimension sizes
sxvol = sizevol[1]
syvol = sizevol[2]
szvol = sizevol[3]
sxnc = sizenc[1]
sync = sizenc[2]
sznc = sizenc[3]

quartmat1 = dblarr(4,4)
quartmat1[3,*] = 0
quartmat1[* ,3] = 0
quartmat1[3,3] = 1
quartmat1[0:2,0:2] = R1
quartmat2 = dblarr(4,4)
quartmat2[3,*] = 0
quartmat2[* ,3] = 0
quartmat2[3,3] = 1
quartmat2[0:2,0:2] = R2

print, quartmat1
print
print, quartmat2

quartvec = TRANSPOSE([1,1,1,1])
newquartvec = TRANSPOSE([1,1,1,1])

; Back to the loops
for z=0, szvol-1 do begin
for y=0, syvol-1 do begin
for x=0, sxvol-1 do begin

```

```

curpix = [x,y,z]

; Convert to centre of mass coordinates
curpix = curpix - volcom
quartvec[0:2] = curpix
newquartvec = quartmat1 ## quartvec
; Convert back to cartesian
newquartvec[0:2] = newquartvec[0:2] + volcom
newquartvec = ABS(FIX(newquartvec))
; Check for outliers
if newquartvec[0] GE sxvol then newquartvec[0] = sxvol -1
if newquartvec[1] GE syvol then newquartvec[1] = syvol -1
if newquartvec[2] GE szvol then newquartvec[2] = szvol -1
; Copy pixel location
newvol[x,y,z] = ivol[newquartvec[0],newquartvec[1],newquartvec[2]]

; Repeat for second image
curpix = [x,y,z]
curpix = curpix - nccom
quartvec[0:2] = curpix
newquartvec = quartmat2 ## quartvec
newquartvec[0:2] = newquartvec[0:2] + nccom
newquartvec = ABS(FIX(newquartvec))
if newquartvec[0] GE sxnc then newquartvec[0] = sxnc -1
if newquartvec[1] GE sync then newquartvec[1] = sync -1
if newquartvec[2] GE sznc then newquartvec[2] = sznc -1
newnc[x,y,z] = inc[newquartvec[0],newquartvec[1],newquartvec[2]]
endfor ; x
endfor ; y
endfor ; z
<snip>
end

```

--

Tel: 0208 725 2857

Fax: 0208 725 2992

St George's Hospital Medical School
Department of Biochemistry and Immunology
Cranmer Terrace
Tooting
London SW17 0RE

--

Martin Downing,
Clinical Research Physicist,
Grampian Orthopaedic RSA Research Centre,
Woodend Hospital, Aberdeen, AB15 6LS.

Subject: Re: Principle axes transform of image volumes
Posted by [David Fanning](#) on Thu, 14 Nov 2002 23:35:29 GMT
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Martin Downing (martin.downing@ntlworld.com) writes:

> And yes I have been in hiding!

Well, it's good of you to show up again. We missed
you. :-)

Cheers,

David

--

David W. Fanning, Ph.D.
Fanning Software Consulting, Inc.
Phone: 970-221-0438, E-mail: david@dfanning.com
Coyote's Guide to IDL Programming: <http://www.dfanning.com/>
Toll-Free IDL Book Orders: 1-888-461-0155
