My Text in Your Handwriting

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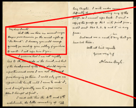
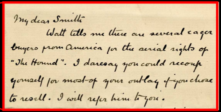
Problem

- To synthesis *user specified text* with a *specific authors handwriting*.
- To a standard that can fool human beings.
- This is guided texture synthesis.

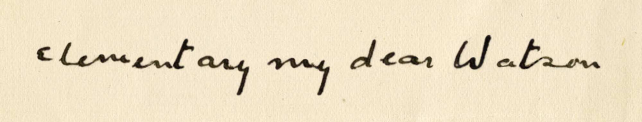


Original letter



My dear Smith
Walt tells me there are several eager buyers from America for the serial rights of "The Hound". I daresay you could recoup yourself for most of your outlay if you chose to resell. I will refer him to you.

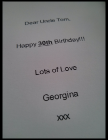
Tagged paragraph



elementary my dear Watson

Synthesised Result (Arthur Conan Doyle)

Why?



Dear Uncle Tom,

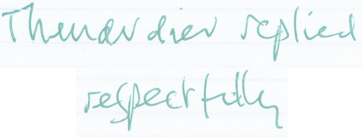
Happy **30th** Birthday!!!

Lots of Love

Georgina

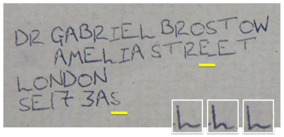
xxx

Gift cards/flowers sent without the giver present (e.g. via Amazon). Either use handwriting model of giver or a celebrities.



Thenardier replied respectfully

Synthesise handwriting when a disability affects writing. Build model with pre-disability samples.



DR GABRIEL BROSTOW
AMELIA STREET
LONDON
SE17 3AS

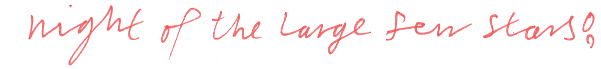
Camouflaging important documents in the mail, such as bank cards.

--NOW FAN OUT--YOU'RE LEAVING YOURSELVES WIDE OP
HHKKK
The slightest dose of Anaconda on the darts-- enough to put a man to sleep--

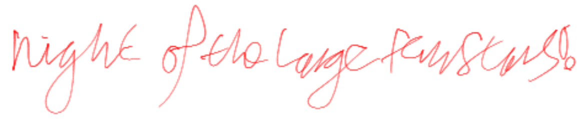
Artistic purposes, such as comic book lettering. Computer games in particular can contain large quantities of text.

The Problem With Graphics Tablets

- Almost all previous methods use graphics tablets for input.
- Distorts the authors handwriting – like a whiteboard.



Real

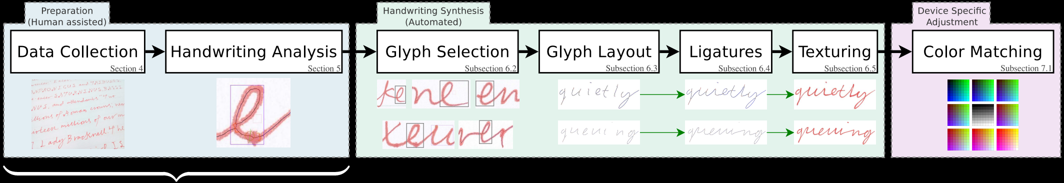


Tablet

(Written by an experienced tablet user)

- Has advantage of actual pen path, but disadvantage of no texture.
- Can't use historical writing.
- Does not satisfy use cases – we therefore scan normal writing on normal paper.

Preparation Overview



Preparation (Human assisted)

Data Collection Section 4 → Handwriting Analysis Section 5

Handwriting Synthesis (Automated)

→ Glyph Selection Subsection 6.2 → Glyph Layout Subsection 6.3 → Ligatures Subsection 6.4 → Texturing Subsection 6.5

Device Specific Adjustment

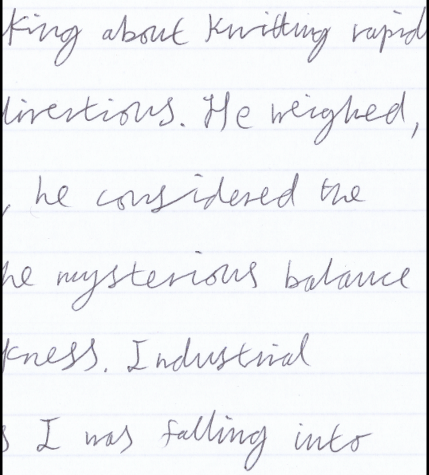
→ Color Matching Subsection 7.1

- Input:
  - A willing *author*.

    or
  - Examples of an *author*s handwriting.
- Output:
  - An authors *tagged handwriting*.

Data Collection

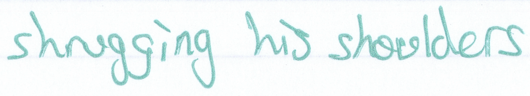
- Author unavailable → Scan in whatever is available.
- Author available → Get them to write out a sample:
  - We can optimise! Maximise coverage for number of words written.
  - Use proper sentences – unfamiliarity changes a persons writing.
  - Select them to minimise extended Scrabble scores.
  - Need a corpus (sentences and statistics) – top 100 books from Project Gutenberg.



king about knitting rapid
irections. He weighed,
, he considered the
he mysterious balance
kness. Industrial
s I was falling into

Extended Scrabble Scores

- Scrabble score: $\sim\propto$ number bits required to encode each letter (Shannon entropy).
  - Original statistics from front page of *The New Your Times* – we use statistics from Project Gutenberg corpus.
  - We don't quantise.
- Extended to also include pairwise statistics – how people write a letter is influenced by the letters position relative to others (even if print, and especially start/end of word).



shrugging his shoulders

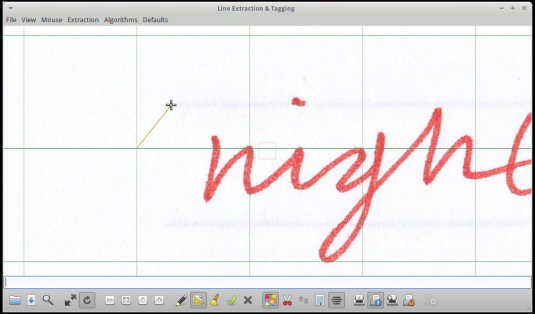
- Extended to consider sentences already selected, so we get variety.

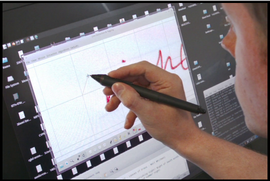
Analysis

- We need to obtain information about scanned handwriting sample:
  - The Rule.
  - Segmentation.
  - Alpha Matting.
  - Spline Fitting.
  - Glyphs / Ligatures.
- We automate as much as reasonable, but allow human intervention.

The Rule

- Rule – line on which the author is writing on.
- On back of page so barely visible in scan (if author available).
- User click-drags to set a homography.
- Not worth automating.



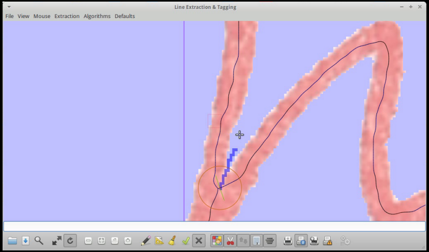


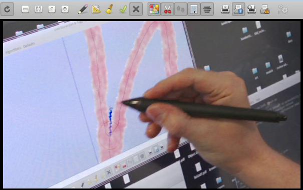
Segmentation

Separate ink line from background:

1. Use mean shift on RGB cube:
   - Largest mode is background colour.
   - Second largest mode is ink colour.
   - Remaining modes are ignored.
2. Perform graph cuts:
   - Unary term from mean shift.
   - Pairwise term from colour difference.
3. Finally, perform a line aware smoothing.
   - Convert mask to signed distance function.
   - Calculate gradient at each pixel.
   - Smooth in gradient direction only.

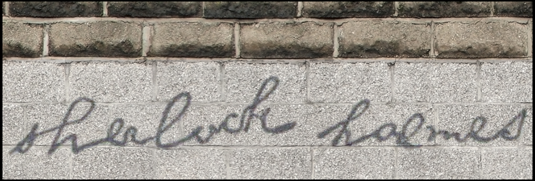
User can force pixels to be foreground/background.





Alpha Matting

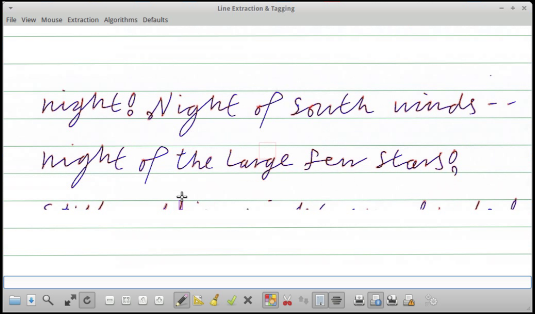
- Need to composite output onto arbitrary backgrounds.
- Use segmentation and inpainting to generate a background-only plate.
- Solve matting equation per-pixel to obtain base colour with alpha channel.
- Automatic only.



(Arthur Conan Doyle's handwriting)

Spline Fitting

- Thin mask to extract line.
- Assign radius as largest circle that fits within mask at each pixel on the line.
- Assign density as mean unary term from segmentation within radius.
- Automatic only.


Line Extraction & Tagging
File View Mouse Extraction Algorithms Defaults

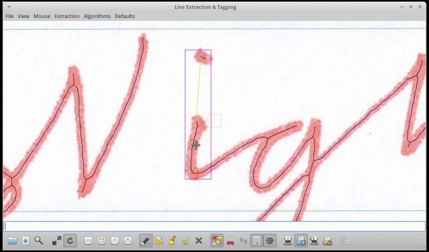
night! Night of South winds - -

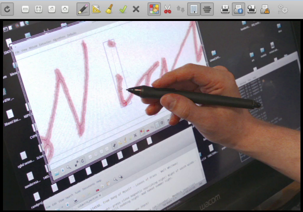
night of the Large Few Stars!

Glyphs / Ligatures

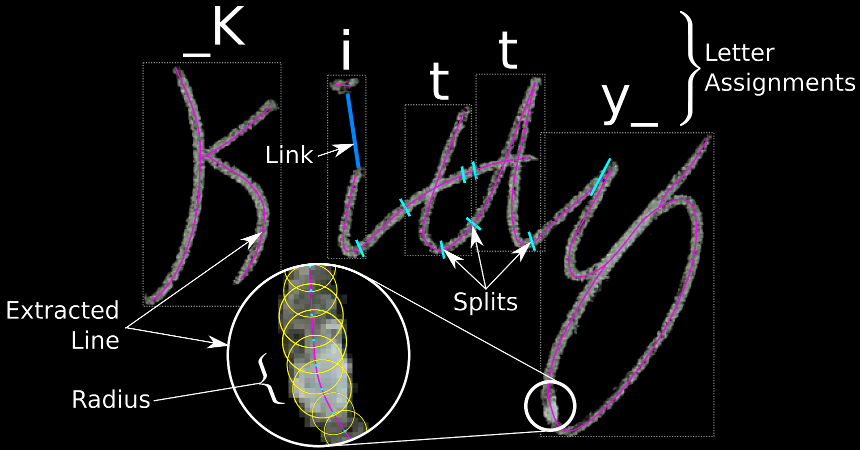
- Attach meta data to the line:
  - *Splits* mark the transitions between glyphs / ligatures.
  - *Links* indicate two separate lines are part of the same glyph (e.g. tittle and stem of "i")
  - *Labels* indicate which UTF-8 character code a glyph represents.

    (Ligatures are implicitly the lines that attach characters. Start and end of word are also indicated.)
- Automatic system solving constrained handwriting recognition problem.
- Manual editing, as automatic system is not 100% reliable.





Analysis Summary



Letter Assignments

Link

Splits

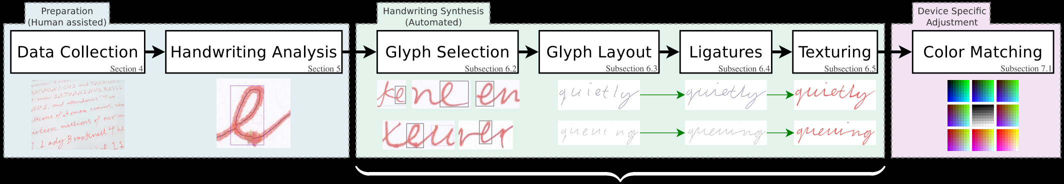
Extracted Line

Radius

Not shown:

- Ink density
- Matting

Synthesis Overview



- Input:
  - User provided *text* to generate.
  - An authors *tagged handwriting*.
- Output:
  - A *texture* containing the users *text* written with the *tagged handwriting*.

Core Idea

- *Glyphs* taken directly from the author are positioned on the page.
- The user provides the text, but there is still a choice of glyphs for each position in the word.
- *Spacing* between glyphs – both horizontal and vertical is important to replicating an authors style.
- *Ligatures* need to be generated when appropriate.
- Ultimately, it all has to be rendered to a *texture*.

A cost function is minimised. . .

Cost Function

We minimise:

$$C(R, t, A) = G_A(g, t) + S_A(g, x) + L_A(g, x, l) + T_A(g, x, l, R).$$

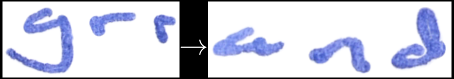
- R – Output texture.
- t – Input text string to synthesis.
- A – Input authors tagged handwriting.

- g – Glyphs to use, one per character in t.
- x – Positions of glyphs, one per glyph.
- l – Set of ligatures to generate between glyphs.

- $G_A(g, t)$ – Match author's glyphs to user's text.
- $S_A(g, x)$ – Match spacing of glyphs to author.
- $L_A(g, x, l)$ – Match ligature use to author.
- $T_A(g, x, l, R)$ – Match output texture to glyphs/ligatures.

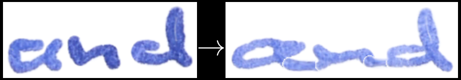
$G_A(g, t)$ – Glyph selection

- Constraint that selected glyphs represent the user-requested characters.
- For historical cases there may be missing characters – allow substituting a lower case letter for an upper case letter if necessary.



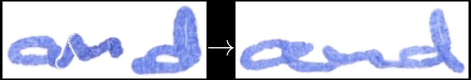
$S_A(g, x)$ – Glyph layout

- Both horizontal and vertical offsets are required between glyphs.
- Original glyph offsets are used where available (ligatures).
- When not available a regression forest estimates them (no ligatures).
- Humans have a feedback mechanism – if you write with your eyes closed you will drift off the rule, but eyes open and you correct for any drift.
- This feedback mechanism is replicated using Kalman smoothing.



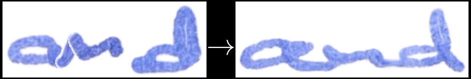
$L_A(g, x, l)$ – Ligatures

- Ligatures are required if both adjacent glyphs have them, but omitted if either is missing one.
- Authors have print handwriting, joined up handwriting, or partially joined up. First two cases are covered by this rule; for third it's a reasonable guess as we don't have enough information to infer exact rules.



$T_A(g, x, l, R)$ – Texturing

- Encourages nearby glyphs to have similar ink density and radius – sudden changes are unrealistic.
- Hides the seams between glyphs / ligatures (graph cut textures).



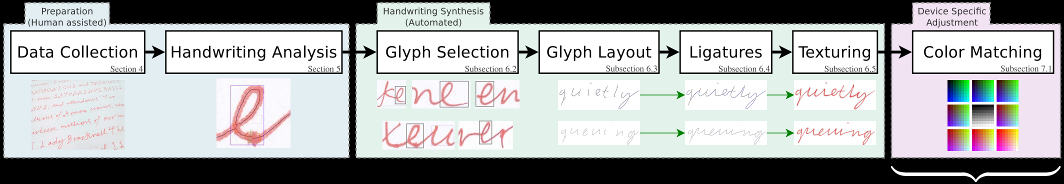
Solving

- Can't solve directly.
- Instead, solve it in four stages, one per equation, in order given.
- Each stage fixes some details using an appropriate representation and approximating other costs with proxies.

Stage	Fixes	Core Technique
Stage 1	Glyphs used (g)	Dynamic programming
Stage 2	Glyph positions (x)	Kalman smoothing
Stage 3	Ligature existence (l)	Heuristic
Stage 4	Output texture (R)	Graph cuts

- Random/regression forests and heuristics are used to estimate proxy costs.

Colour Calibration



- If printing we need to get as close as possible to real ink.
- Perform a closed loop colour calibration by printing out and then scanning back in a calibration target.
- Uses thin-plate splines.
- Printers lack the dynamic range to cover most inks, but it still helps fool an observer.