Algorithm for Semi-Automatic Detection and Computational Analysis of Harris Lines in X-Ray Images

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Starting Position

- **Intra- and interobserver variability is high** (Macciarelli, Bondioli et al., 1994; Grolleau-Raoux, Crubezy et al. 1997)
- **Various methods for age computation** (Clare, 1982; Maat, 1984; Hummert and van Gerven, 1984; Byers, 1991)
- **Measurements of bone unclear**

By now, Harris lines cannot be processed with current biomedical imaging software

Criteria for Harris Lines Detection

- **Standard: Garn et al., 1968, and Gindhart, 1969:**
  - **Visible by naked eye**
  - **Minimal line length: 1/2 of diaphyses**
  - **Distal lines are primary, proximal lines secondary**

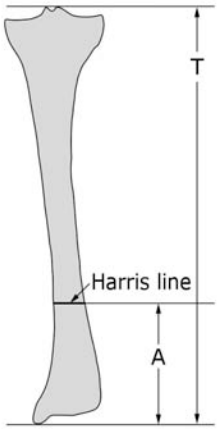
- **Clarke and Mack, 1988:**
  - **Minimal line length: 1/3 of diaphyses**
  - **45° < alpha < 135°**

Visibilty by naked eye is a vague definition

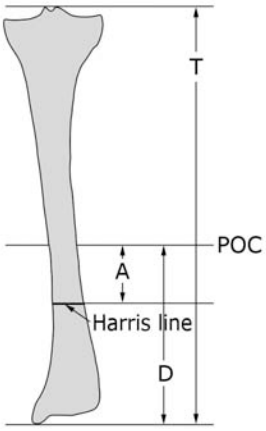
We know what it means to recognize a face, but we cannot explain how we do it!

Age Computation: Adults

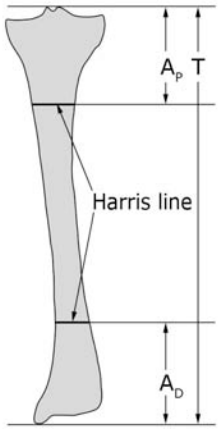
Clarke, 1982 | Maat, 1984 | Byers, 1991



T: Total tibial length
A: Distance from HL to bone end



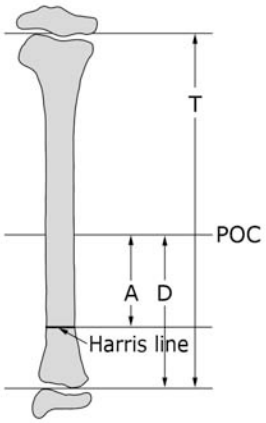
T: Total tibia length
POC: Primary ossification center (43% of distal T)
A: Distance HL to POC
D: Distance POC to bone end



T: Total tibia length
A_P: Distance HL to proximal bone end
A_D: Distance HL to distal bone end

Age Computation: Juveniles

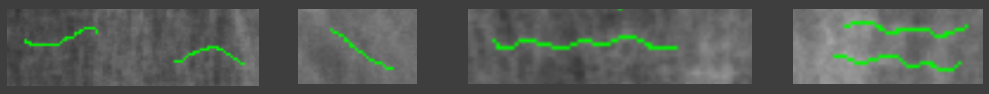
Hummert & van Gerven, 1985



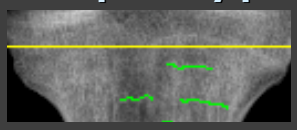
T: Total tibia length without epiphyses
POC: Primary ossification center
(43% of distal T)
A: Distance HL to POC
D: Distance POC to bone end

Problems of Automatic Detection

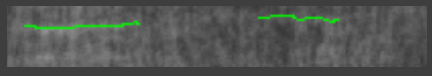
- **Epiphyseal fusion**
- **Other trabecular structures**



- **Not horizontal Harris lines -> especially proximal**



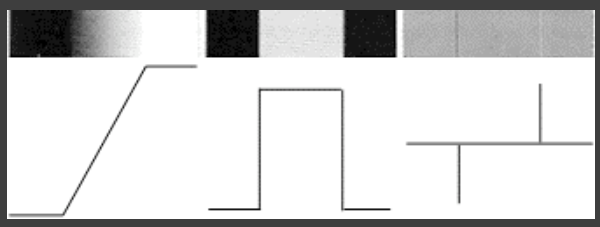
- **Projection errors during x-ray imaging**
- **Gaps in Harris lines**



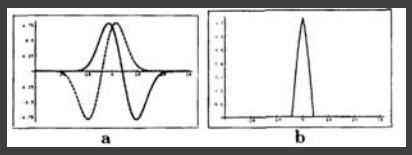
Core Algorithm

- **Line detection algorithm that finds horizontal lines (Koller et al. , 1995)**
- **Parameters:**
  - **Minimal line length according to shaft width**
  - **Angle of Harris lines according to bone orientation**
  - **Curly lines are excluded**
  - **Lines in epiphyses are excluded**

Line Detection



Edge detection

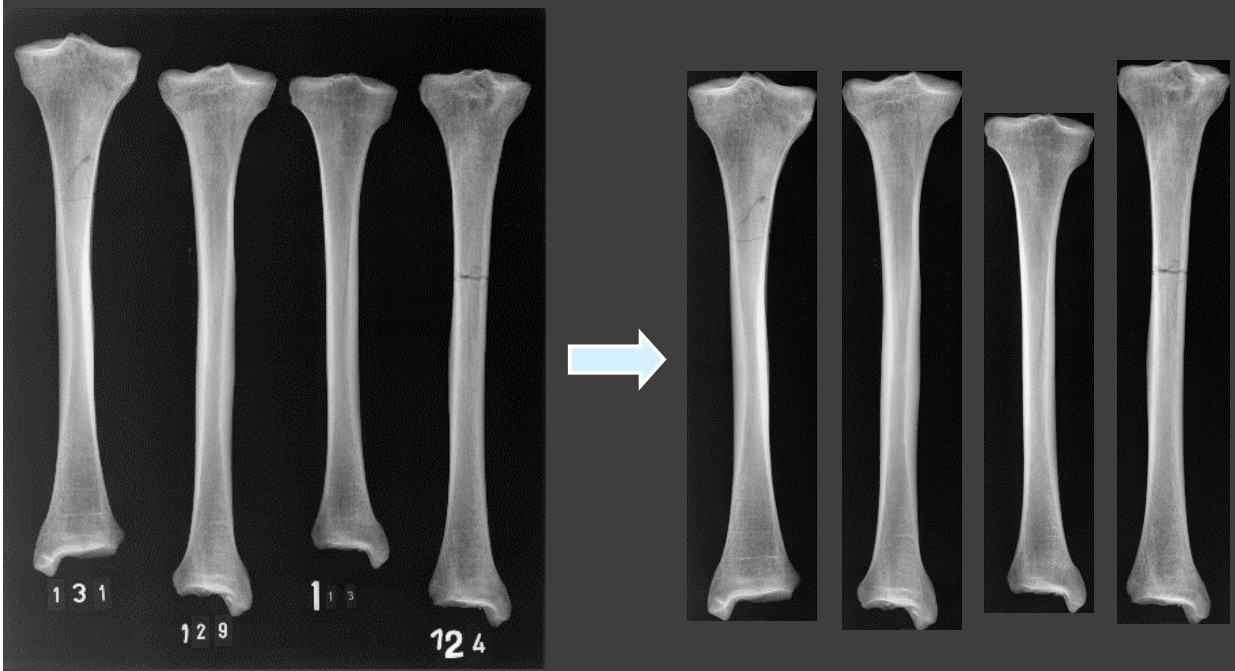


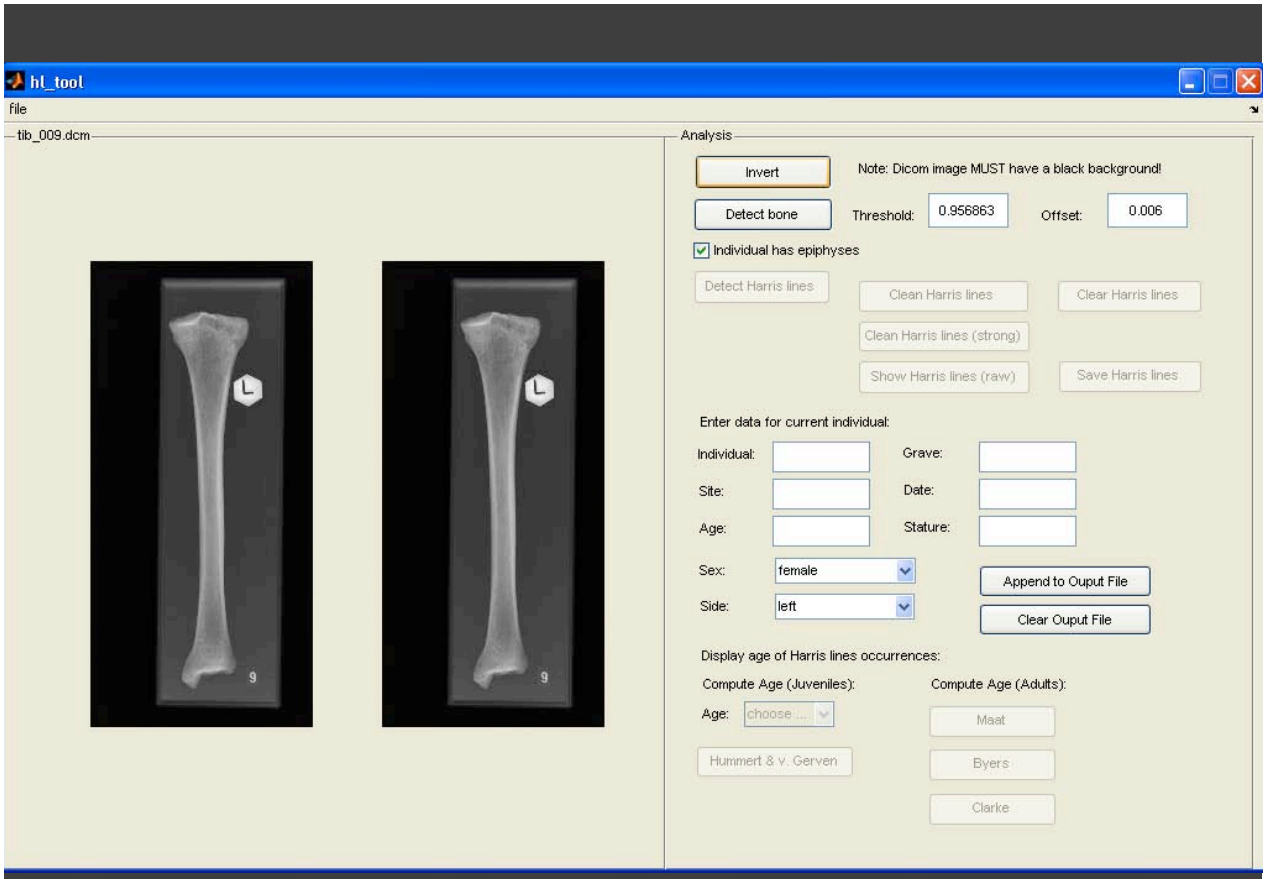
Line detection

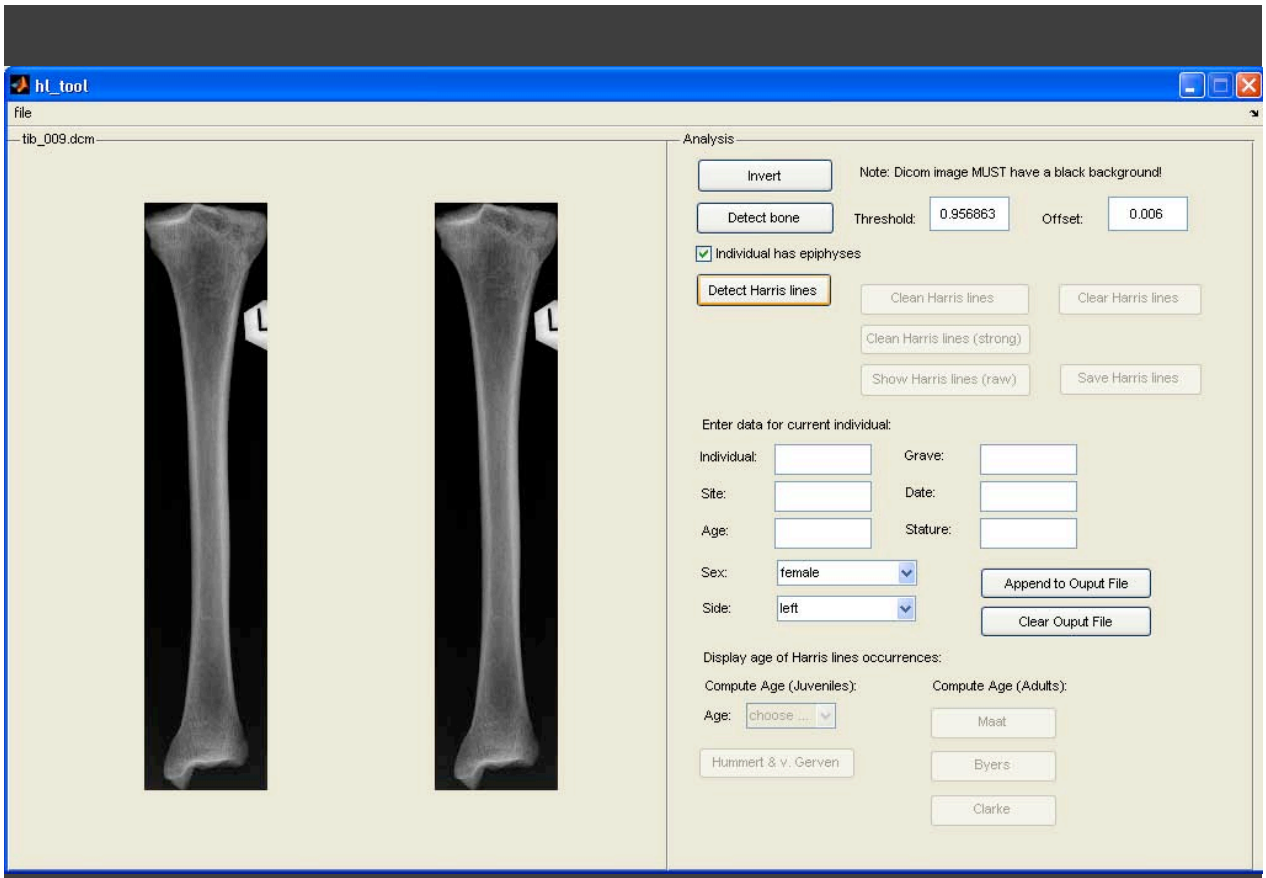
Parameter Settings

	RAW	A	B
Absolute minimal line length (image resolution)	35 (200 dpi)	35 (200 dpi)	60 (200 dpi)
Sector for proximal line occurrences	(0.06 – 0.3) T T: tibia length	(0.06 – 0.3) T	(0.06 – 0.3) T
Sector for distal line occurrences	(0.07 – 0.35) T	(0.07 – 0.35) T	(0.07 – 0.35) T
Straightness of a line	-	0.995	0.995
Orientation tolerance (angle)	-	6°	6°

Crop dicom tool




hl_tool
file
tib_009.dcm
Analysis
Invert
Note: Dicom image MUST have a black background!
Detect bone
Threshold:
0.956863
Offset:
0.006
Individual has epiphyses
Detect Harris lines
Clean Harris lines
Clear Harris lines
Clean Harris lines (strong)
Show Harris lines (raw)
Save Harris lines
Enter data for current individual:
Individual:
Grave:
Site:
Date:
Age:
Stature:
Sex:
female
Side:
left
Append to Ouput File
Clear Ouput File
Display age of Harris lines occurrences:
Compute Age (Juveniles):
Compute Age (Adults):
Age:
choose ...
Maat
Hummert & v. Gerven
Byers
Clarke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Individual:
Grave:
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Date:
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Stature:
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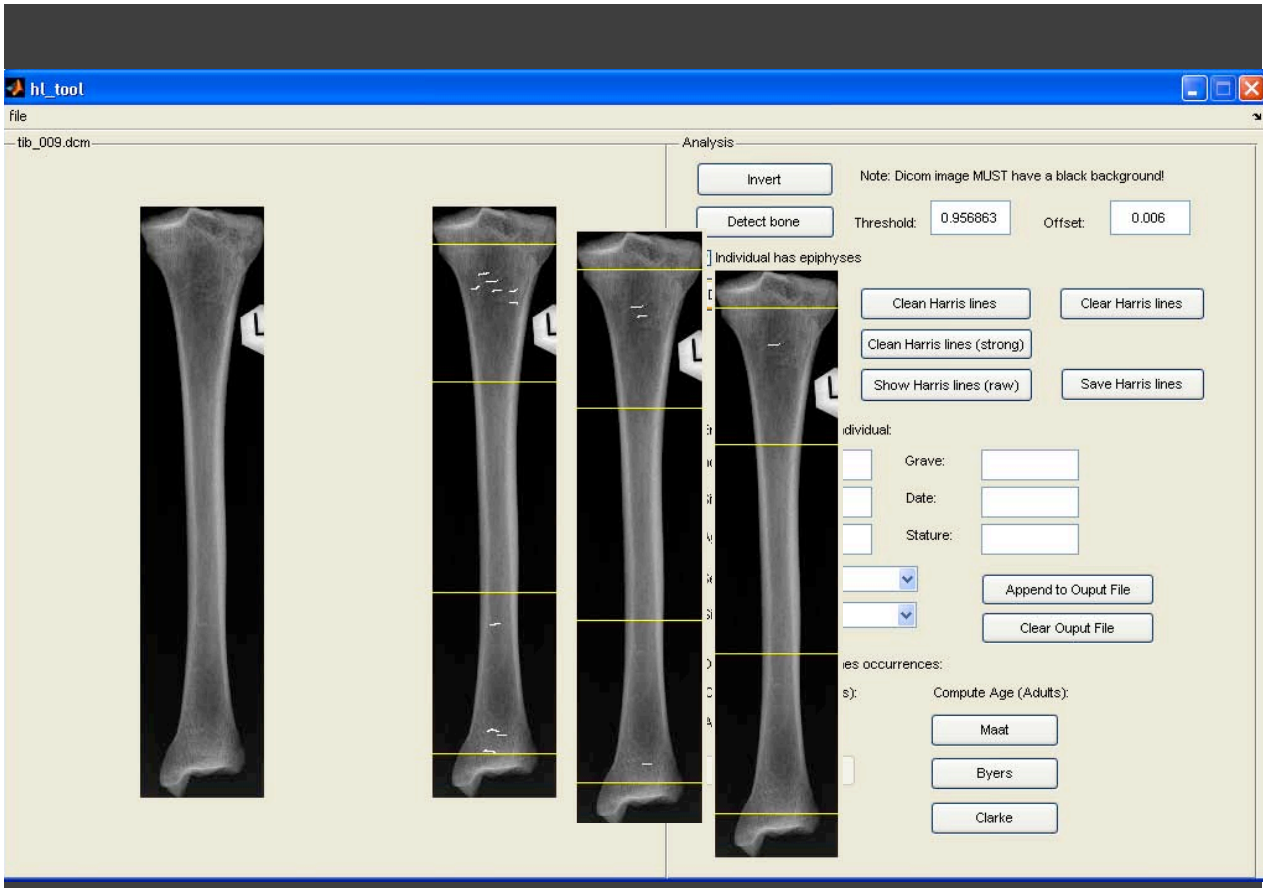
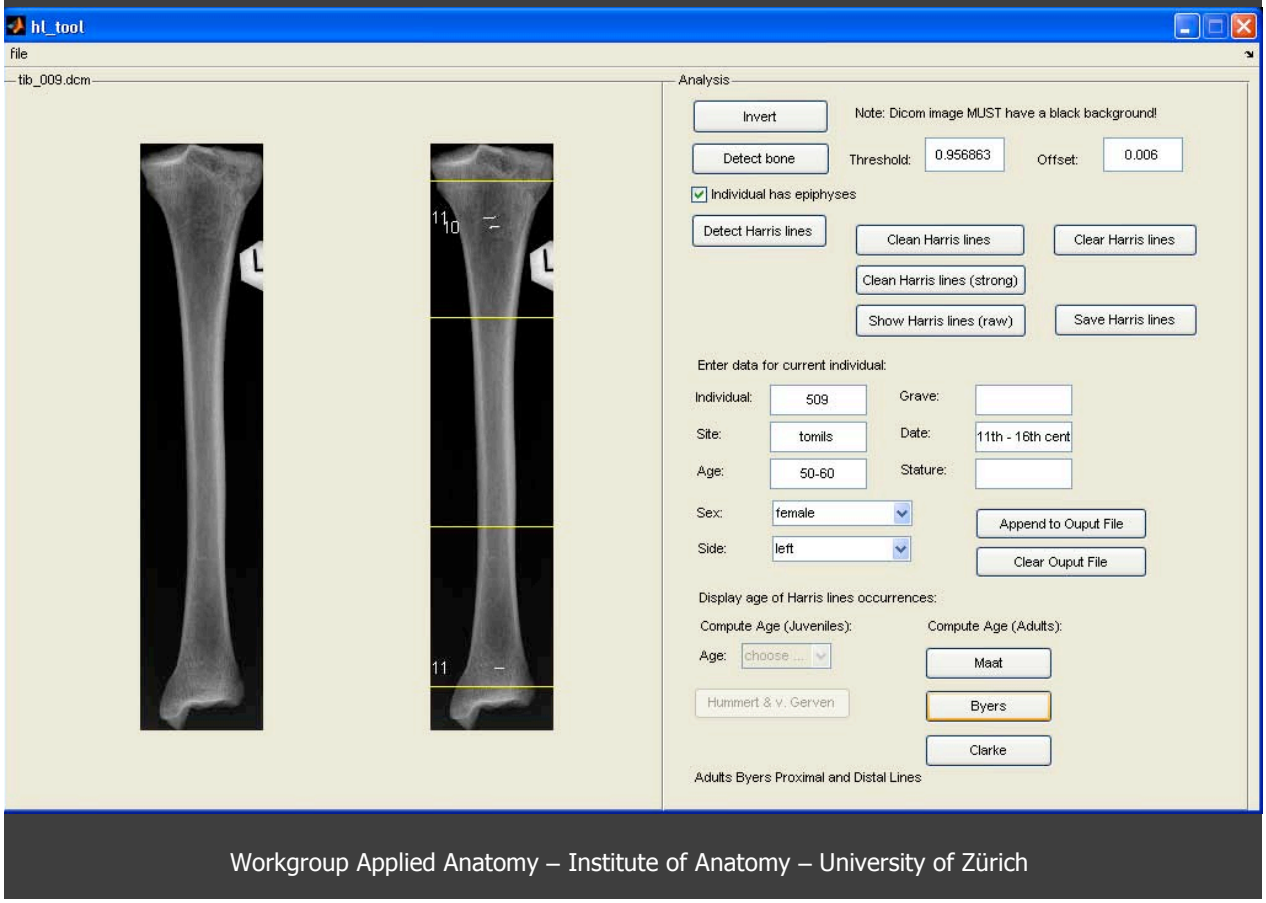


Workgroup Applied Anatomy – Institute of Anatomy – University of Zürich



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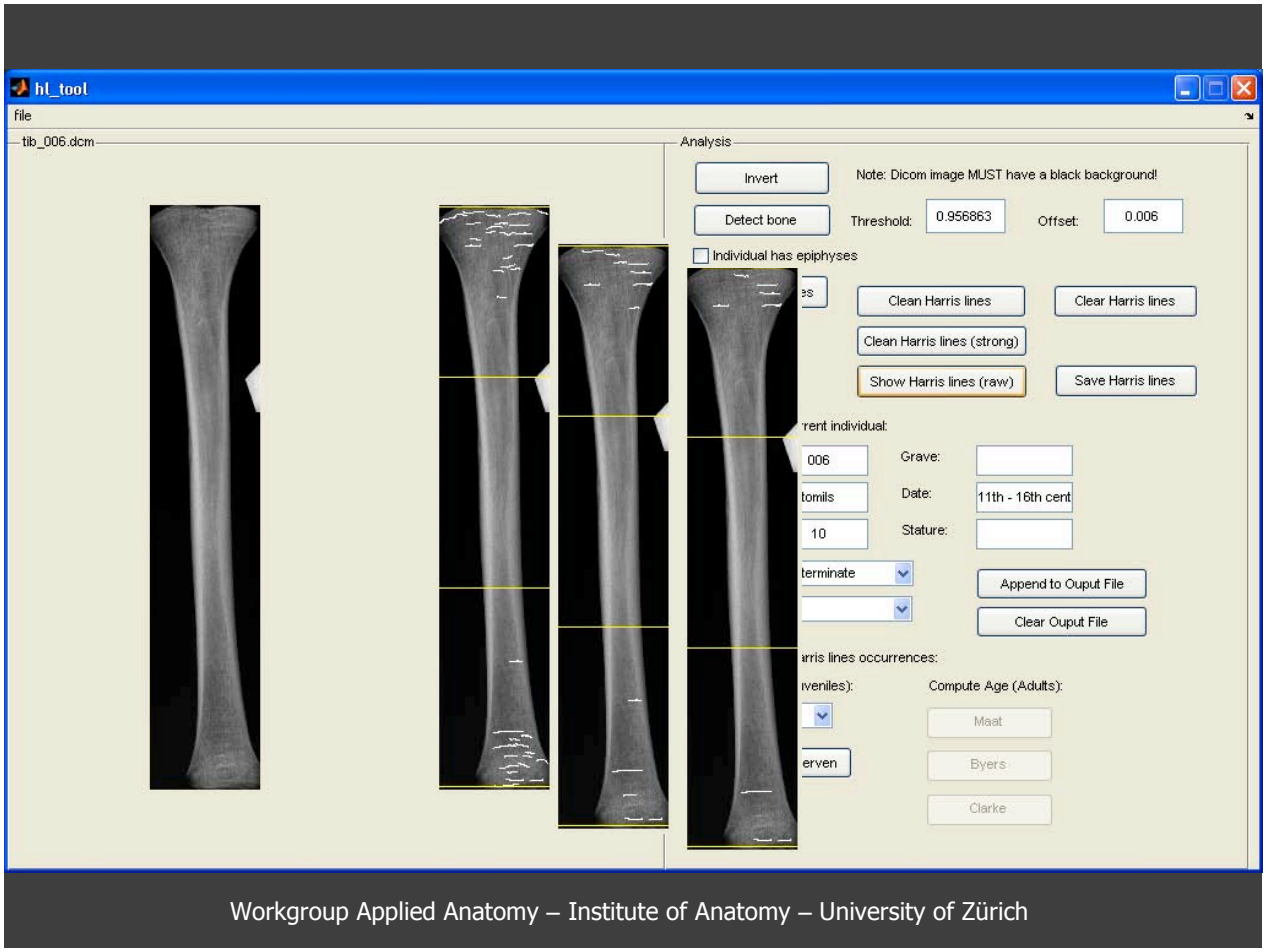
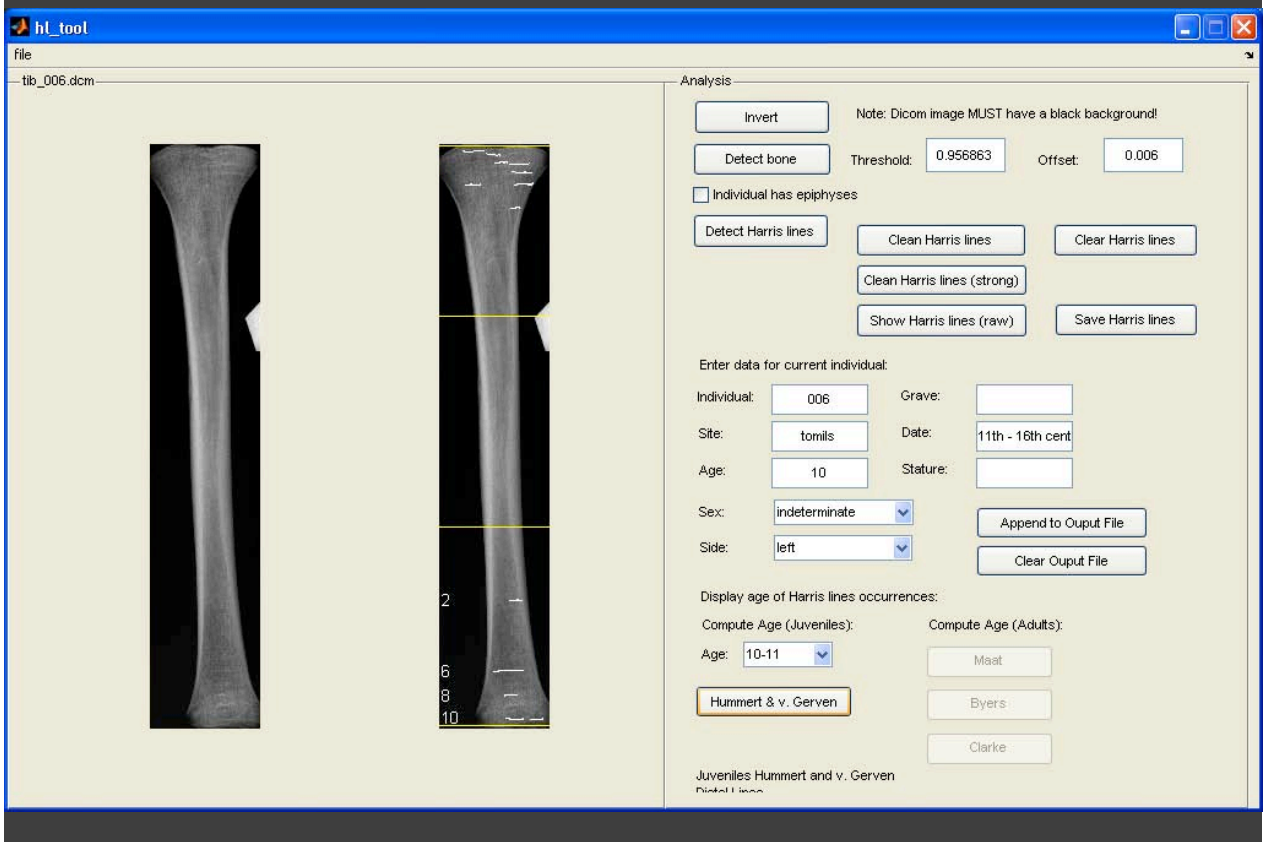

hl_tool
file
tib_006.dcm
Analysis
Invert
Note: Dicom image MUST have a black background!
Detect bone
Threshold:
0.956863
Offset:
0.006
Individual has epiphyses
Clean Harris lines
Clear Harris lines
Clean Harris lines (strong)
Show Harris lines (raw)
Save Harris lines
006
Grave:
tomils
Date:
11th - 16th cent
10
Stature:
terminate
Append to Ouput File
Clear Ouput File
Compute Age (Adults):
Maat
Byers
Clarke


hl_tool
file
tib_006.dcm
Analysis
Invert
Note: Dicom image MUST have a black background!
Detect bone
Threshold:
0.956863
Offset:
0.006
Individual has epiphyses
Detect Harris lines
Clean Harris lines
Clear Harris lines
Clean Harris lines (strong)
Show Harris lines (raw)
Save Harris lines
Enter data for current individual:
Individual:
006
Grave:
Site:
tomils
Date:
11th - 16th cent
Age:
10
Stature:
Sex:
indeterminate
Side:
left
Append to Ouput File
Clear Ouput File
Display age of Harris lines occurrences:
Compute Age (Juveniles):
Compute Age (Adults):
Age:
10-11
Maat
Hummert & v. Gerven
Byers
Clarke
Juveniles Hummert and v. Gerven

Output File

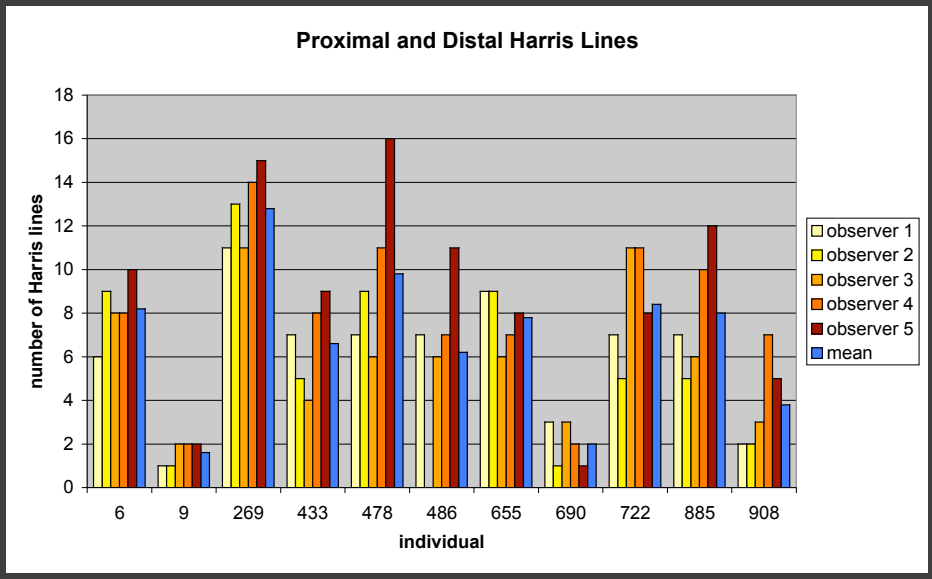
Name	Grave	Archeologica	Date	Age	Sex	Side	Stature	Tibia lenght	Distance fro	Orientation
509	unknown	tomils	11th - 16th century	50-60	female	l	unknown	38.3286	4.8895	proximal
509	unknown	tomils	11th - 16th century	50-60	female	l	unknown	38.3286	5.4737	proximal
509	unknown	tomils	11th - 16th century	50-60	female	l	unknown	38.3286	4.0386	distal
6	unknown	tomils	11th - 16th century	10	indeterminate	l	unknown	29.2608	0.3937	distal
6	unknown	tomils	11th - 16th century	10	indeterminate	l	unknown	29.2608	0.5207	distal

Name	Byers, 1991	Maat, 1984	Clarke, 1982	Hummert and Van Gerven, 1985
509	11			
509	10			
509	11	12	13	
6				2
6				6

Verification

- **Population: Tomils-Sogn Murezi, GR, Switzerland**
- **Tibiae of 12 individuals**
  - **11 x left, 1 x right**
  - **f, m**
  - **juveniles and adults**
- **Digital x-rays (12 bit): anterior-posterior Orthopedic University Clinic Balgrist Zürich**

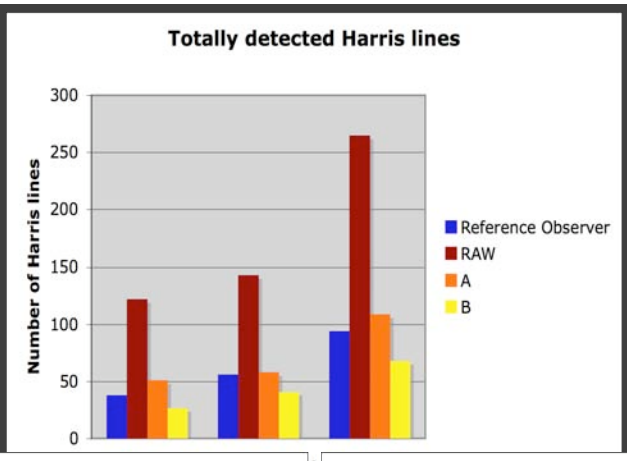
Interobsever Error



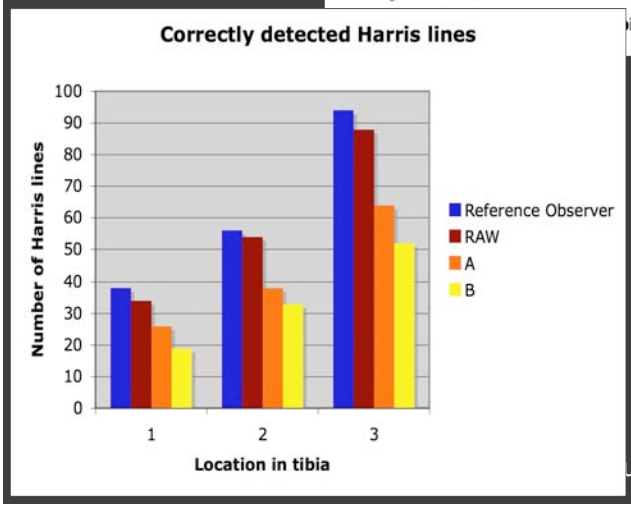
Results 2

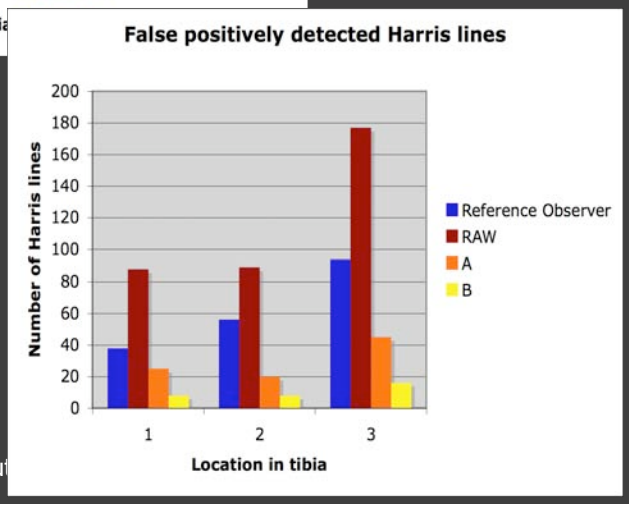
Original | Automatic 1 | Automatic 2 | Observer 5

Age of Harris line occurence computed by Byers, 1991.



1: proximal
2: distal
3: total





Further Development

- **Manually add and remove Harris lines**
- **Zoom in, zoom out**
- **Choose the sector for Harris lines detection**
- **Further import formats: Tiff ? others?**
- **Combining two lines on screen**
- **Database**
- **...**

Relevance and Perspective

For the first time Harris lines can be detected and analyzed with a biomedical imaging tool

- ➡ **Intra- and inter-observer error reduced**
- ➡ **Standardization and classification**
- ➡ **4 standard methods for computational analysis**
- ➡ **Shorter data acquisition time**

Discussion