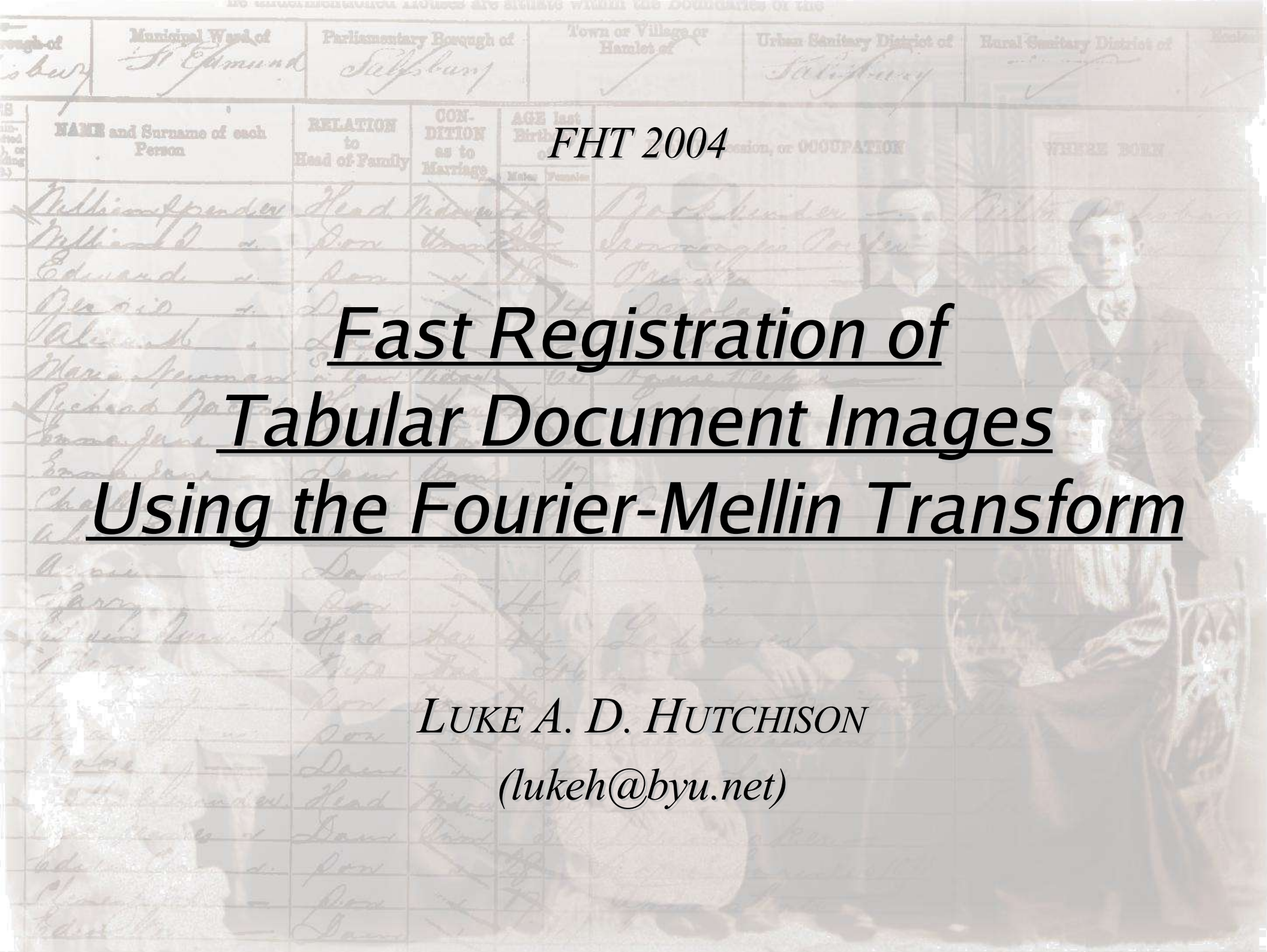




FHT 2004

Fast Registration of Tabular Document Images Using the Fourier-Mellin Transform

LUKE A. D. HUTCHISON

(lukeh@byu.net)

Document Image Registration

Example: Data Extraction (UDE)

UDE - [Packet - C:\UDE\WINDATA\A10101-1.GGD - 1 G Sarah/Britton F]

File Edit Batch Packet Records Fields Image Reports Search Window Help

NAME and Surname of each Person: Edland d. Boat No. 1
(If rural, give location)

4. Date (Month) (Day) (Year)
Of Death: May 28, 1953

9. Age (In years last birthday) If Under 1 Year Months Days If Under 24 Hrs. Hours Min.
3 7 45

12. Citizen of What Country?
U.S.A.

PRINCIPAL'S NAME: Sarah/Britton
Sex: F
Death Date: 28May1953
Death Place: Birmingham, Jefferson County, Alabama

Death Date: 28May1953 Data Entry Mode

1 G Sarah/Britton F

UDE - [Packet - C:\UDE\WINDATA\A10101-1.GGD - 1 G Abraham/Fairbanks M]

File Edit Batch Packet Records Fields Image Reports Search Window Help

(If rural, give location)

4. Date (Month) (Day) (Year)
Of Death: 9-26-53

9. Age (In years last birthday) If Under 1 Year Months Days If Under 24 Hrs. Hours Min.
22

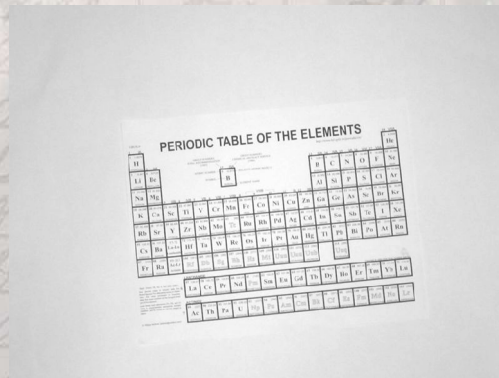
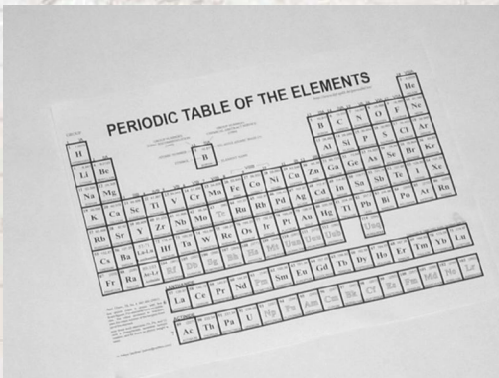
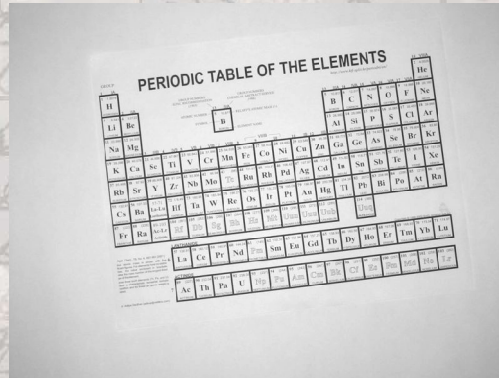
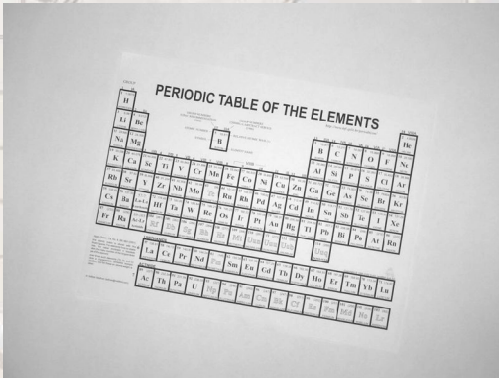
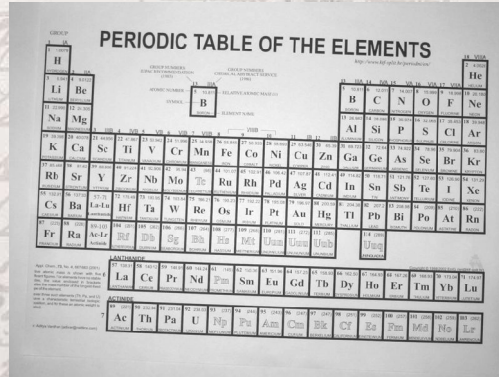
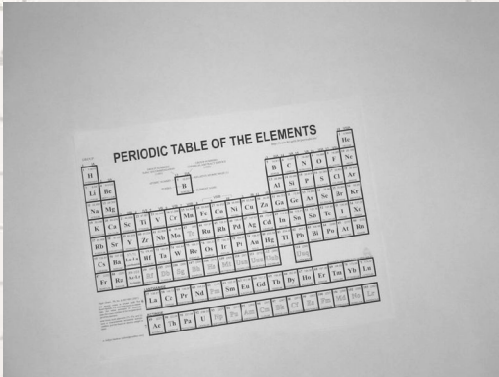
12. Citizen of What Country?
U.S.A.

PRINCIPAL'S NAME: Abraham/Fairbanks
Sex: M
Death Date: 26Sep1953
Death Place: Birmingham, Jefferson County, Alabama

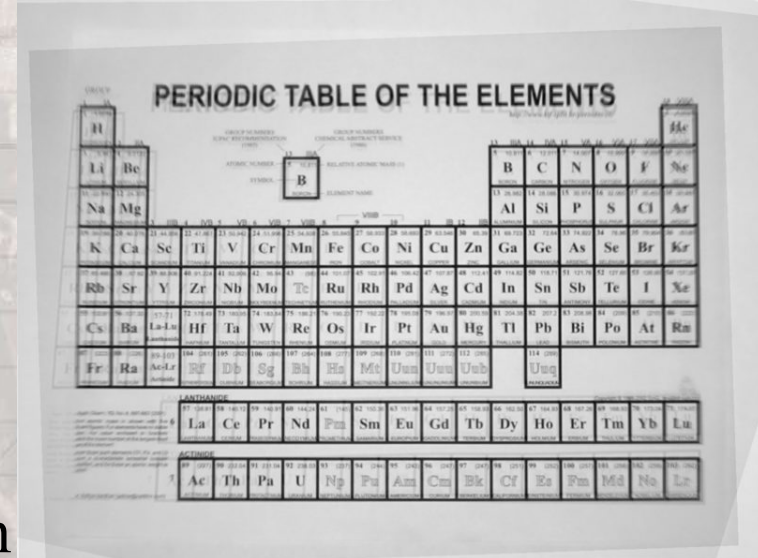
Death Date: 26Sep1953 Data Entry Mode

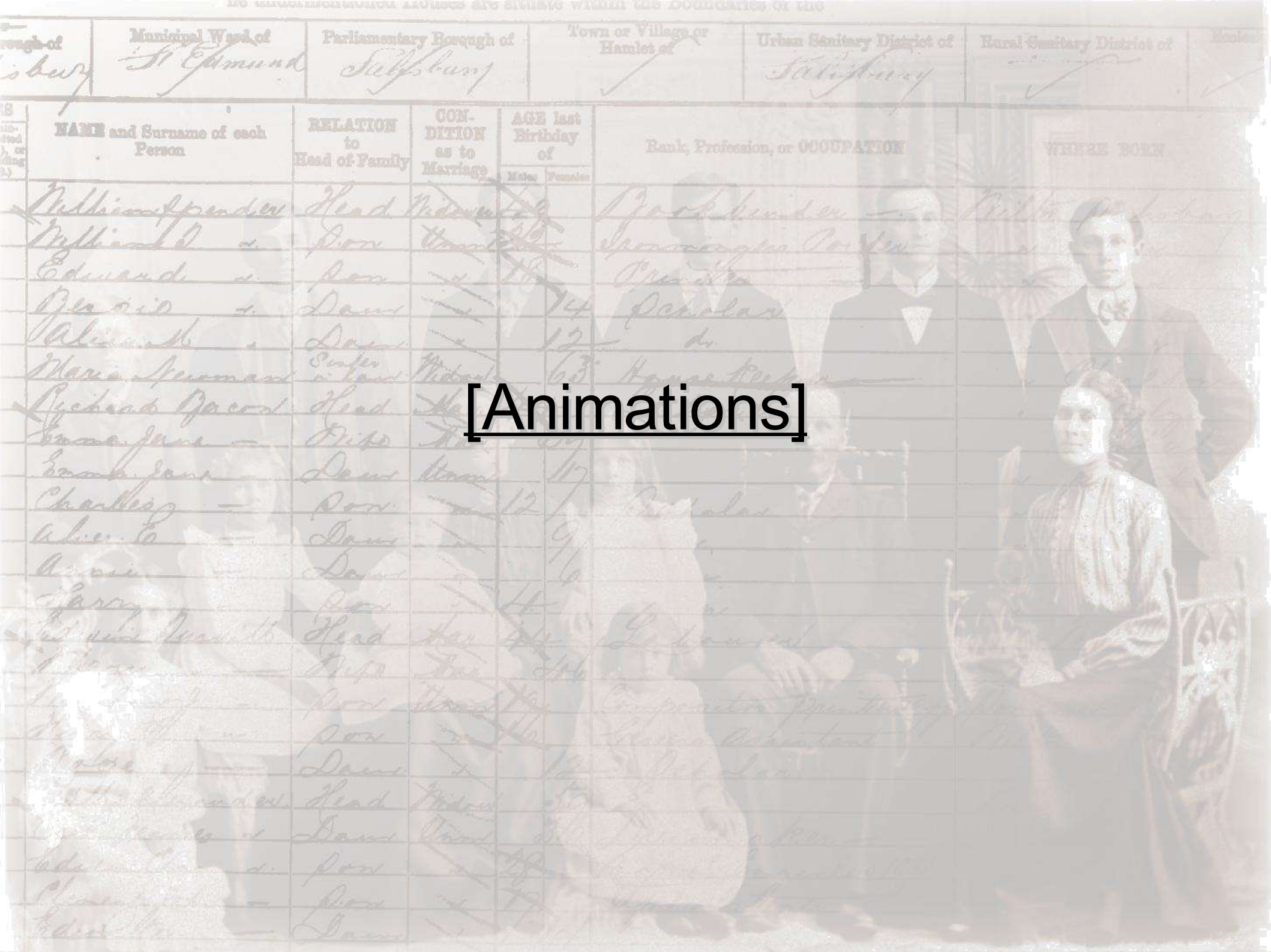
1 G Abraham/Fairbanks M

Document Image Registration



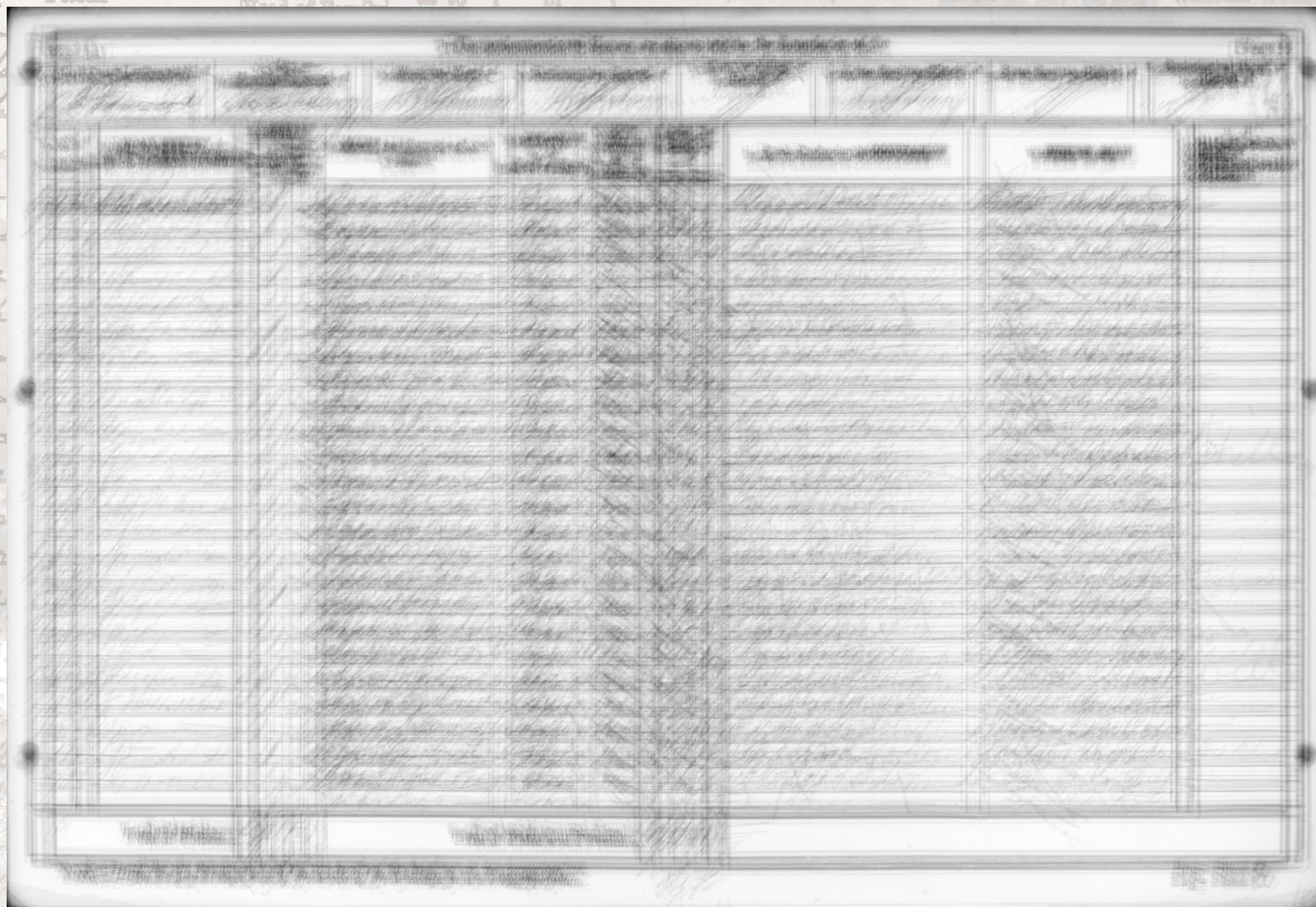
Rotation
Scale
Translation
Shear





Animations

Document Image Registration



Before registration (pointwise mean of 27 unregistered images)

Document Image Registration

Document Image Registration

Document Image Registration

Document Image Registration

Document Image Registration

Pointwise median of registered images, producing a blank form

NOTE.—Draw the pen through such of the words of the headings as are inappropriate.

Document Image Registration

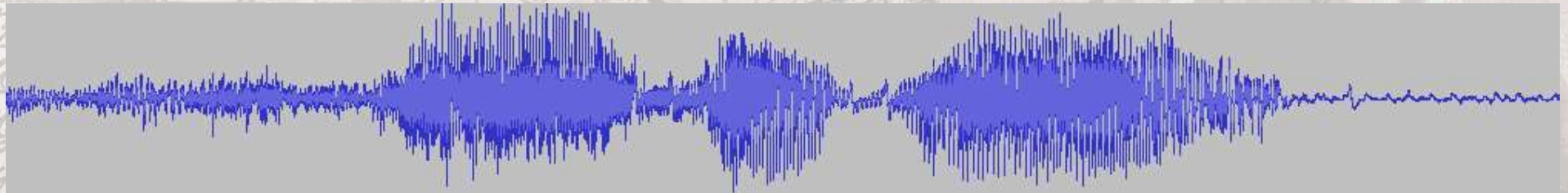
City or Municipal Borough of		Municipal Ward of	Parliamentary
Salisbury		St Edmund	Salisbury
HOUSES	Inhabited (U.) or Building (B.)	NAME and Surname of each Person	RELATION to Head of Family
1		James Parsons	Head
		Annie	Wife
		Alfred	Son
		Edith	Daughter
		Ernest	Son
		Elizabeth Harrington	Visitor

City or Municipal Borough of		Municipal Ward of	Parliamentary
Salisbury		St Edmund	Salisbury
HOUSES	Inhabited (U.) or Building (B.)	NAME and Surname of each Person	RELATION to Head of Family
1		James Parsons	Head
		Annie	Wife
		Alfred	Son
		Edith	Daughter
		Ernest	Son
		Elizabeth Harrington	Visitor

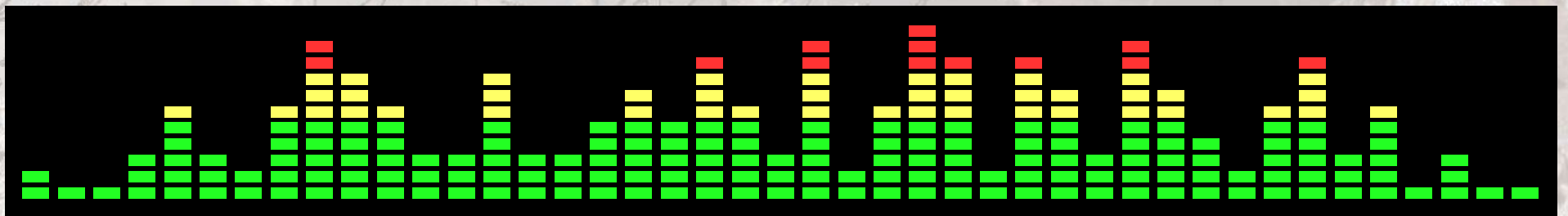
Predictive image compression by registration (14% reduction)

The Discrete Fourier Transform (DFT)

- Conversion from time domain to frequency domain



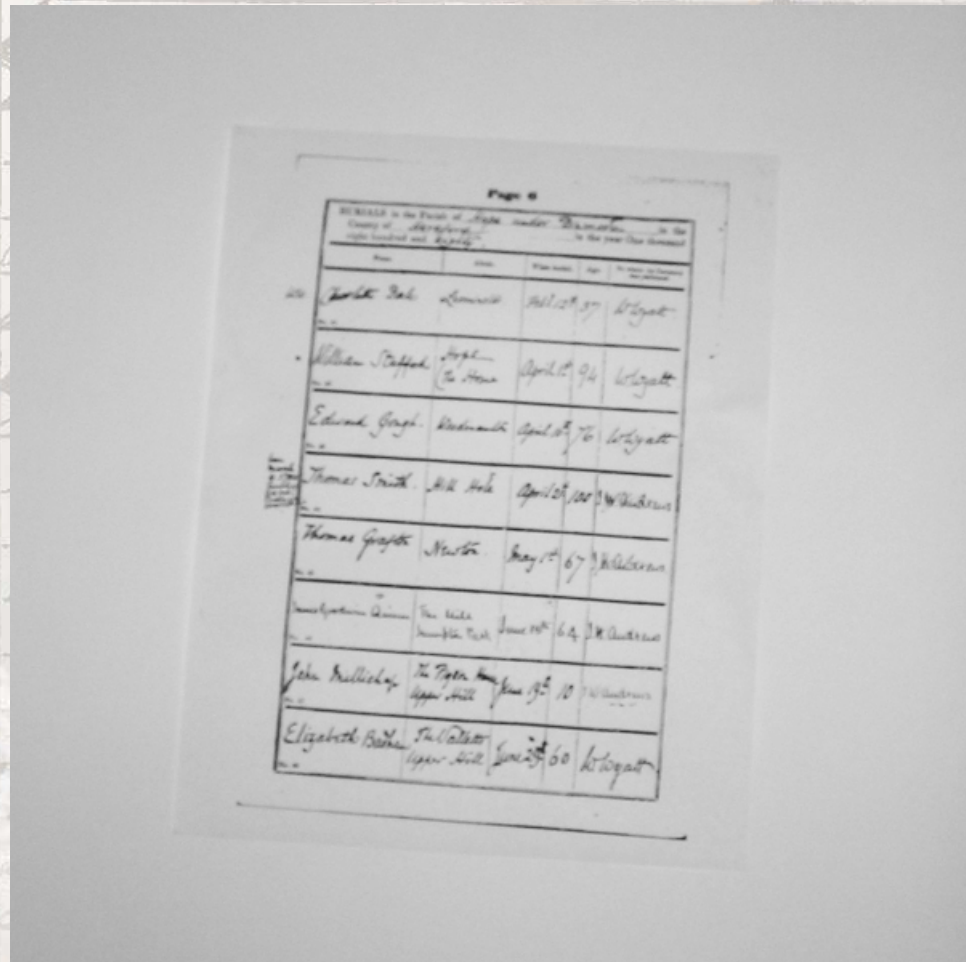
← Time →



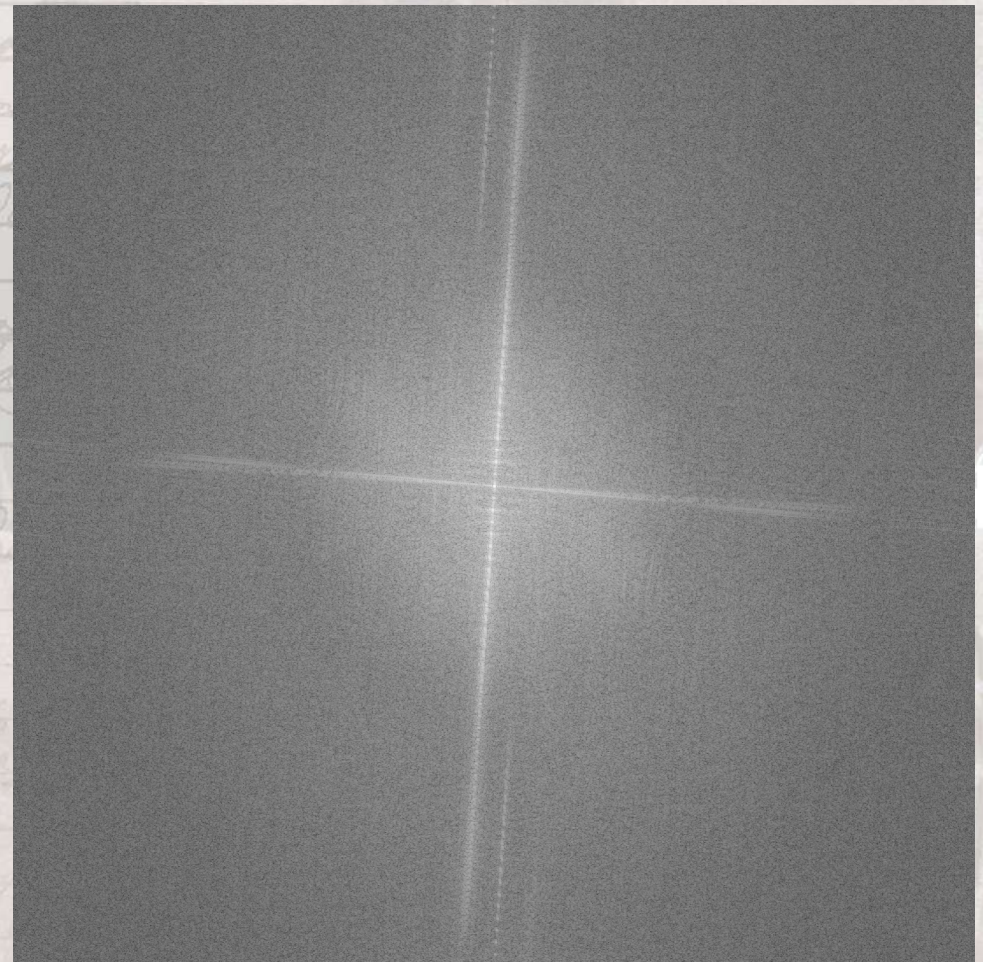
← Frequency →

- Can also perform DFT in 2 or more dimensions: breaks down spatially-distributed signal (e.g. image) into individual frequency components

The 2D DFT



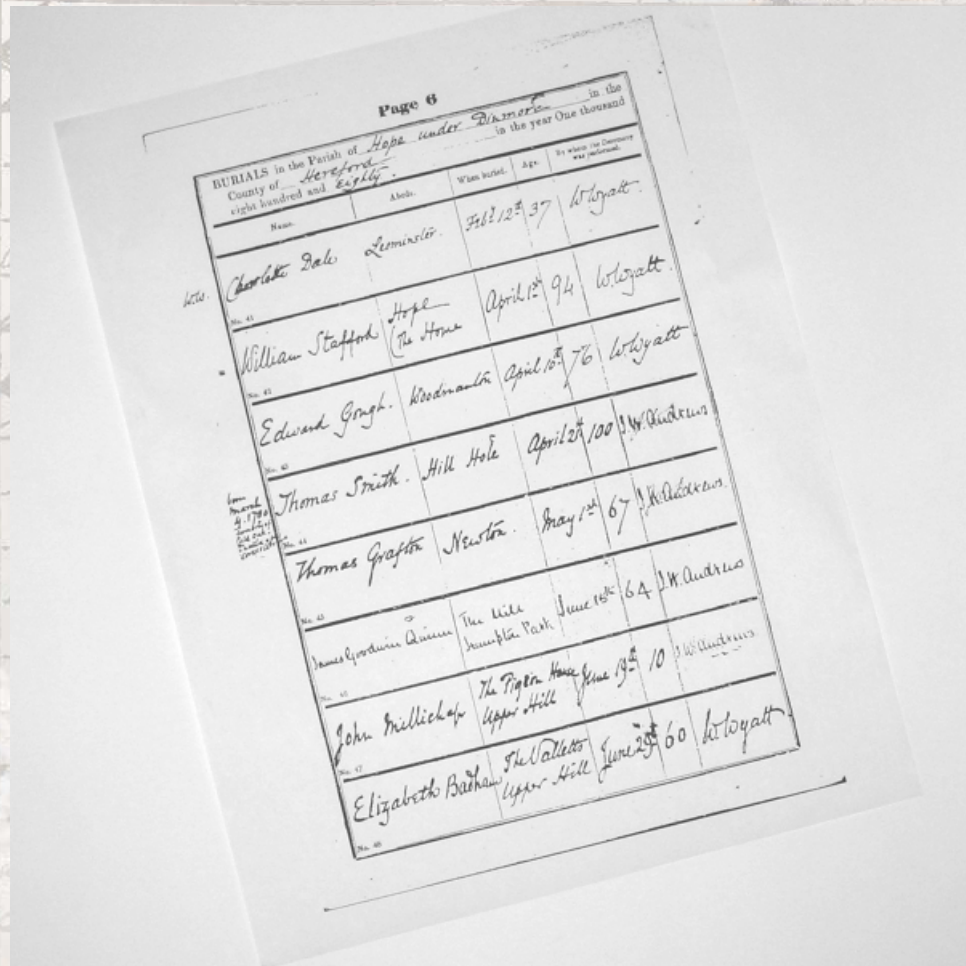
Document image



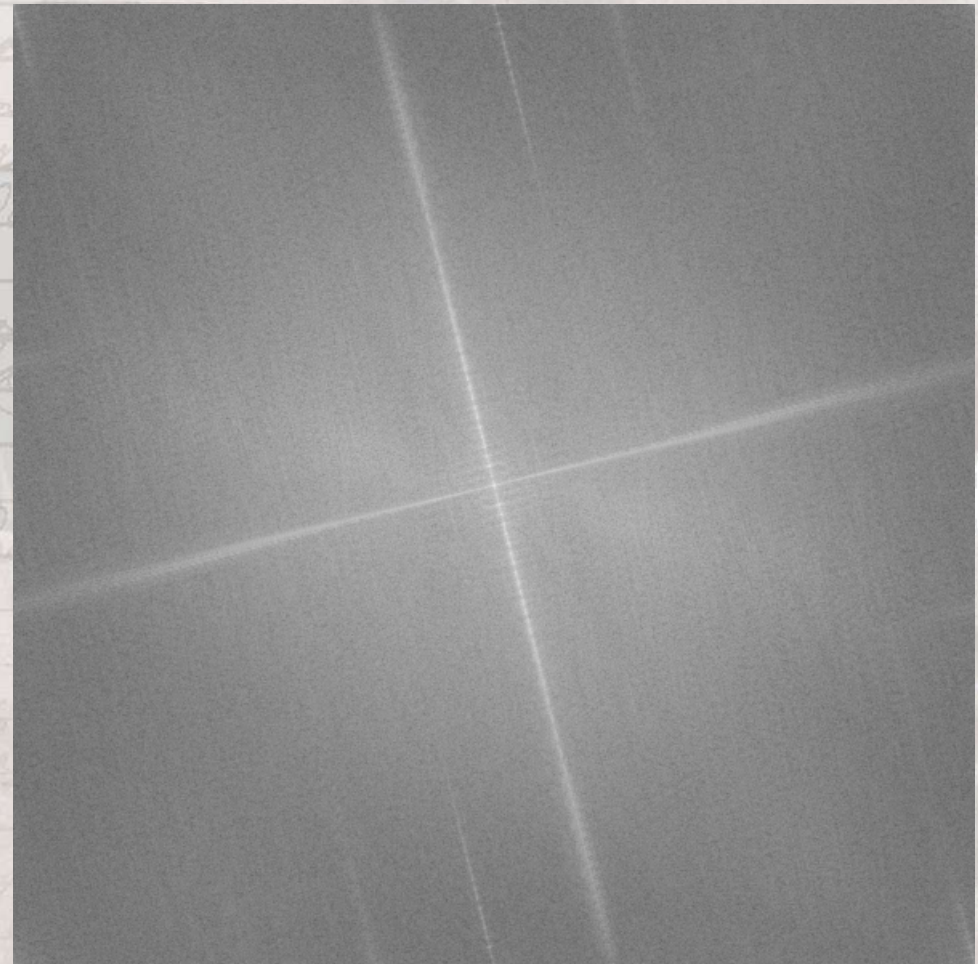
DFT of document image

- Sets of parallel lines act as periodic “wavefronts”

The 2D DFT



Document image



DFT of document image

- Sets of parallel lines act as periodic “wavefronts”

The Mellin Transform

- A function is sampled at exponential intervals to produce a log-domain representation

$$\phi(z) = \int_0^{\infty} t^{z-1} f(t) dt$$

- Scaling a function by a factor of S results in a shift in the Mellin transform by $\log(S)$:

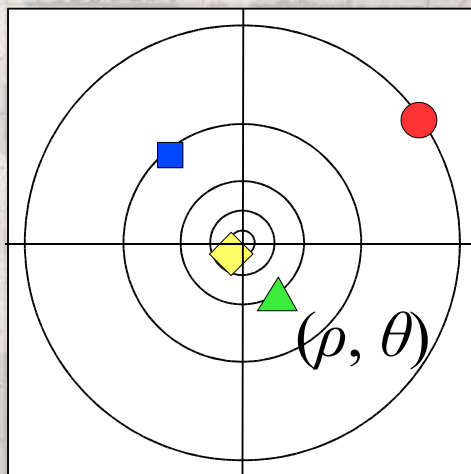
$$x' = x \cdot S$$

$$\log(x') = \log(x) + \log(S)$$

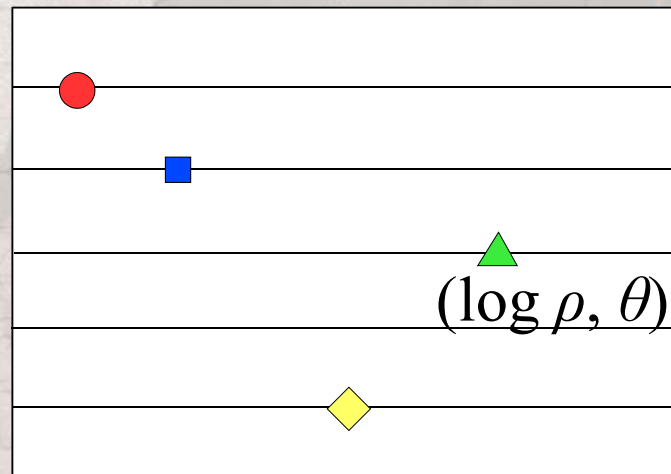
The Fourier-Mellin Transform

= The Mellin transform of the Fourier transform of a signal (or image)

DFT of image

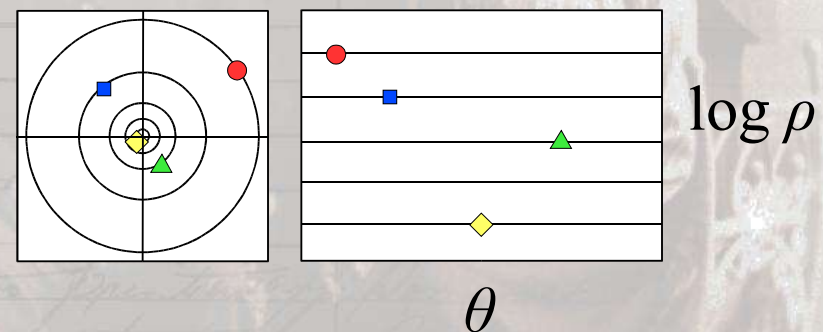


FMT of image



Fourier-Mellin Transform for Image Registration

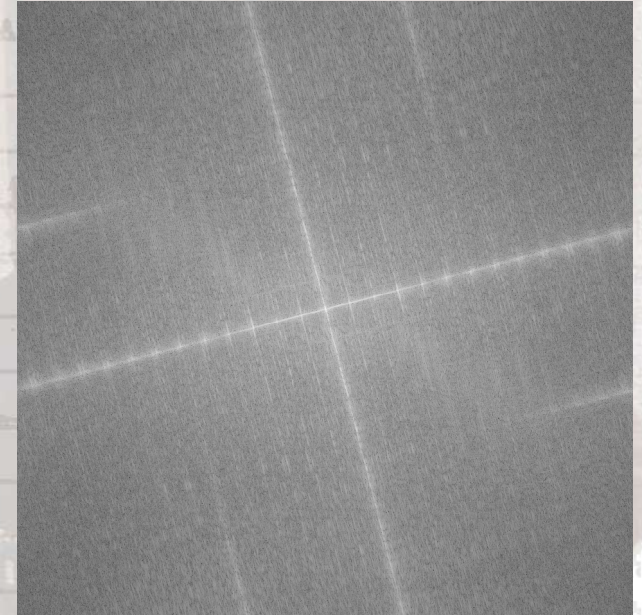
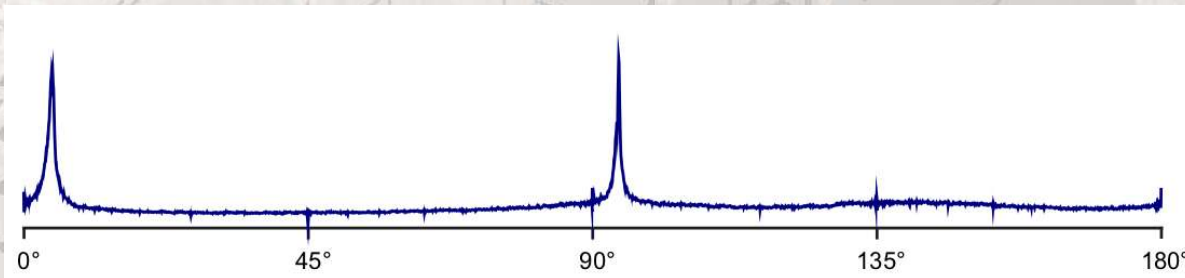
- Fourier Shift Theorem $\Rightarrow$ ignore translation when dealing with magnitudes
- Mellin Transform of DFT used for registration
 - $(\log \rho, \theta)$ histogram: Recovery of scale, rotation is a 2D correlation problem



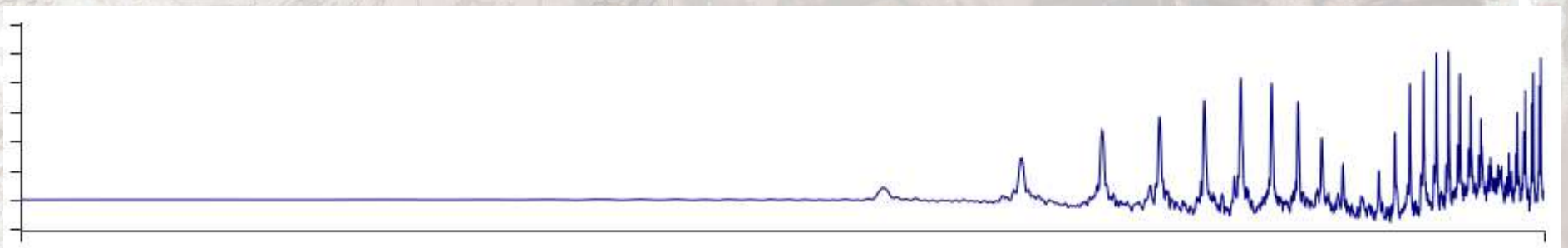
- Several issues, e.g.
 - Rotationally-dependent aliasing
 - “Edge Effects” (rotation and periodicity don't commute)

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



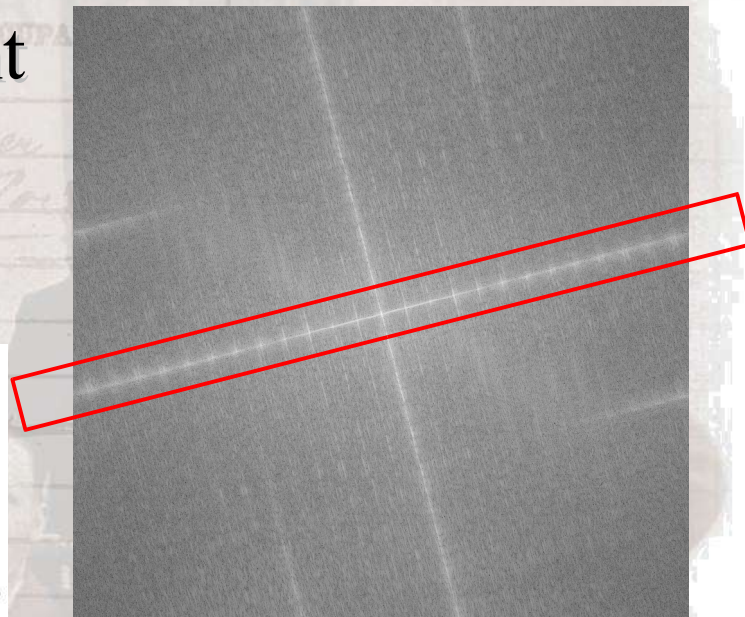
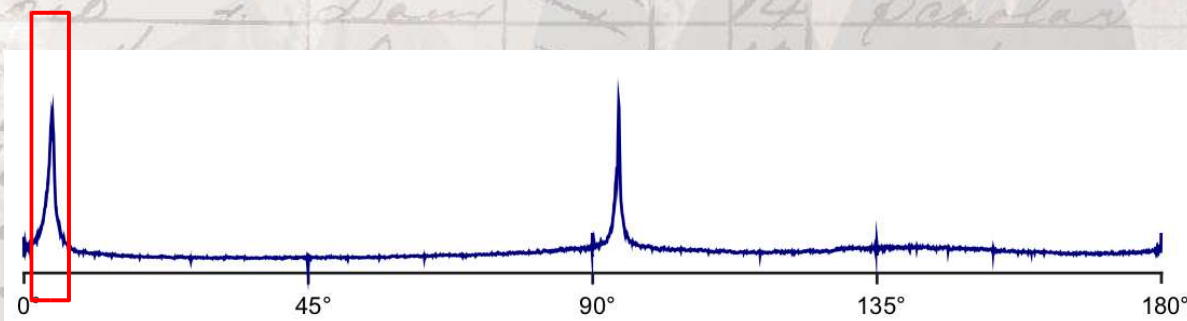
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



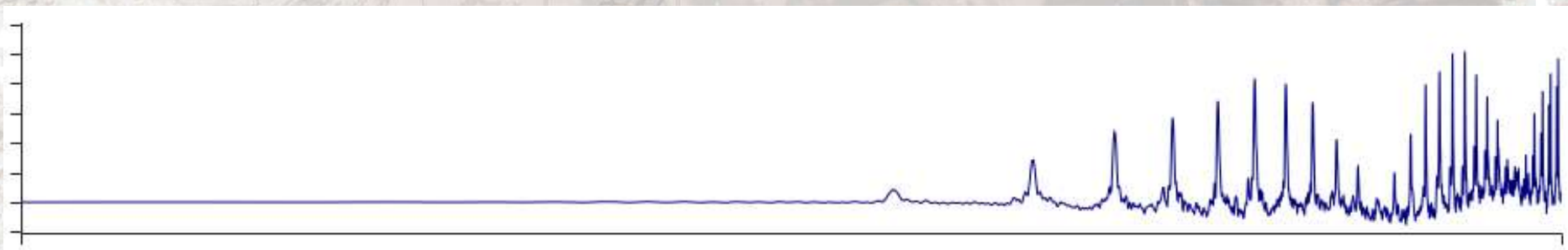
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



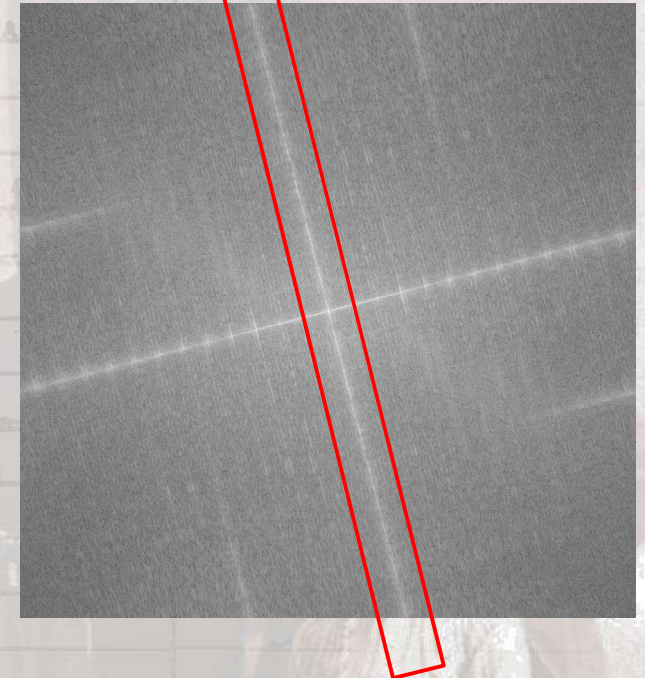
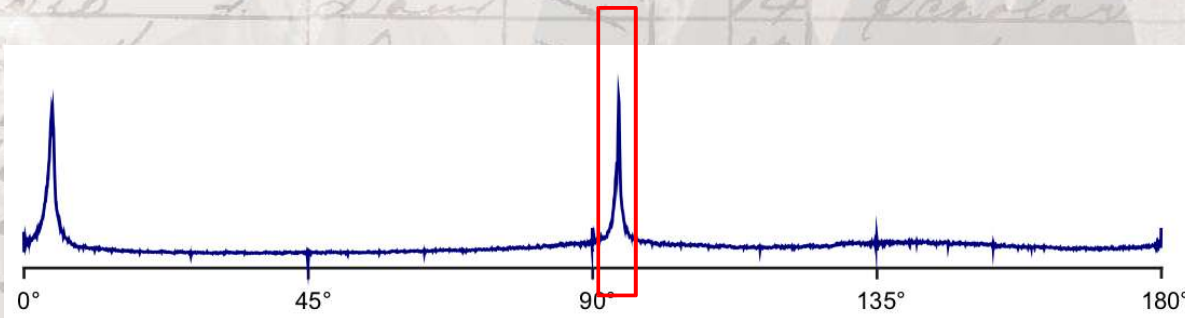
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



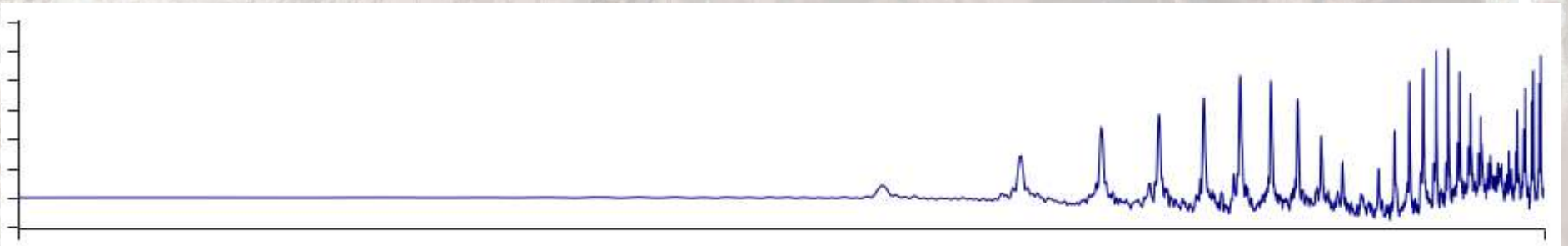
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



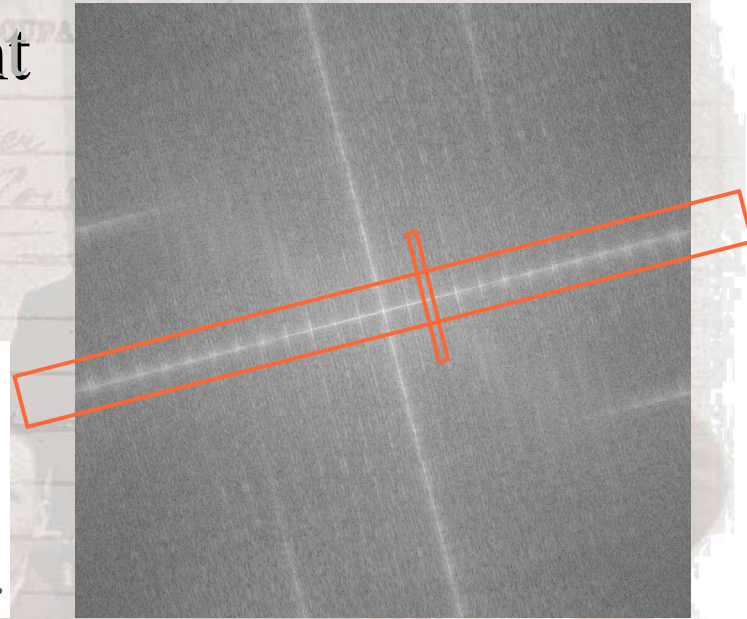
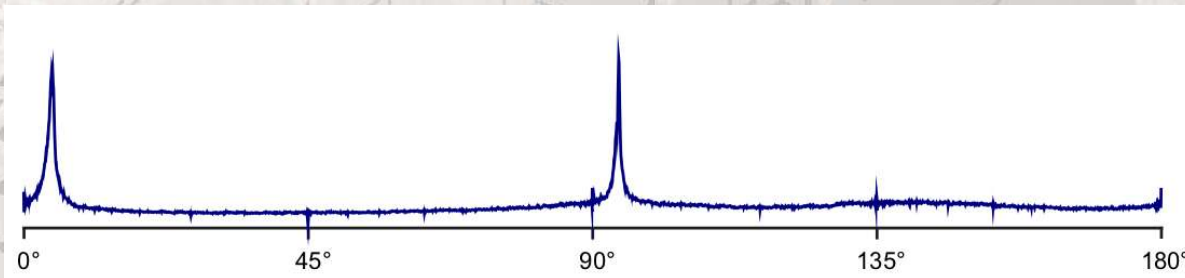
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



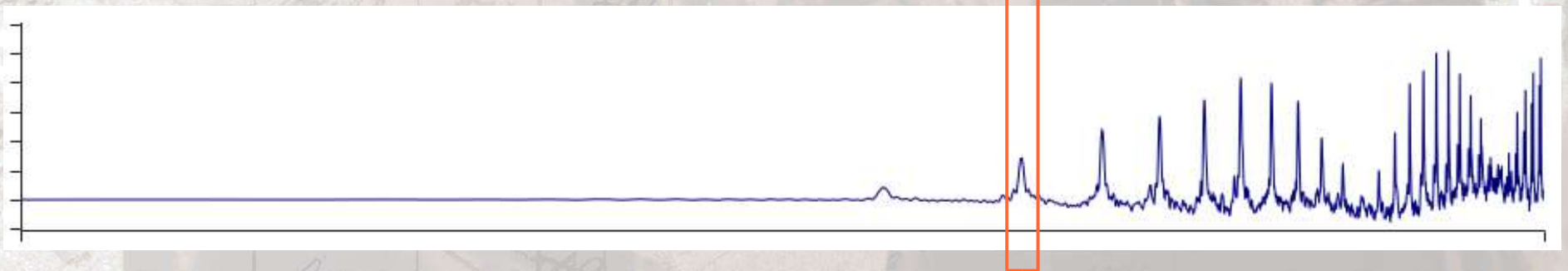
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



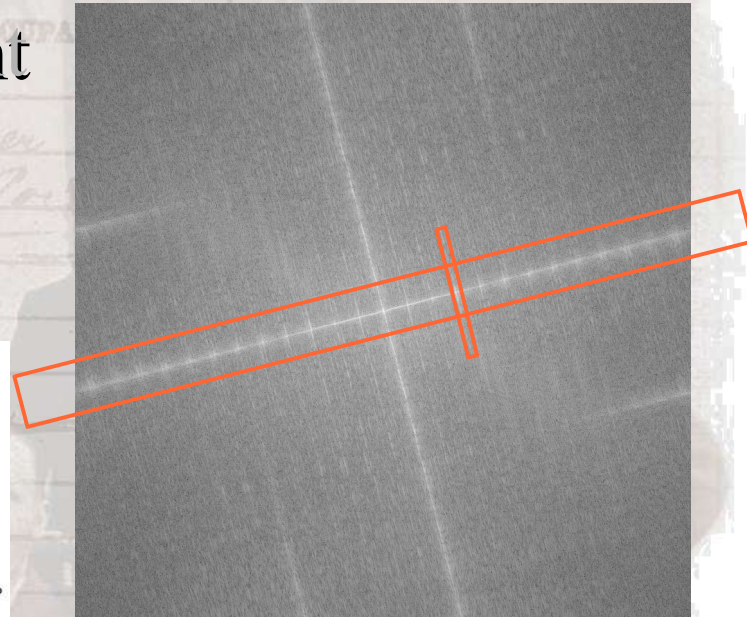
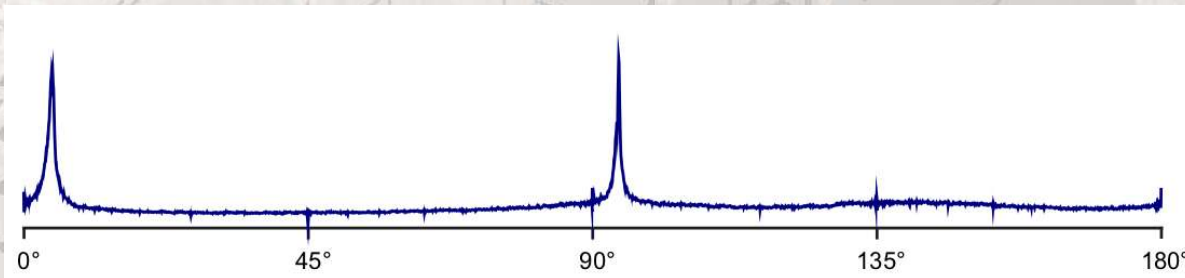
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



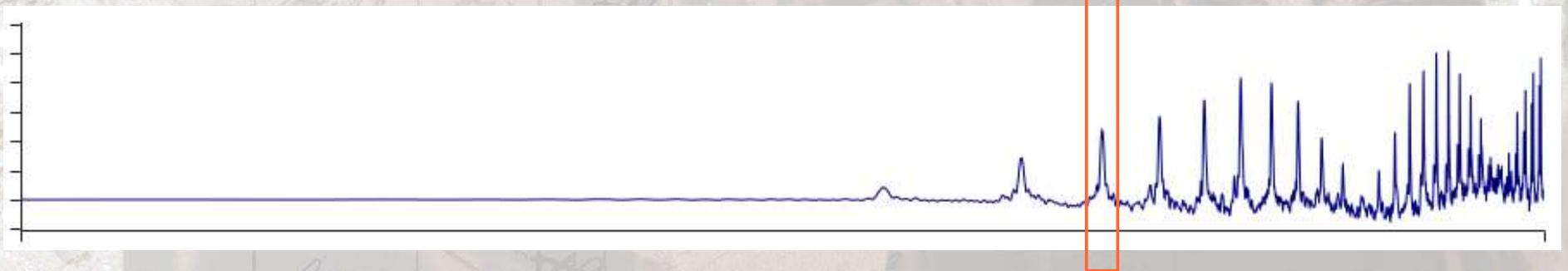
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



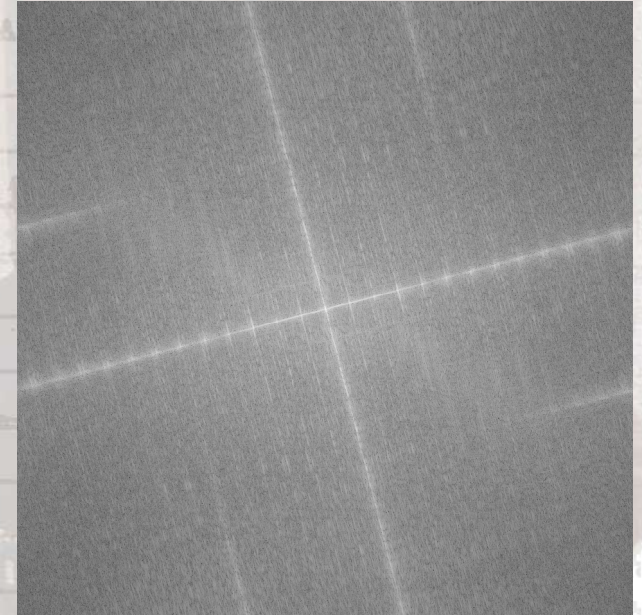
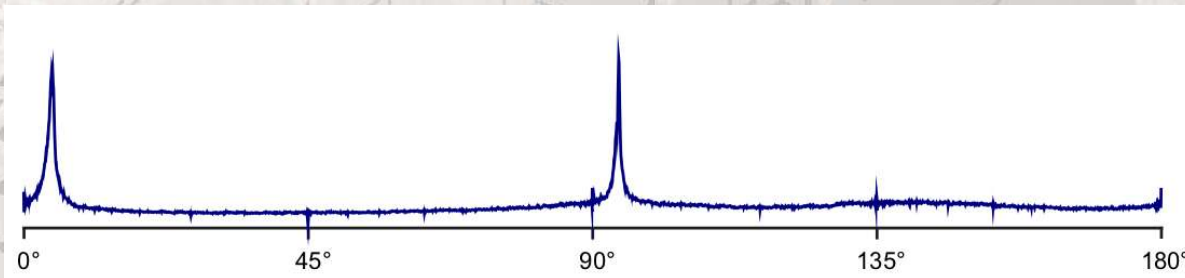
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



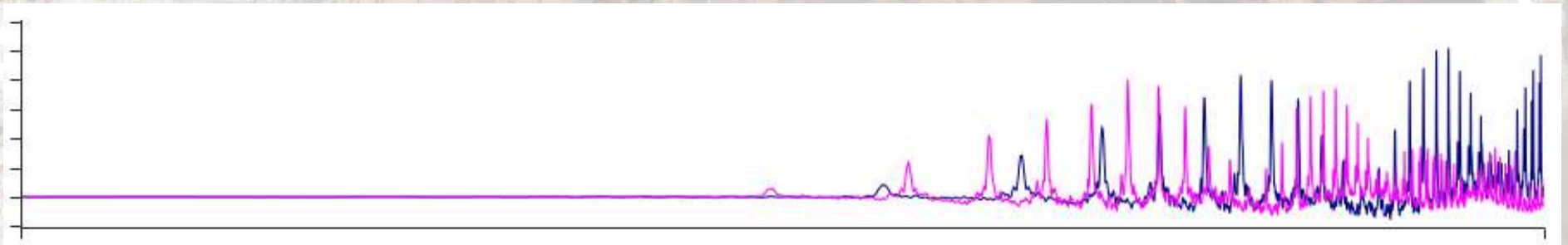
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



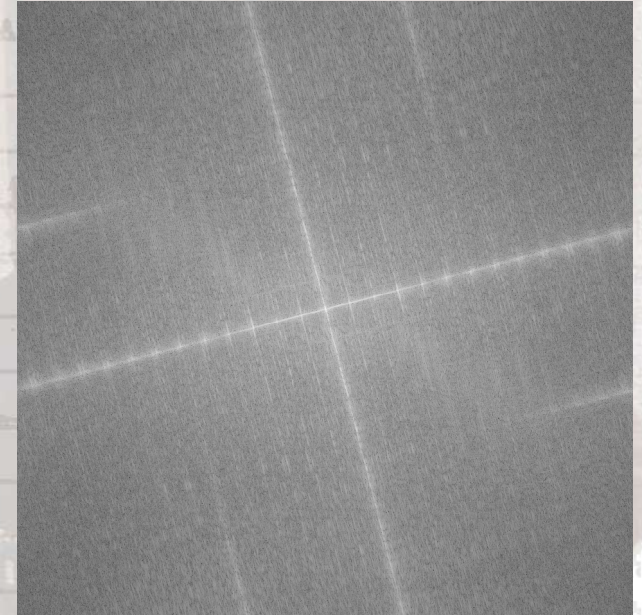
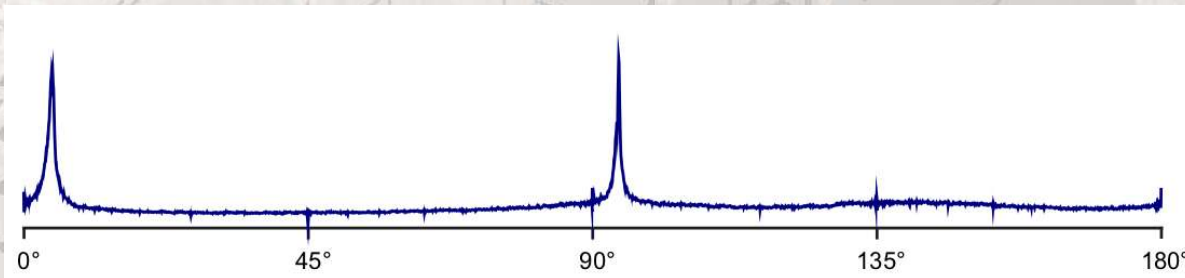
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



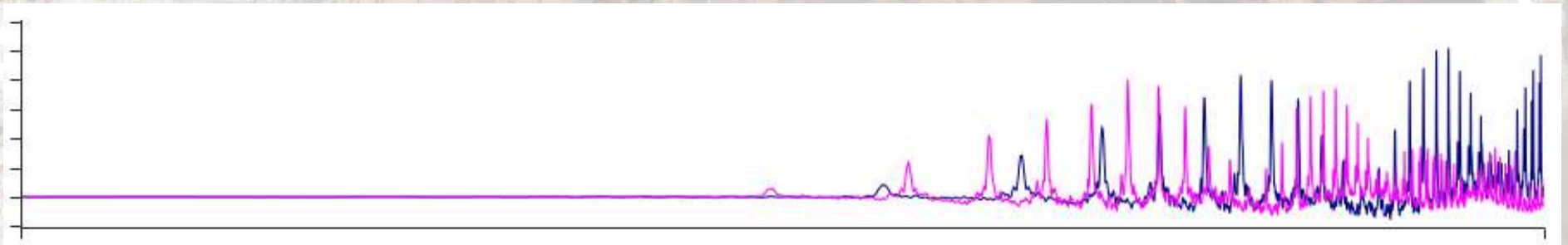
- Translation: Simple 2D correlation – needs bg removal

Parameter Recovery

- Rotation [+ *shear*]: Recover document axes by finding two largest peaks in radial projection histogram



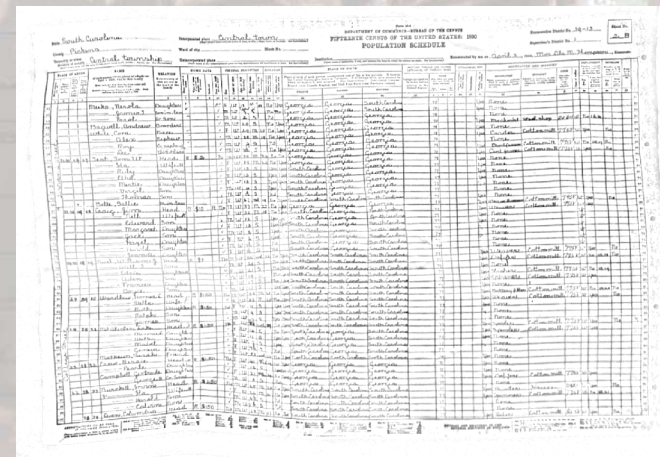
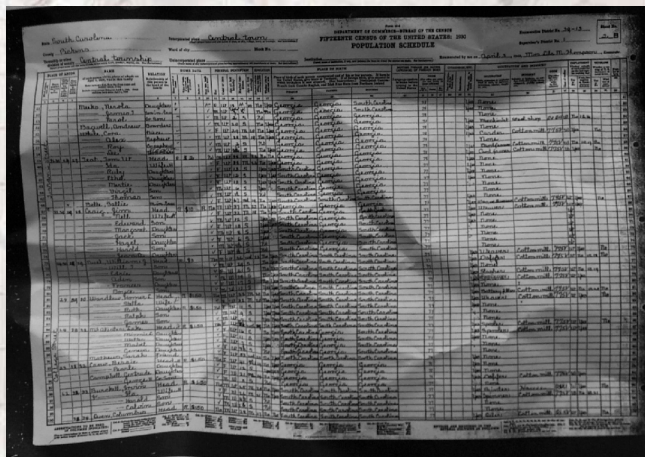
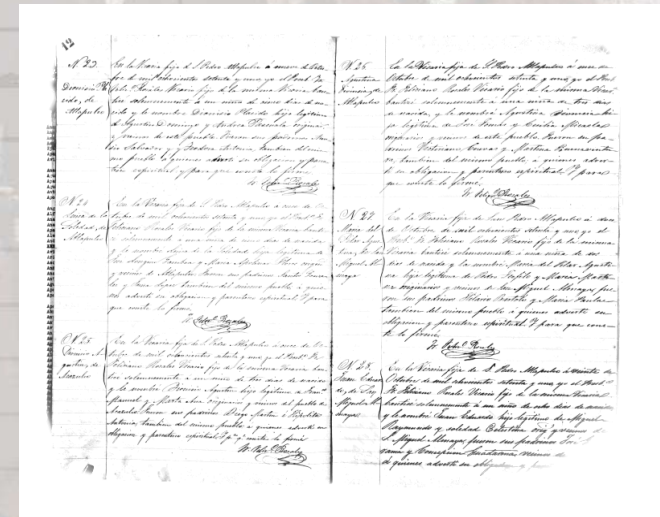
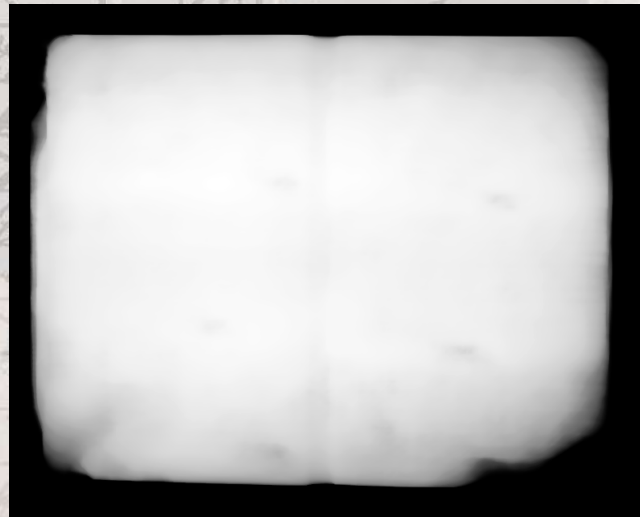
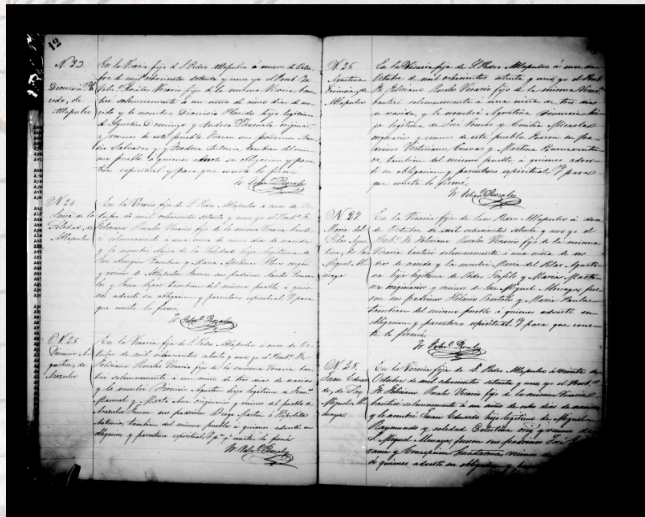
- Scale: Sample along recovered axes at exponential intervals; offset of best 1D correlation gives $\log(\text{scale})$



- Translation: Simple 2D correlation – needs bg removal

Preprocessing: Automatic Background Removal

- Subtract median-filtered image from original, leaving only fine features
- Removes shading *and* black borders



F-M Transform: Edge Effects

- DFT assumes domain wraps; wrapping does not commute with rotation

Station

by the Marshal of the Northern District (or Territory) of Alabama

FREE COLORED PERSONS

SLAVES

MALES

FEMALES

Color

Age

Under 10

10 to 20

20 to 30

30 to 40

40 to 50

50 to 60

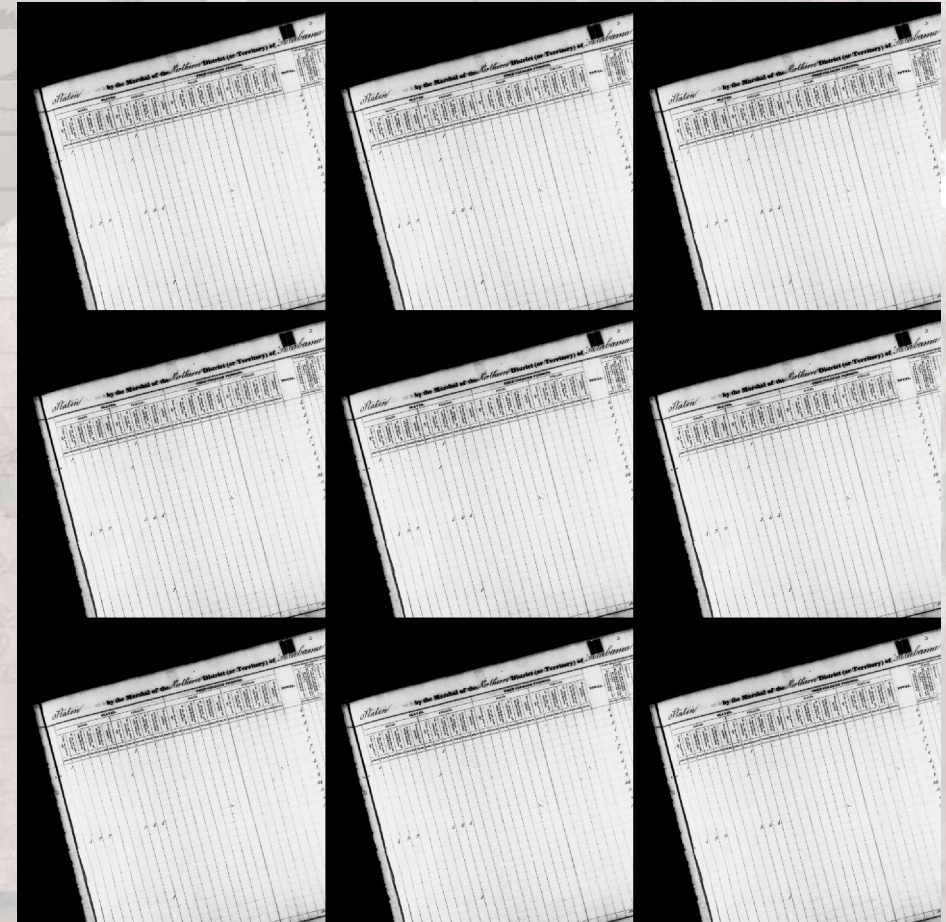
60 to 70

70 to 80

80 to 90

90 to 100

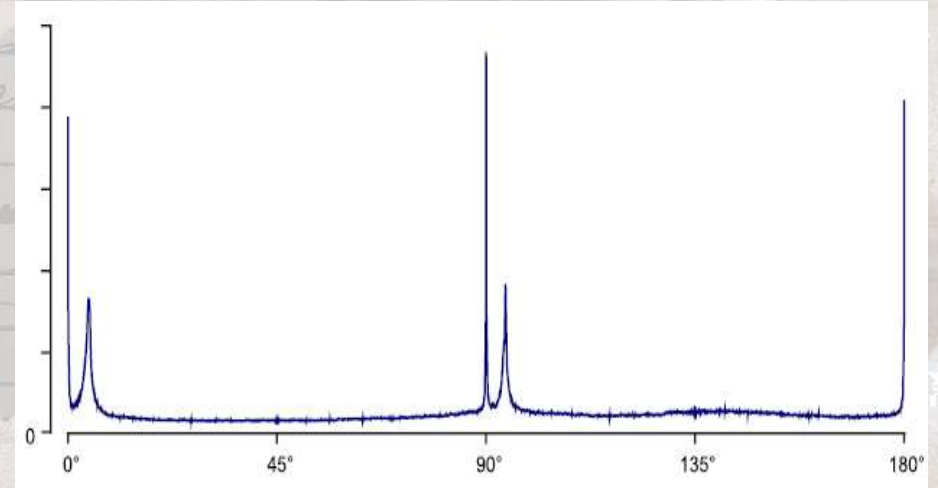
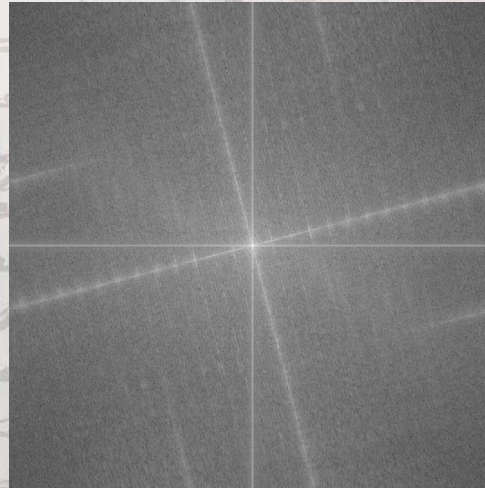
TOTAL



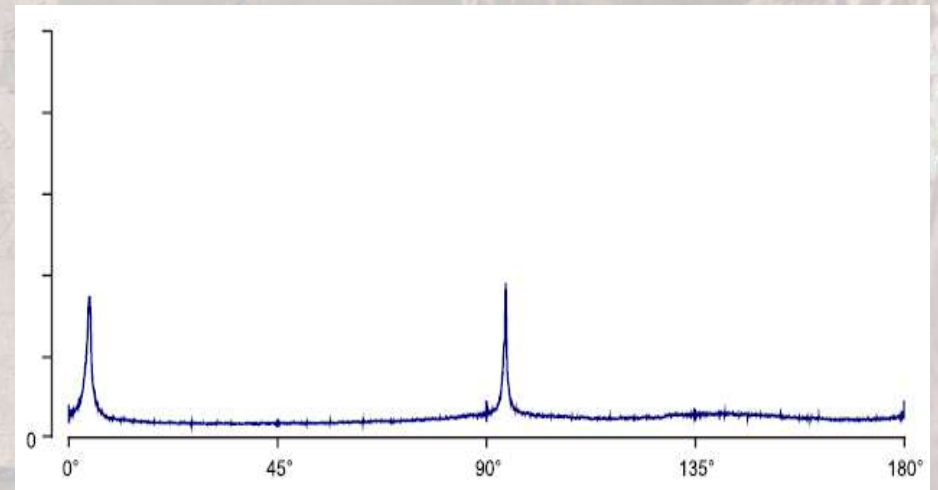
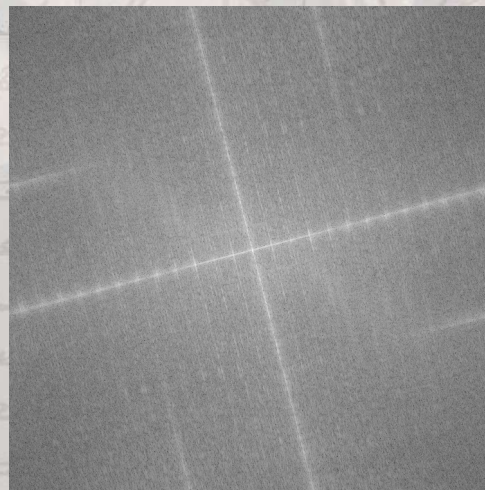
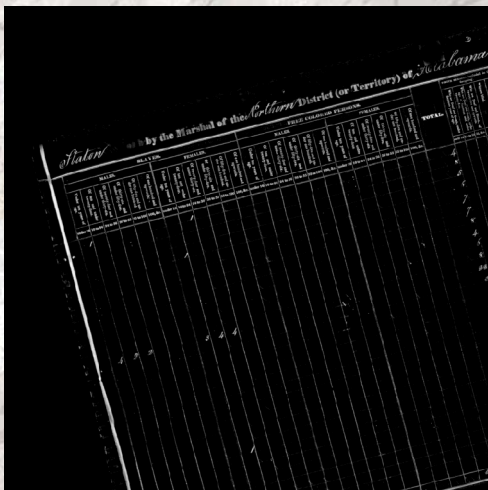
F-M Transform: Edge Effects

Background removal eliminates the need for apodization

Without background removal:

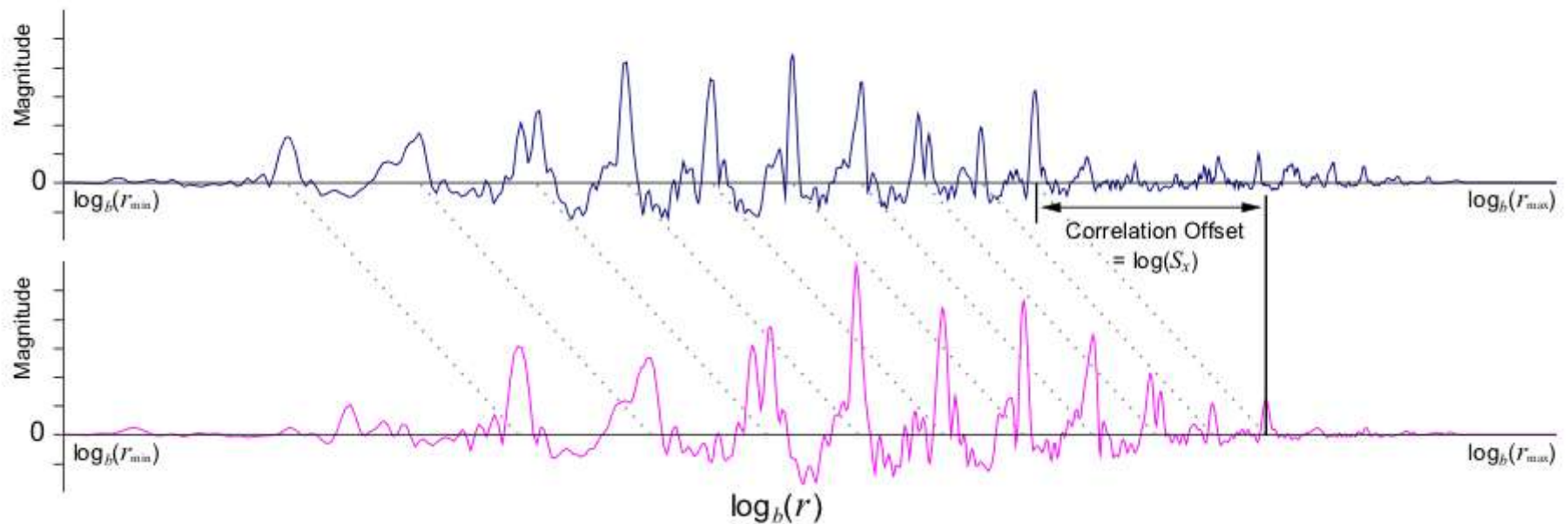


With background removal:

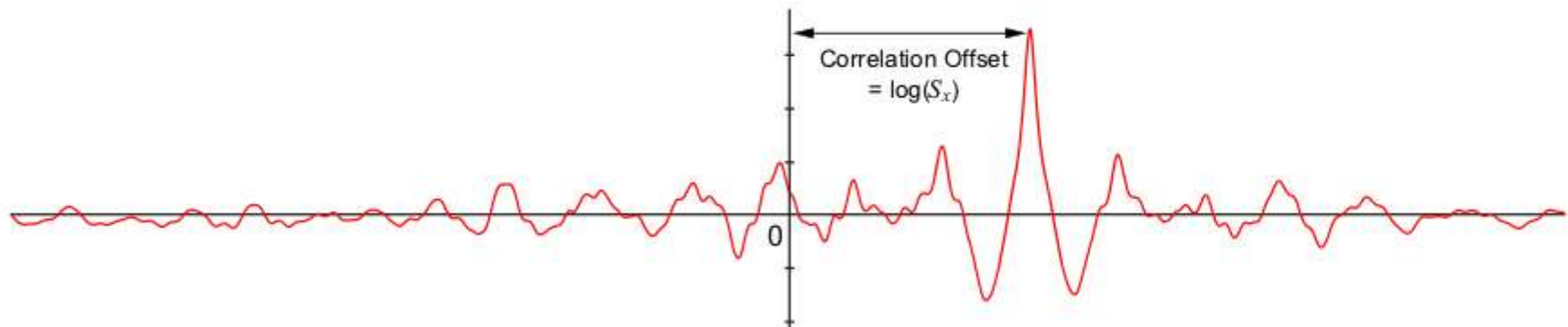


Scale Recovery – Example

Log- r Histogram of x -Axis in DFT (For Two Images)



x -Axis Correlation Result



RMS Error

(100 Different Transformation Reversals of the Same Image)

Rotation / Shear: 0.001°

Scale: 0.030 %

Translation: 0.16 pixels

Conclusions

- Specialization of Fourier-Mellin image registration for tabular document images
- Each transform component is completely separable, and recovered in the frequency domain
- F-M registration extended to handle arbitrary affine transforms (including shear)
- Elimination of edge effects and correlation problems through median filter background removal algorithm

Questions?

THIS IS A
LEGAL
RECORD AND
WILL BE PER-
MANENTLY
FILED

SEE OTHER
SIDE

FILL IN
WITH A
TYPEWRITER
OR WRITE
PLAINLY
WITH DARK
INK. DO NOT
USE GREEN
NOR RED INK.
LEGAL COPIES
CANNOT BE
MADE IF
ENTRIES
ARE DIM

ALL ITEMS
MUST BE
COMPLETE
AND
ACCURATE

IF NO DOCTOR
WAS IN
ATTENDANCE
MEDICAL CER-
TIFICATION
SHOULD BE
COMPLETED
BY THE LOCAL
HEALTH
OFFICER, OR
CORONER IF
HE IS A
PHYSICIAN OR
IF INQUEST
WAS HELD

CERTIFICATE OF DEATH STATE OF ALABAMA

1. PLACE OF DEATH a. County		b. Beat No.		2. USUAL RESIDENCE (Where deceased lived. If institution; resi- dence before admission).			
c. City (If outside city or town limits, write RURAL) Or Town		d. Length of Stay (in this place)		e. State		f. County	
3. Full Name of (If not in hospital or institution, give street address Hospital Or Institution)				d. Street Address (If rural, give location)			
3. Name Of DECEASED (Type or Print)		a. (First)		b. (Middle)		c. (Last)	
5. Sex		6. Color or Race		7. Married, Never Married, Widowed, Divorced (Specify)		8. Date of Birth	
10a. Usual Occupation (Give kind of work done during most of working life, even if retired)		10b. Kind of Business or Industry		9. Age (In years last birthday)		11. Birthplace (State and county or foreign country)	
13. Father's Name		14. Mother's Maiden Name		12. Citizen of What Country?		15. Was Deceased Ever in U. S. Armed Forces? (If yes, give war and dates of service)	
16. Social Security No.		17. Informant's Name and Address		18. Cause of Death Enter only one cause per line for (a), (b), and (c)		MEDICAL CERTIFICATION	
This does not mean the mode of dying, such as heart failure, as- thma, etc. It means the disease, injury, or complica- tion which caused death.		I. Disease or Condition Directly Leading to Death (a)		Interval Between Onset and Death			
Antecedent Causes Morbidity conditions, if any, giving rise to the above cause (a) stating the underlying cause last.		Due To (b)					
		Due To (c)					
II. Other Significant Conditions Conditions contributing to death but not related to the disease or condition causing death.		19a. Date of Operation		19b. Major Findings of Operation		20. Autopsy? Yes [] No []	
21a. Accident Suicide, Homicide (Specify)		21b. Place of Injury (Home, Farm, Factory, Street, Office, Shop, etc.)		21c. (City, Town, or Rural) (County) (State)			
21d. Time (Month) (Day) (Year) (Hour) of Injury		21e. Injury Occurred While at Not While m. Work [] at Work []		21f. How Did Injury Occur?			
22. I hereby certify that I attended the deceased from _____, 19____, to _____, 19____, that I last saw the deceased alive on _____, 19____, and that death occurred at _____ from the causes and on the date stated above.							
23a. SIGNATURE (Degree or Title)		23b. Address		23c. Date Signed			
24a. Burial, Crema- tion, Removal (Specify)		24b. Date		24c. Name of Cemetery or Crematory		24d. Location (City, town, or county) (State)	
Date Rec'd by Local Dep.		Registrar's Signature		25. Funeral Director		Address	

VS-2-100M

ALABAMA DEPARTMENT OF HEALTH AND PUBLIC SAFETY IN COOPERATION

(445 images, registered)

Pointwise Mean, Median, Percentile

[illegible]

Pointwise mean

The undermentioned Houses are situate within the Boundaries of the									
Civil Parish (or Township) of	City or Municipal Borough of	Municipal Ward of	Parliamentary Borough of	Town or Village or Hamlet of	Urban Sanitary District of	Rural Sanitary District of	Recreation Ground or District of		
No. of Inhabitants	ROAD, STREET, &c., and No. or NAME of HOUSE	HOUSE No. in the City or Municipal Borough	NAME and Surname of each Person	RELATION Head of Family	CON- DITION as to Marriage	AGE last Birthday	Race, Profession, or OCCUPATION	WHERE BORN	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 79

Pointwise median

Page 12		The undermentioned Houses are situated within the boundaries of the							Page 13	
Civil Parish (Parish) of	City or Municipal Borough of	Municipal Ward of	Parliamentary Borough of	Village or Village or Hamlet of	Urban Sanitary District of	Rural Sanitary District of	Residential Parish or District of	H		
of	of	of	of	of	of	of	of	1	2	3
No. of Inhabitants	ROAD STREET, No. and No. or NAME of HOUSE	NUMBER of HOUSES in the Ward	NAME and Surnames of each Person	RELATION of each Person to Head of Family	SEX of each Person	AGE last Birthday of each Person	Rank, Profession, or OCCUPATION of each Person	WEAR SORE	1	2
									1	2
116	46	1	James	Head	M	30	Labourer			
			James	Wife	F	28				
			James	Son	M	5				
			James	Daughter	F	4				
			James	Son	M	3				
			James	Daughter	F	2				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				
			James	Son	M	1				
			James	Daughter	F	1				

Pointwise 30th Percentile

[illegible]

Pointwise 70th Percentile

Apodization

Attenuation to zero at the edge of the image, to reduce sharp transitions on wrapping

[illegible][illegible]