Why is graphics specialized?

We have general purpose retrieval software for text, and we've had it since the 1960s.

We have specialized graphics software for charts, maps, faces, CAD, abstract graphs, and so on.

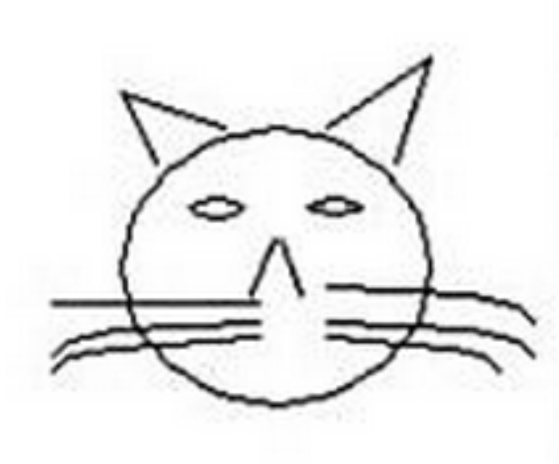
Image retrieval in general still relies on words that can be found in the vicinity of the images.

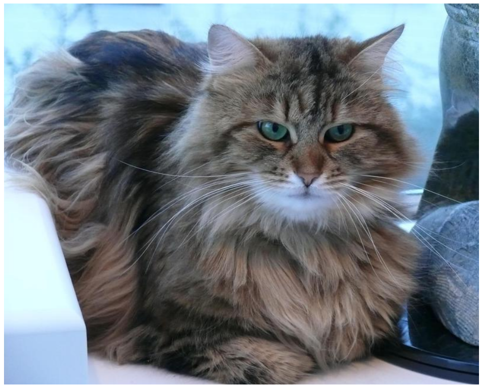
Why is this baffling?

Words are not particularly precise. We have problems of synonymy and ambiguity. Depending on the language, we have problems of word order, declensional endings, and specialized phrases.

We can train pigeons to do some kinds of image retrieval; we can't imagine training pigeons to do text retrieval.

You see these as the same

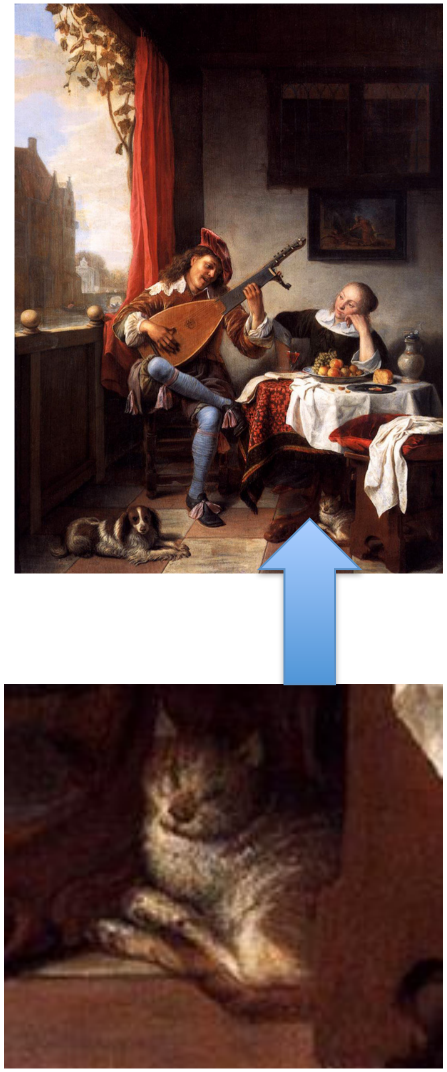


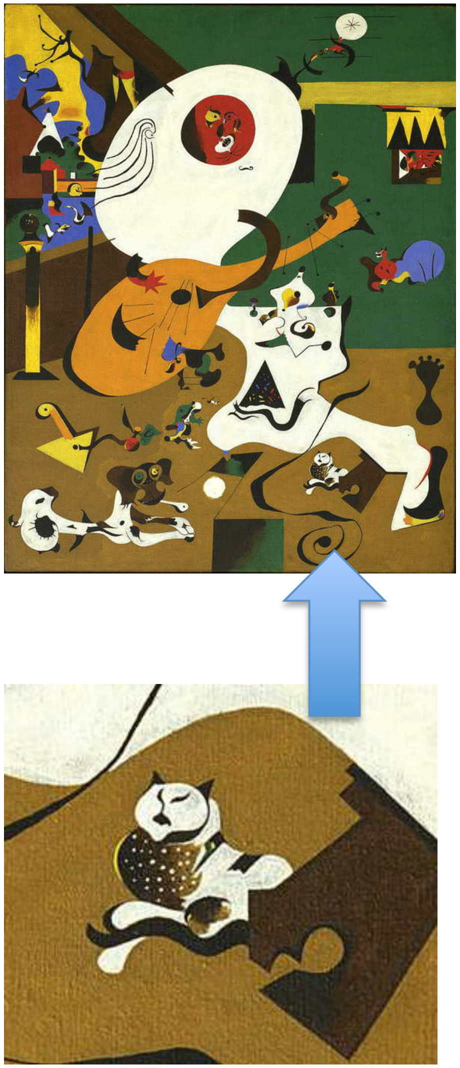


There is no similarity of color histogram, texture, or other simple image features. Nor, for that matter, is there any overlap with

cat

And for that matter





Left: Hendrick Sorgh, *The Lute Player;* Rijksmuseum.

Right: Joan Miro, *Dutch Interior I*; Museum of Modern Art (NY).

Words, not the alphabet

This can’t be about the alphabet, since the major search engines do Chinese retrieval every microsecond.

There are about the right number of words. Letters are too common, and multi-word phrases are too rare.

Herman Simon suggested that 50,000 patterns was about the right number for an intellectually challenging but interesting activity. Shakespeare’s vocabulary is about 30,000 words; Jane Austen’s about 15,000.

There are too many different pictures.

It’s not the only difficult case

There are other examples of knowledge areas that we typically search with nearby words, despite better precision than we have with language:

Mathematical theorems

Musical scores (aside from exact-match)

and most puzzling to me

Software

We need a vocabulary or a model

If we could reduce these difficult problems in size by having a reasonable set of units, we could search those. Or, if we could fit them into a model, we could search the parameters – this is actually what is done in many domains. Chess is an example: we can scan pages from old books of games, recognize the symbols, and put the games into a formal notation and a large database of known chess games.

For imagery in general – whether vector or raster – we do not have an overall discussion model.

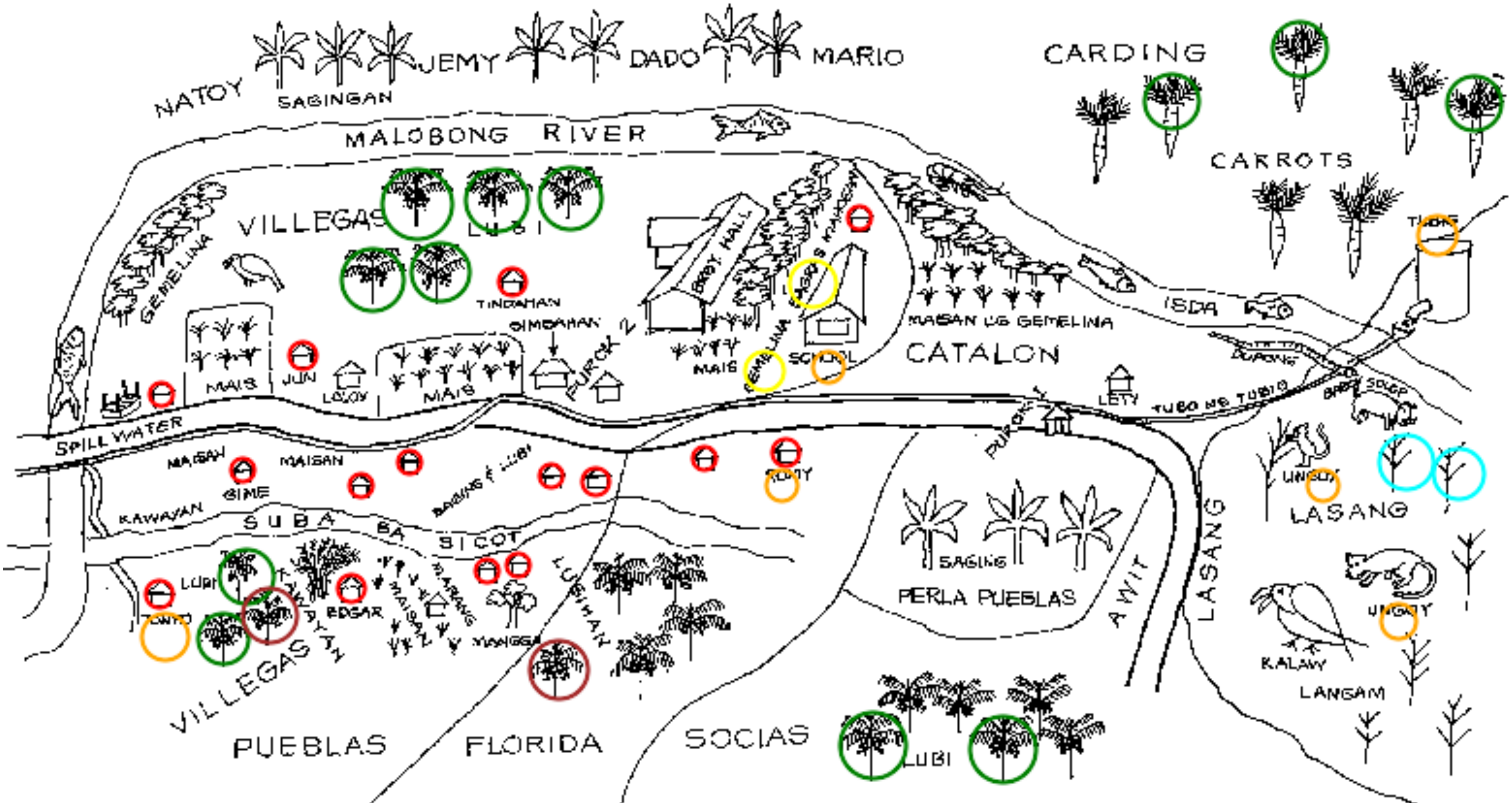
So images are too complex

If images are too complicated, then it helps to segment the space of graphical images. So we have specialized tools for the various kinds of imagery.

In recent decades we’ve seen ideas such as SIFT features or Gabor filters to try to find more generalized ways of describing images. Most of these are efforts to deal with photographs of naturalistic images, and great progress has been made; see Noah Snavely’s work on “Rome built in a day” which recognizes multiple amateur photographs of the same building.

Can we try to find elements?

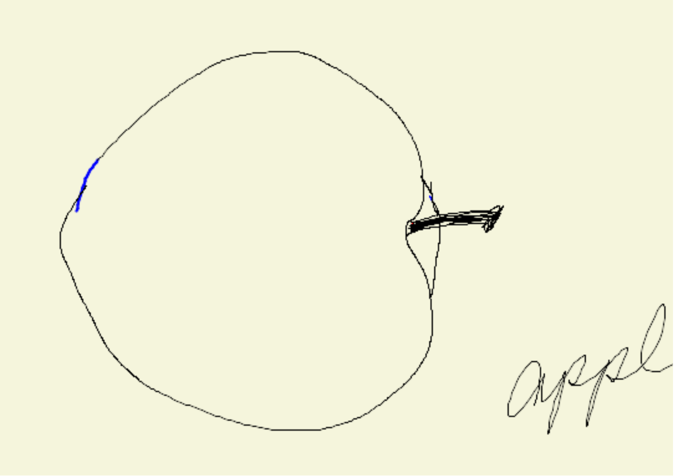
Looking for repeated elements in a diagram isn't that useful:



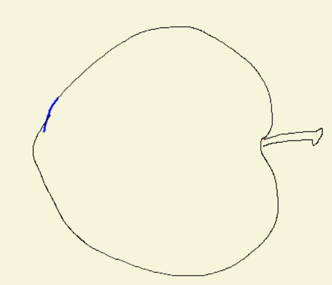
An easy image, but the similar items are not what is important.

What might work better?

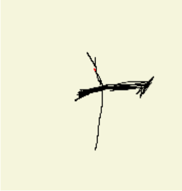
After a suggestion from Venu Govindaraju, I tried looking at images drawn on a tablet. I asked a student, Annamarie Klose, to draw some pictures freehand. We captured the stroke timing as well as the final output (timings are slow because tablets are hard to draw upon). So for example:



was drawn as



32 sec; stylus not lifted

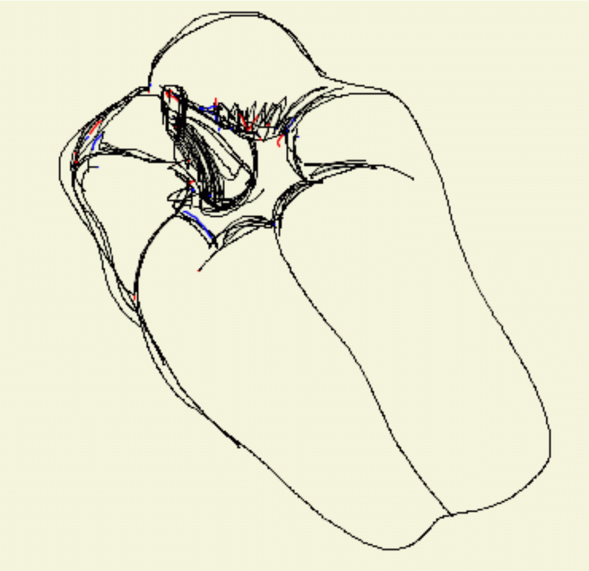


26 sec; 4 strokes

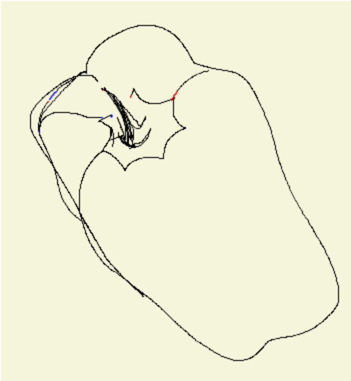
3 sec, one stroke

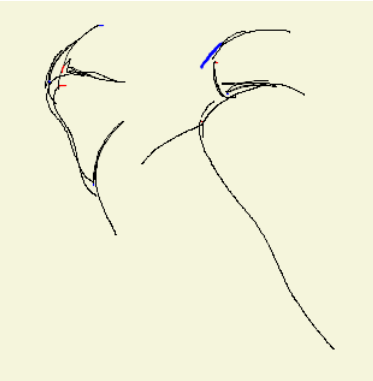
It’s not always so neat

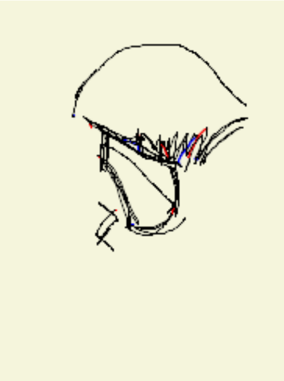
You can draw from the outside in..



was drawn as shown (top left first, bottom right last)

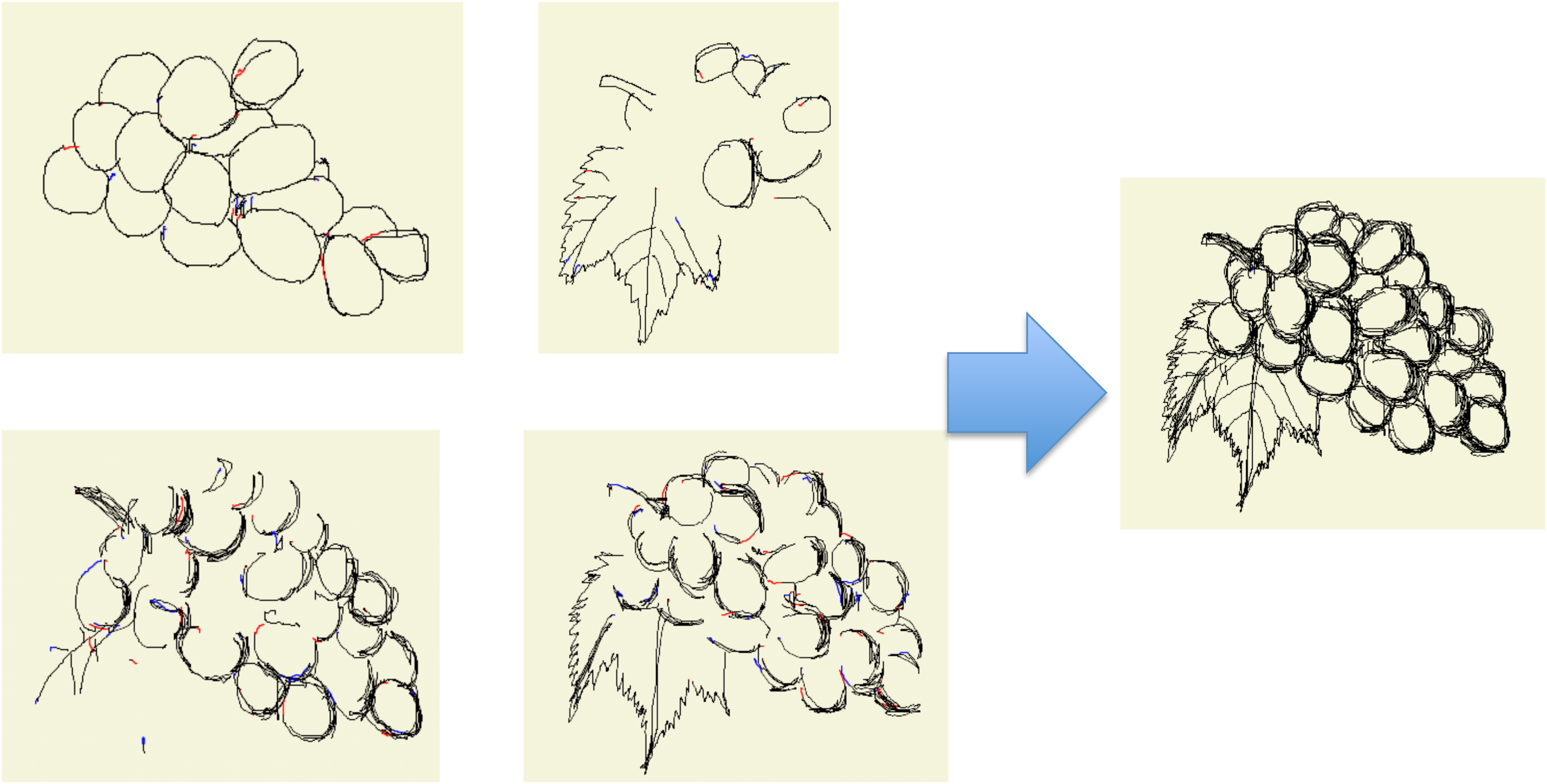






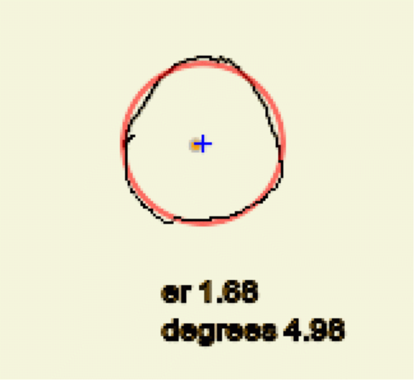
Still more complex

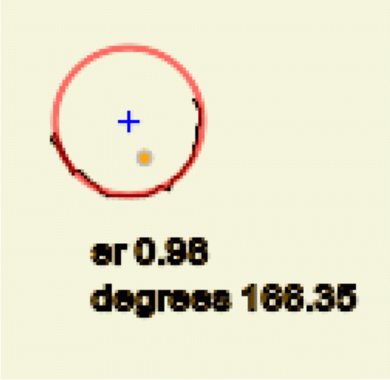
Steady polishing of the drawing to suggest texture

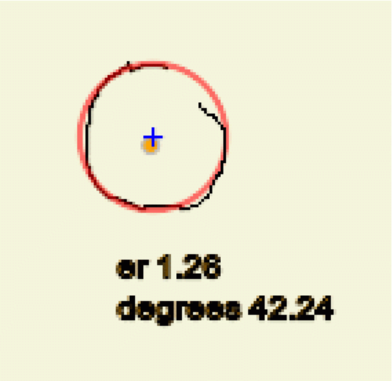


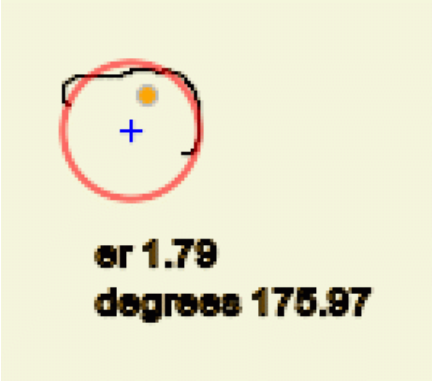
Little segmentation problem

System knows when the stylus was lifted or there was a pause; it then takes the segments and fits circles. Among 200 segments:

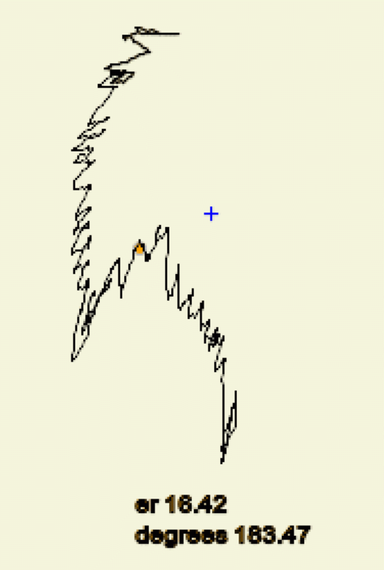


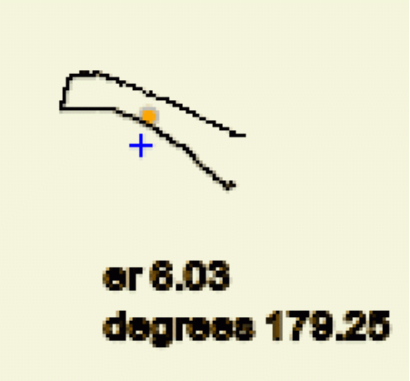






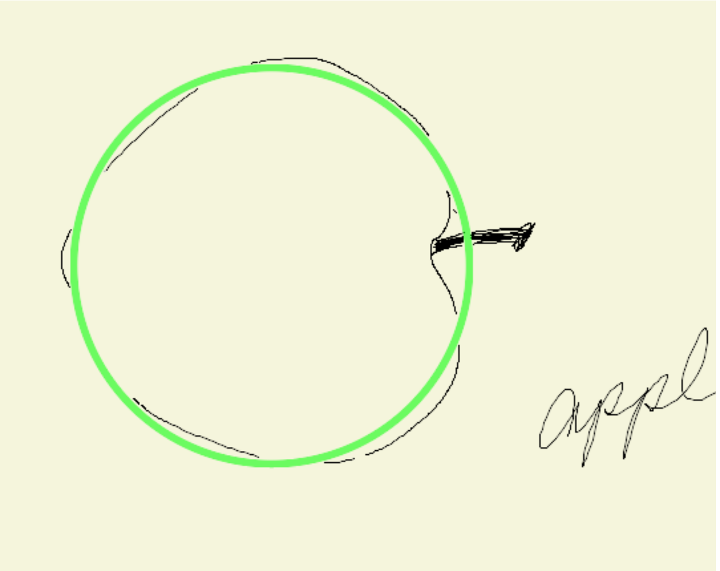
Circles on left, segments which are not circles on right. The degree measure is the gap in the circle.

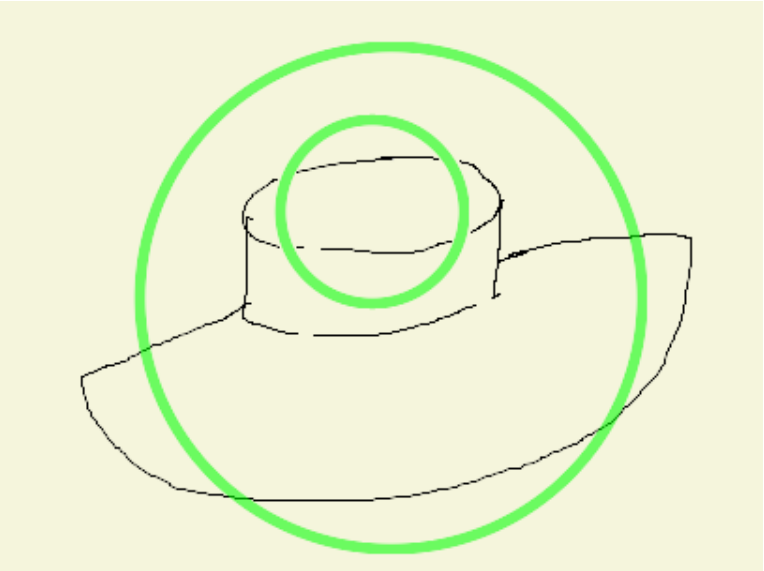




But one can find elements

What about looking for circles in drawings?

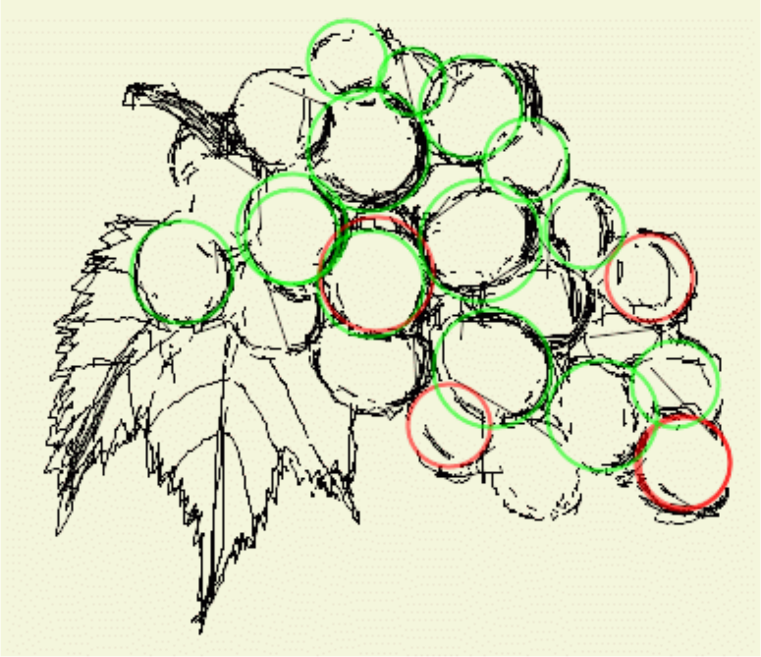


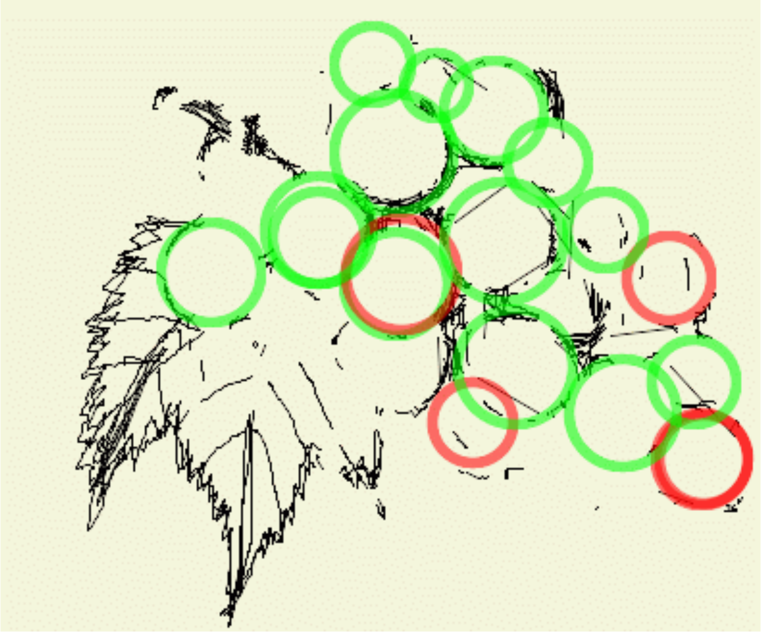


The apple is pretty close to round, the hat really needs to be fit as a pair of ellipses.

A more challenging example

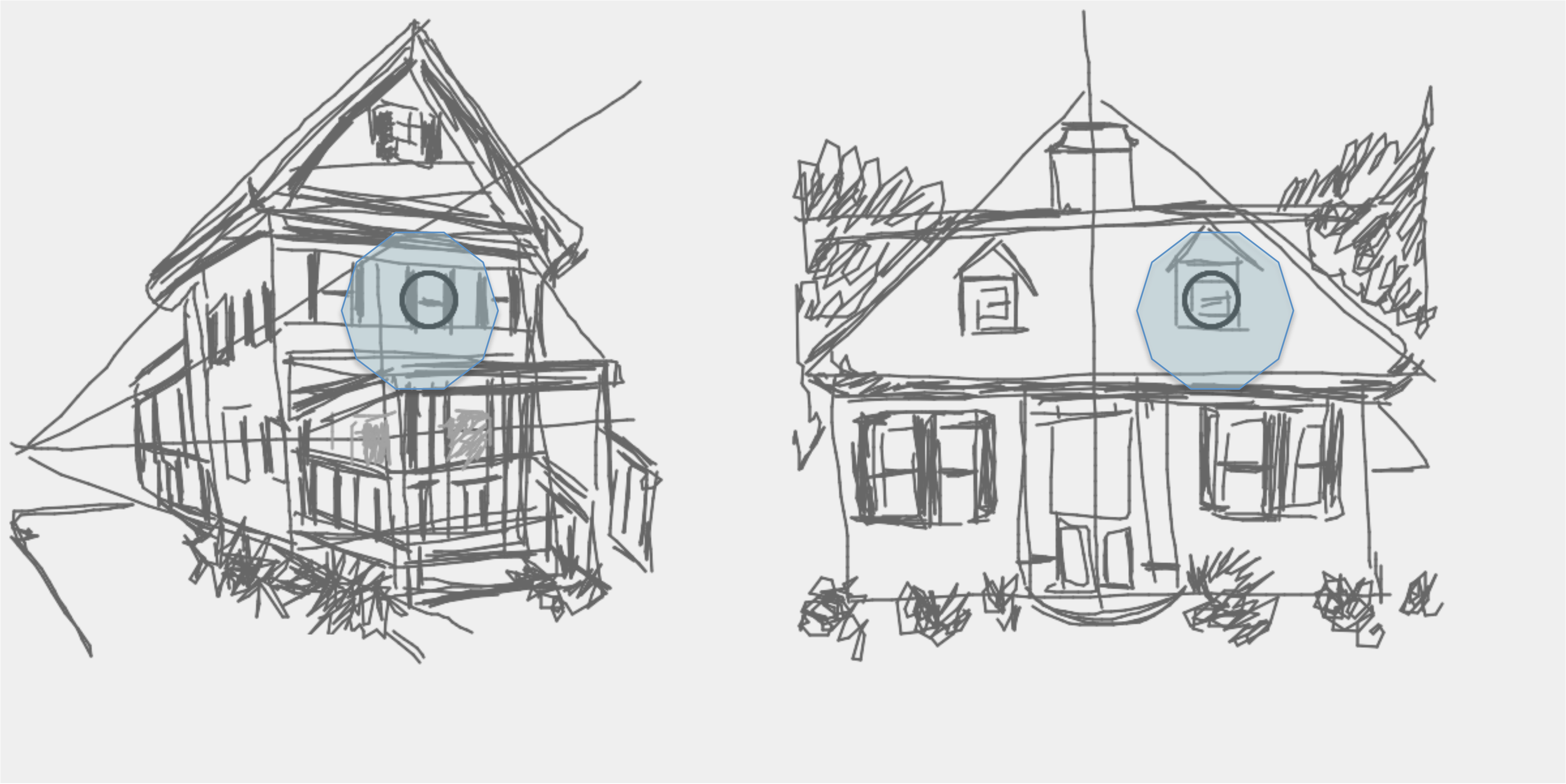
Here’s a search for circles in the grape drawing (left shows the circles on top of the original; in the right drawing only strokes not under the circles are shown).





Straight lines also work

Here are two more drawings with a match on similar features made of lines:



What do I hope to do?

The goal is to be able to search and to summarize.

Summarization, in this context, means making a simpler drawing with the same “meaning”.

Why? Let’s consider one specific application. Another student, Tony Gruenewald, works at LearningAlly (perhaps still better known as Recording for the Blind). They would like to be able to prepare tactile representations of the diagrams in the books and articles they read (see ACM SIGASSIST conferences for lots more on this problem).

Are circles and lines enough?

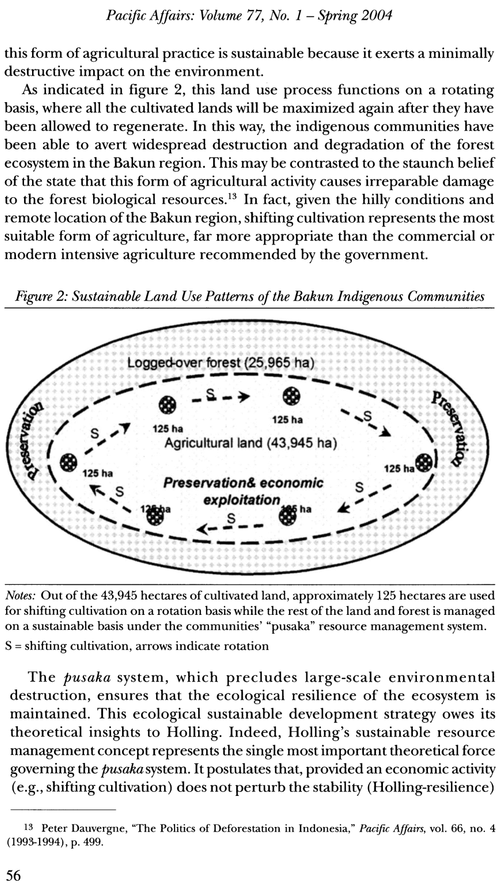
Realistically, no. People do not search at that level of detail, or even at the level of SIFT features. Nor would it make sense to say “I will abbreviate this picture by leaving out all horizontal lines” or anything like that.

So we are going to need something more ambitious and more semantically meaningful.

The goal is to take an image and produce a simpler one with a shorter description, that will be easier both to present and to compare with other images, without having to assume that the image comes from a particular population of well-modeled imagery.

Relevance to ICDAR

So we can zone a page, separate out the graphics, and then separate out the words inside the graphics.



Pacific Affairs: Volume 77, No. 1 – Spring 2004

this form of agricultural practice is sustainable because it exerts a minimally destructive impact on the environment.

As indicated in figure 2, this land use process functions on a rotating basis, where all the cultivated lands will be maximized again after they have been allowed to regenerate. In this way, the indigenous communities have been able to avert widespread destruction and degradation of the forest ecosystem in the Bakun region. This may be contrasted to the staunch belief of the state that this form of agricultural activity causes irreparable damage to the forest biological resources.[13] In fact, given the hilly conditions and remote location of the Bakun region, shifting cultivation represents the most suitable form of agriculture, far more appropriate than the commercial or modern intensive agriculture recommended by the government.

Figure 2: Sustainable Land Use Patterns of the Bakun Indigenous Communities

Logged-over forest (25,965 ha)
Preservation
Preservation
Agricultural land (43,945 ha)
Preservation& economic exploitation
125 ha
125 ha
125 ha
125 ha
125 ha
125 ha
S
S
S
S
S
S

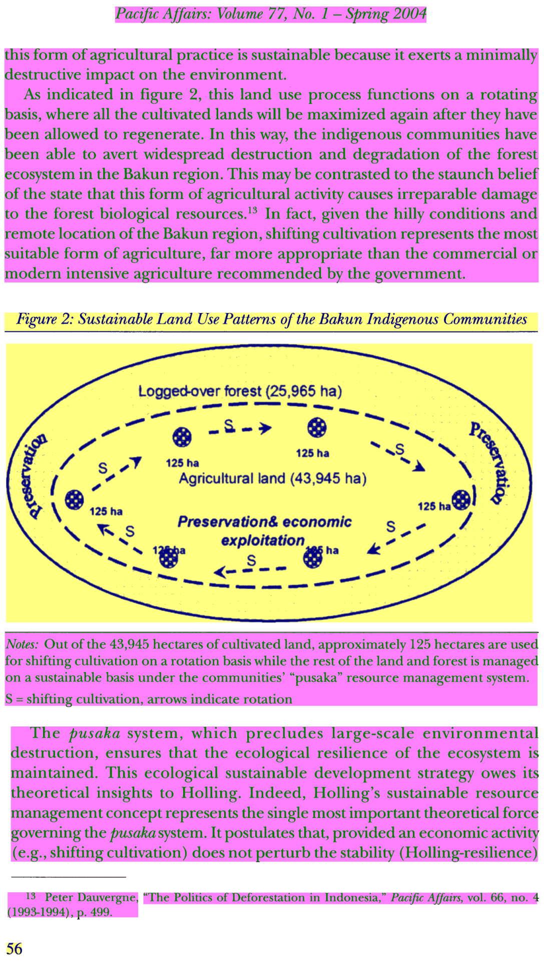
Notes: Out of the 43,945 hectares of cultivated land, approximately 125 hectares are used for shifting cultivation on a rotation basis while the rest of the land and forest is managed on a sustainable basis under the communities' "pusaka" resource management system.

S = shifting cultivation, arrows indicate rotation

The *pusaka* system, which precludes large-scale environmental destruction, ensures that the ecological resilience of the ecosystem is maintained. This ecological sustainable development strategy owes its theoretical insights to Holling. Indeed, Holling's sustainable resource management concept represents the single most important theoretical force governing the *pusaka* system. It postulates that, provided an economic activity (e.g., shifting cultivation) does not perturb the stability (Holling-resilience)

[13] Peter Dauvergne, "The Politics of Deforestation in Indonesia," *Pacific Affairs*, vol. 66, no. 4 (1993-1994), p. 499.

56



Pacific Affairs: Volume 77, No. 1 – Spring 2004

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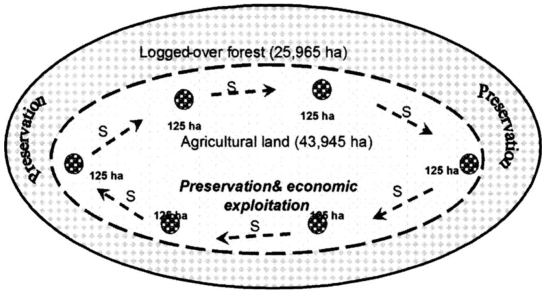
56

(continued)


Logged-over forest (25,965 ha)
Preservation
Preservation
S
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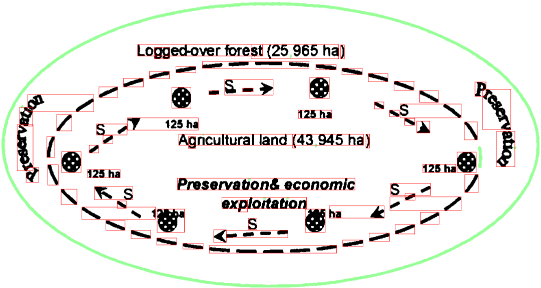
125 ha
125 ha
125 ha
125 ha
125 ha
125 ha
Agricultural land (43,945 ha)
Preservation& economic exploitation


Logged-over forest (25 965 ha)
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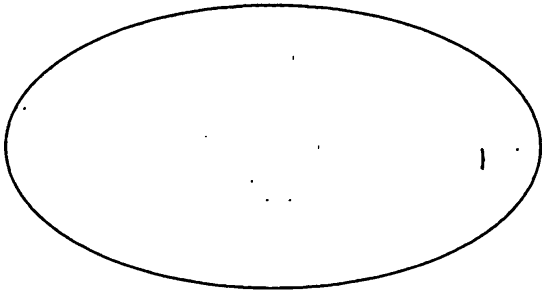


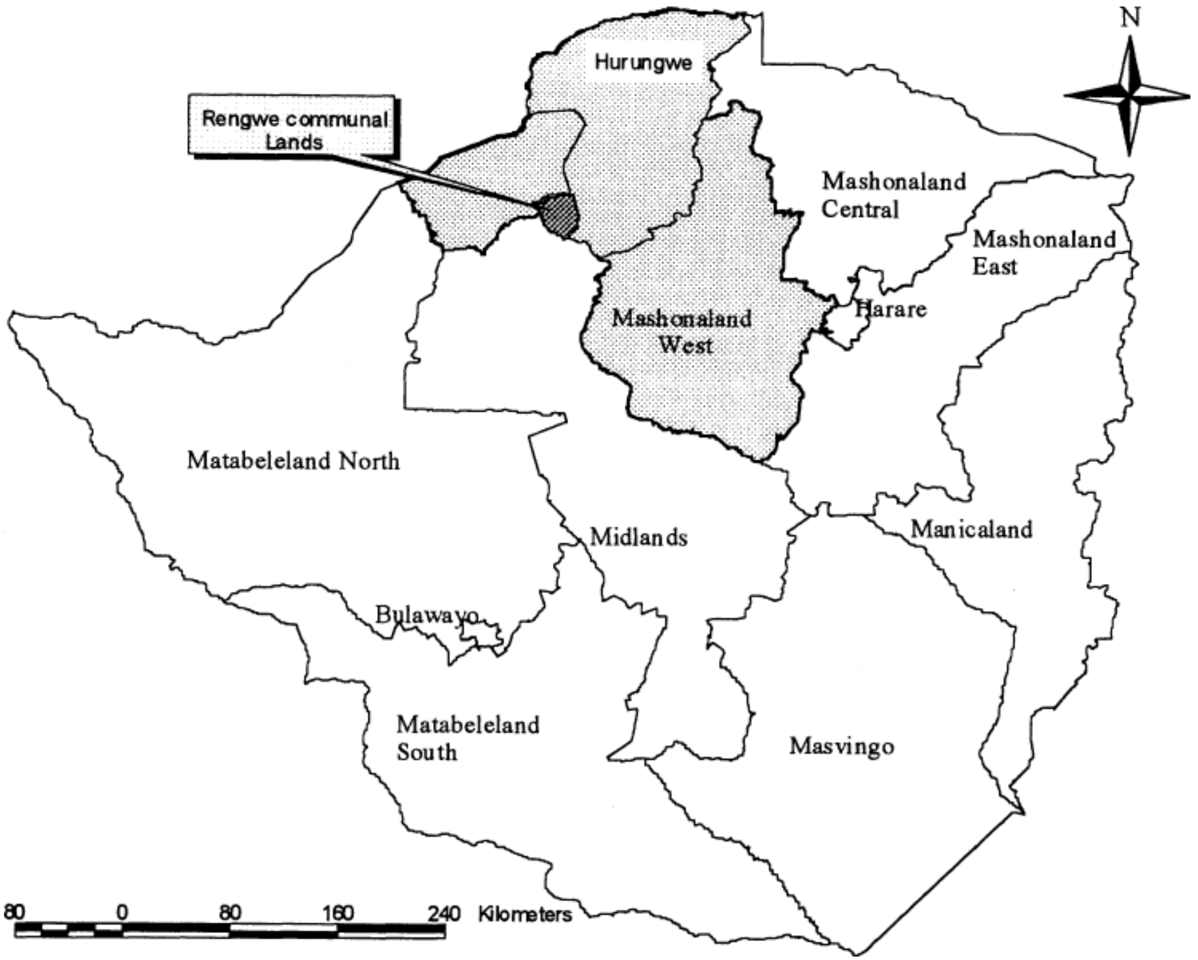
Top: whole excerpted image

Middle: the letters

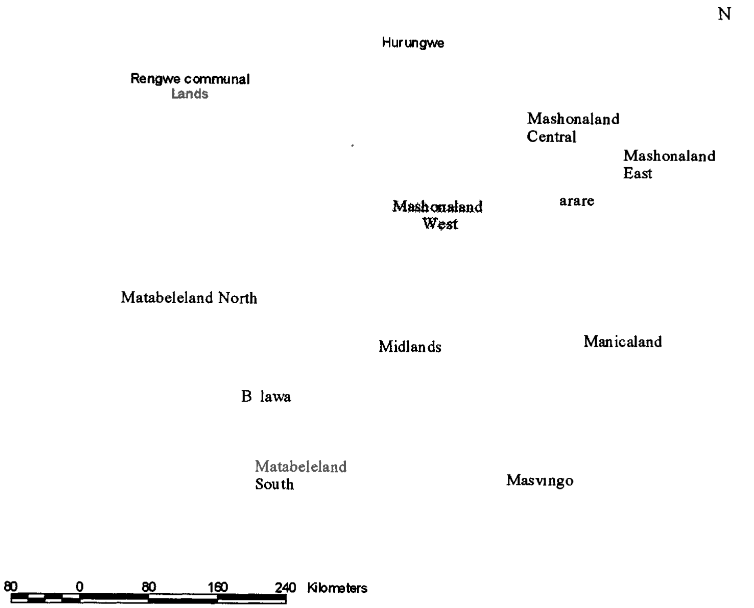
Bottom: the graphics

Then you feed the words to an OCR program and eventually try to print them in Braille.

Another example of separation



(Continued)


N
Hurungwe
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Lands
Mashonaland
Central
Mashonaland
East
Mashonaland
West
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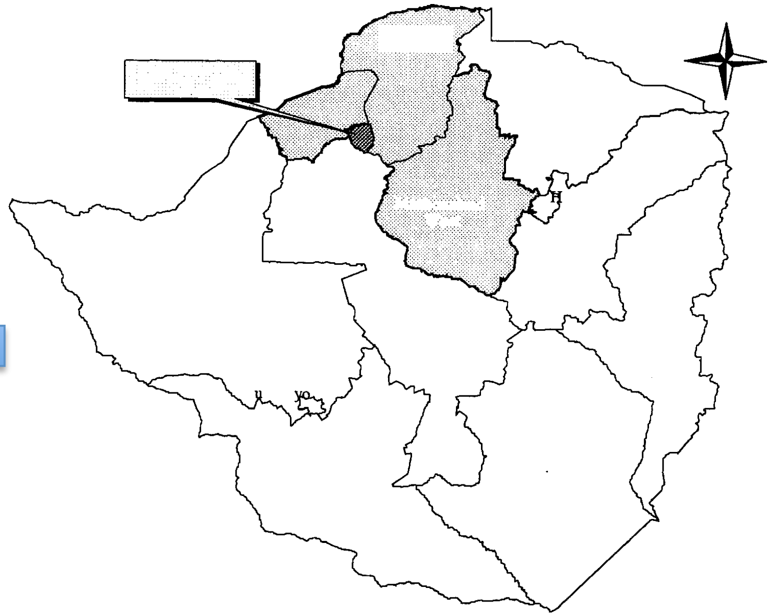
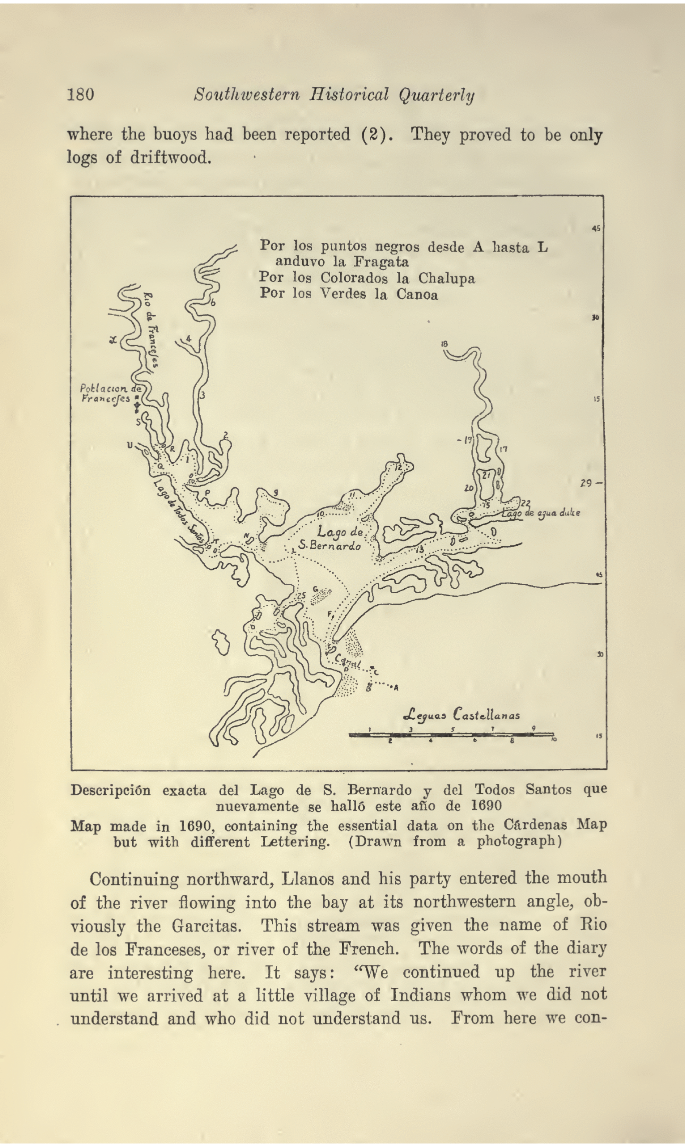
Matabeleland North
Midlands
Manicaland
B lawa
Matabeleland
South
Masvingo
80
0
80
160
240
Kilometers


H

A more complex example



180 *Southwestern Historical Quarterly*

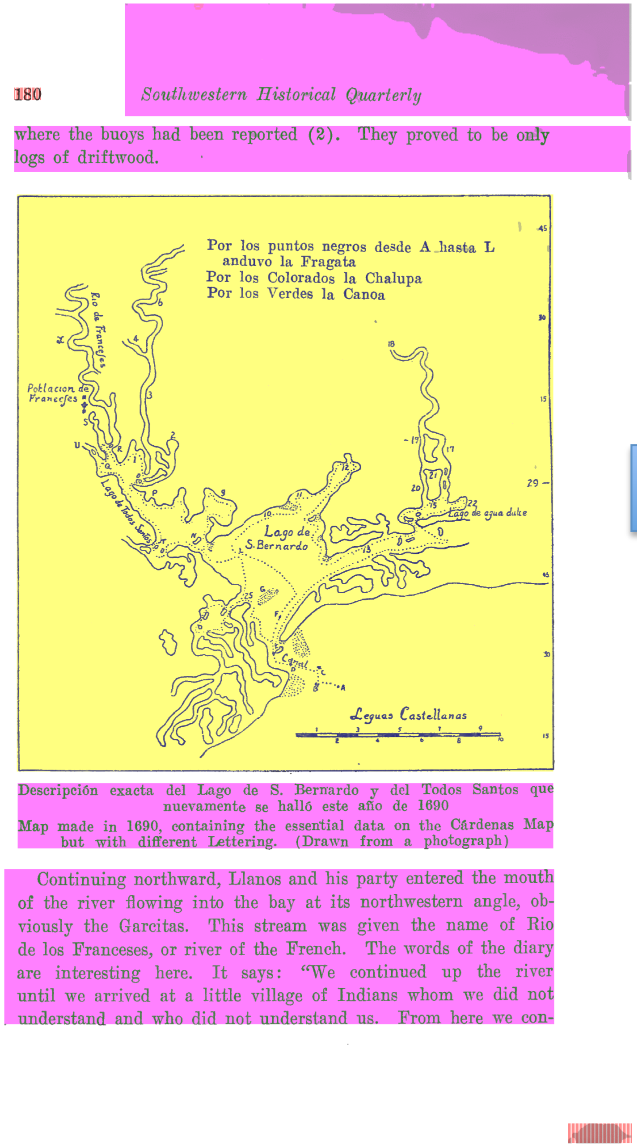
where the buoys had been reported (2). They proved to be only logs of driftwood.

Por los puntos negros desde A hasta L
anduvo la Fragata
Por los Colorados la Chalupa
Por los Verdes la Canoa
Rio de Franceses
Poblacion de Franceses
Lago de Todos Santos
Lago de S. Bernardo
Lago de agua dulce
Canal
Leguas Castellanas
29

Descripción exacta del Lago de S. Bernardo y del Todos Santos que nuevamente se halló este año de 1690

Map made in 1690, containing the essential data on the Cárdenas Map but with different Lettering. (Drawn from a photograph)

Continuing northward, Llanos and his party entered the mouth of the river flowing into the bay at its northwestern angle, obviously the Garcitas. This stream was given the name of Rio de los Franceses, or river of the French. The words of the diary are interesting here. It says: "We continued up the river until we arrived at a little village of Indians whom we did not understand and who did not understand us. From here we con-



180 *Southwestern Historical Quarterly*

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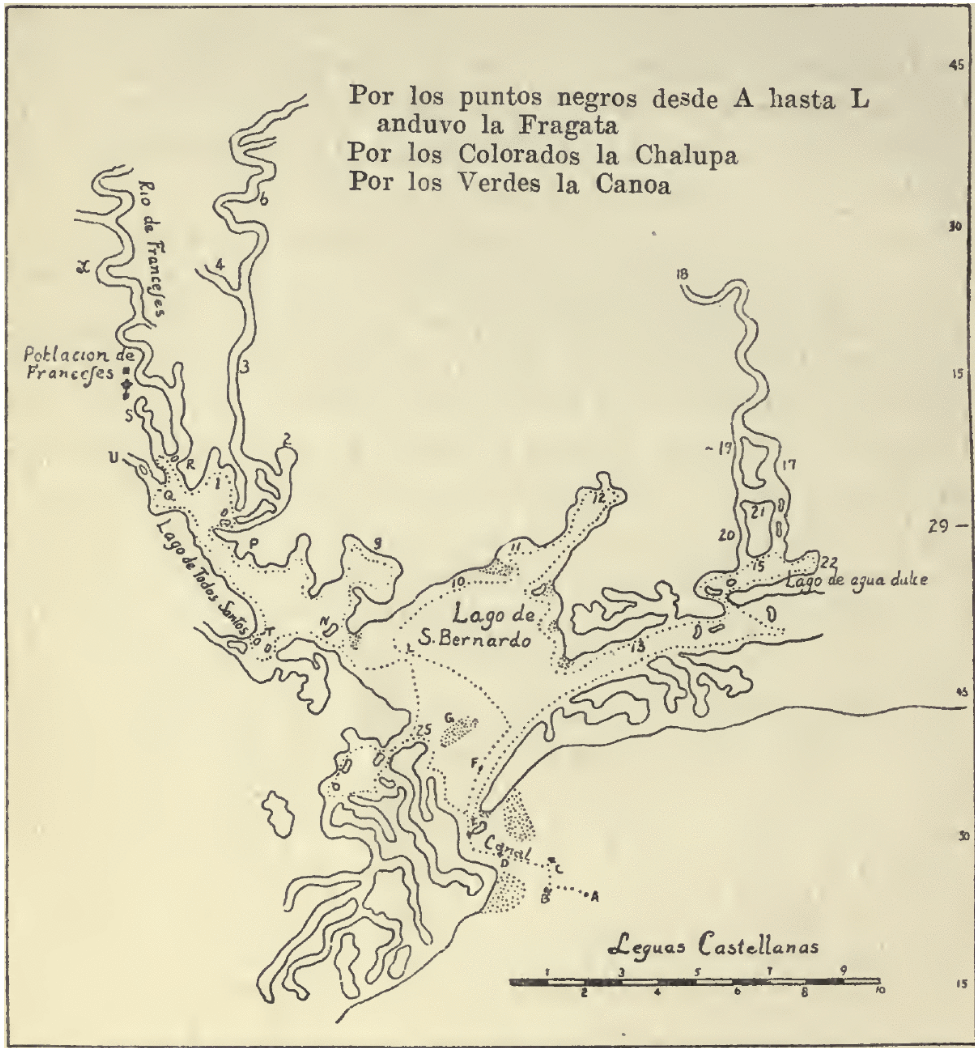
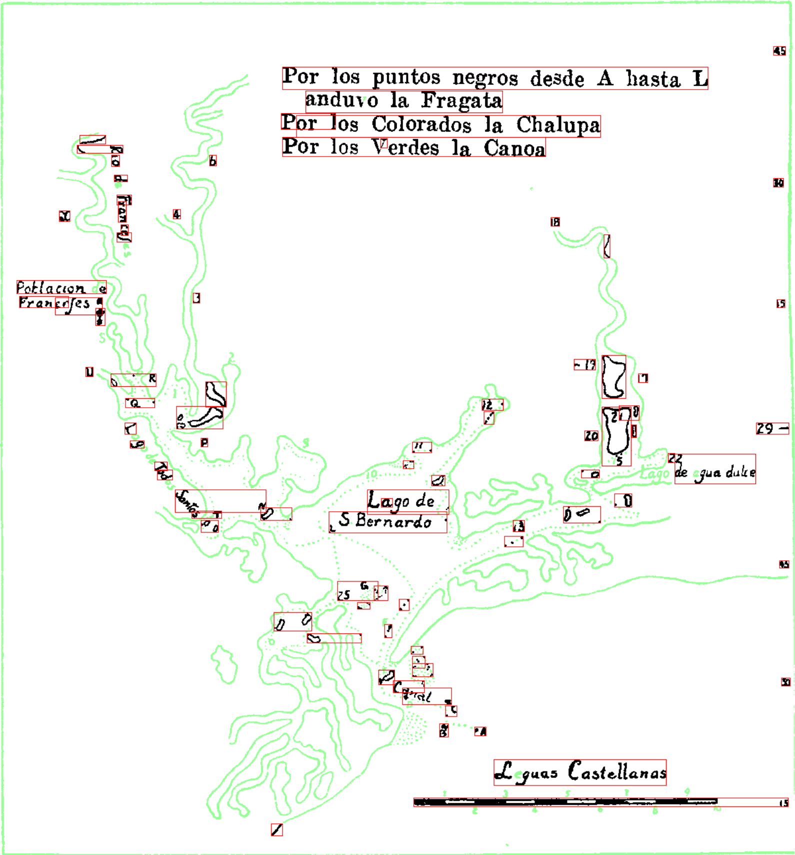
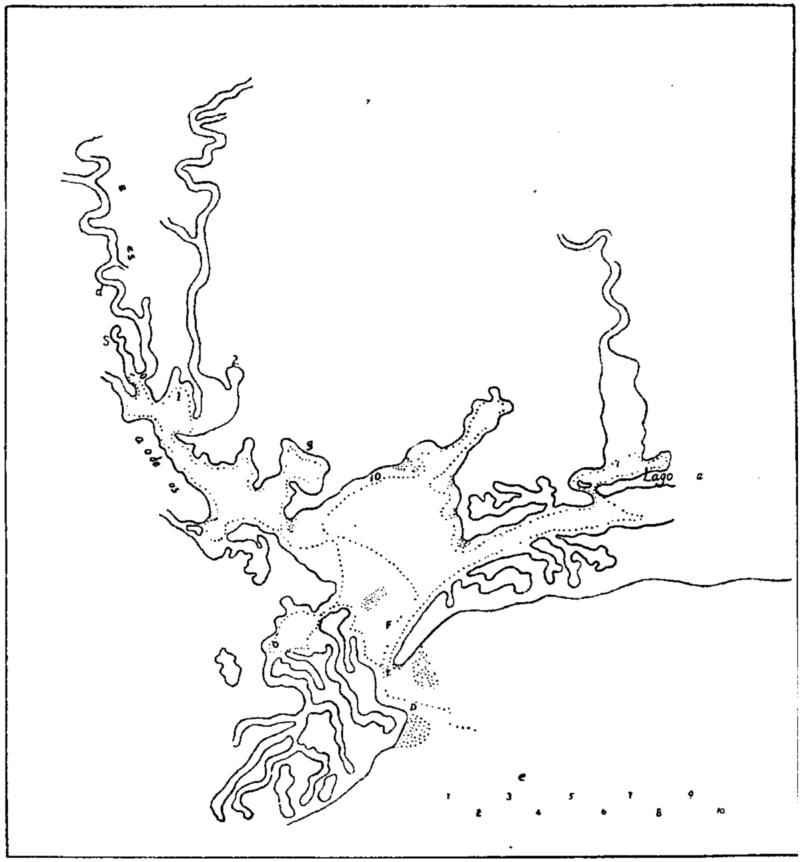
(continued)



Por los puntos negros desde A hasta L anduvo la Fragata
Por los Colorados la Chalupa
Por los Verdes la Canoa

(continued)


Por los puntos negros desde A hasta L
anduvo la Fragata
Por los Colorados la Chalupa
Por los Verdes la Canoa
Rio de Franceses
Poblacion de Franceses
Lago de S Bernardo
Lago de agua dulce
Leguas Castellanas
Canal
Santos
29


Lago

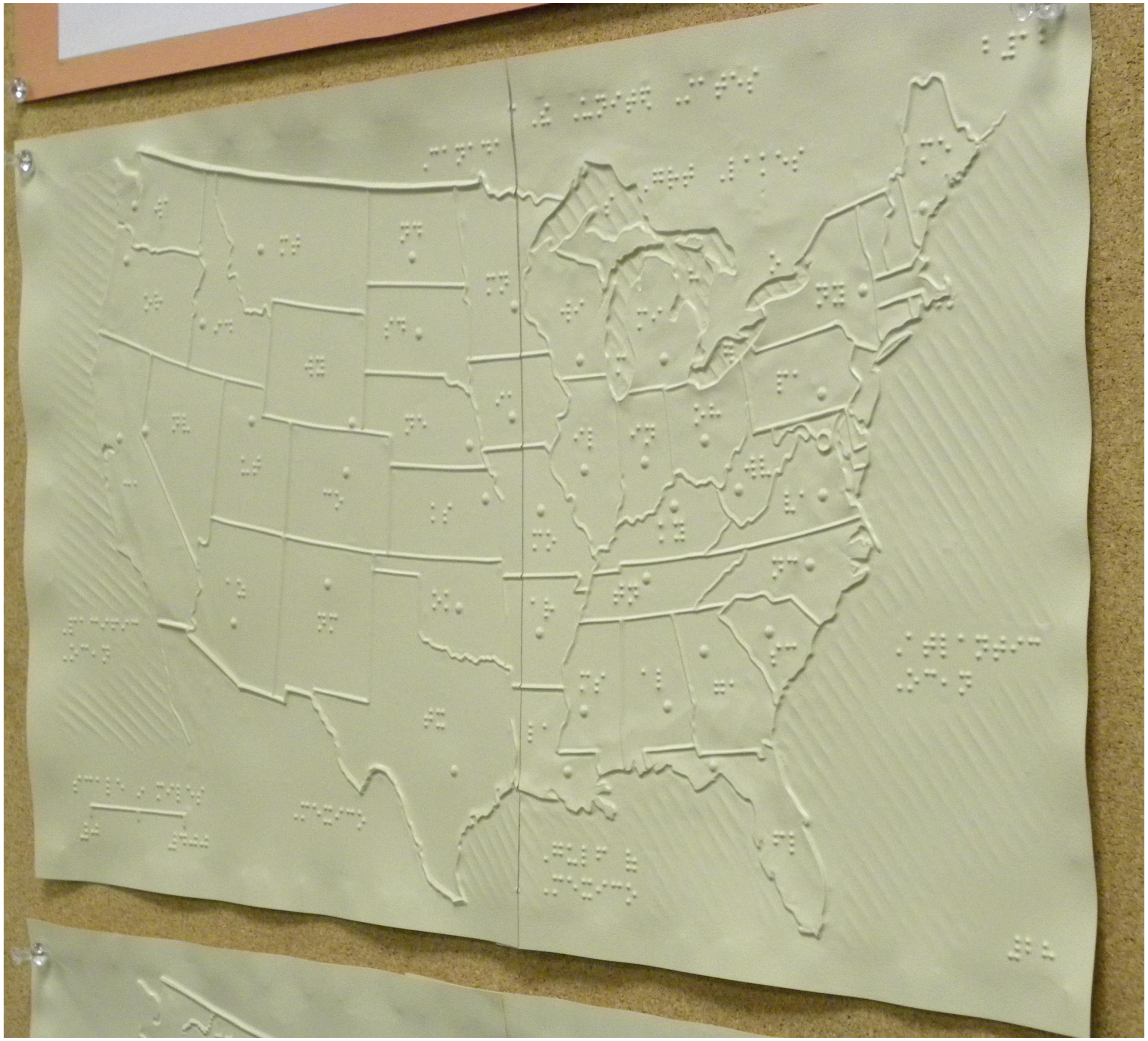
Limitations of tactile media

The problem with this imagined pipeline – document to a separation into text (to be read aloud) and graphics (to be presented as a tactile image with Braille) – is resolution.

The standard for tactile presentation is that the minimum feature size is 0.1” while for a printed document a minimum feature size is more like 0.01” (good printing is at least 0.001”, but you’d a magnifying glass to see that properly).

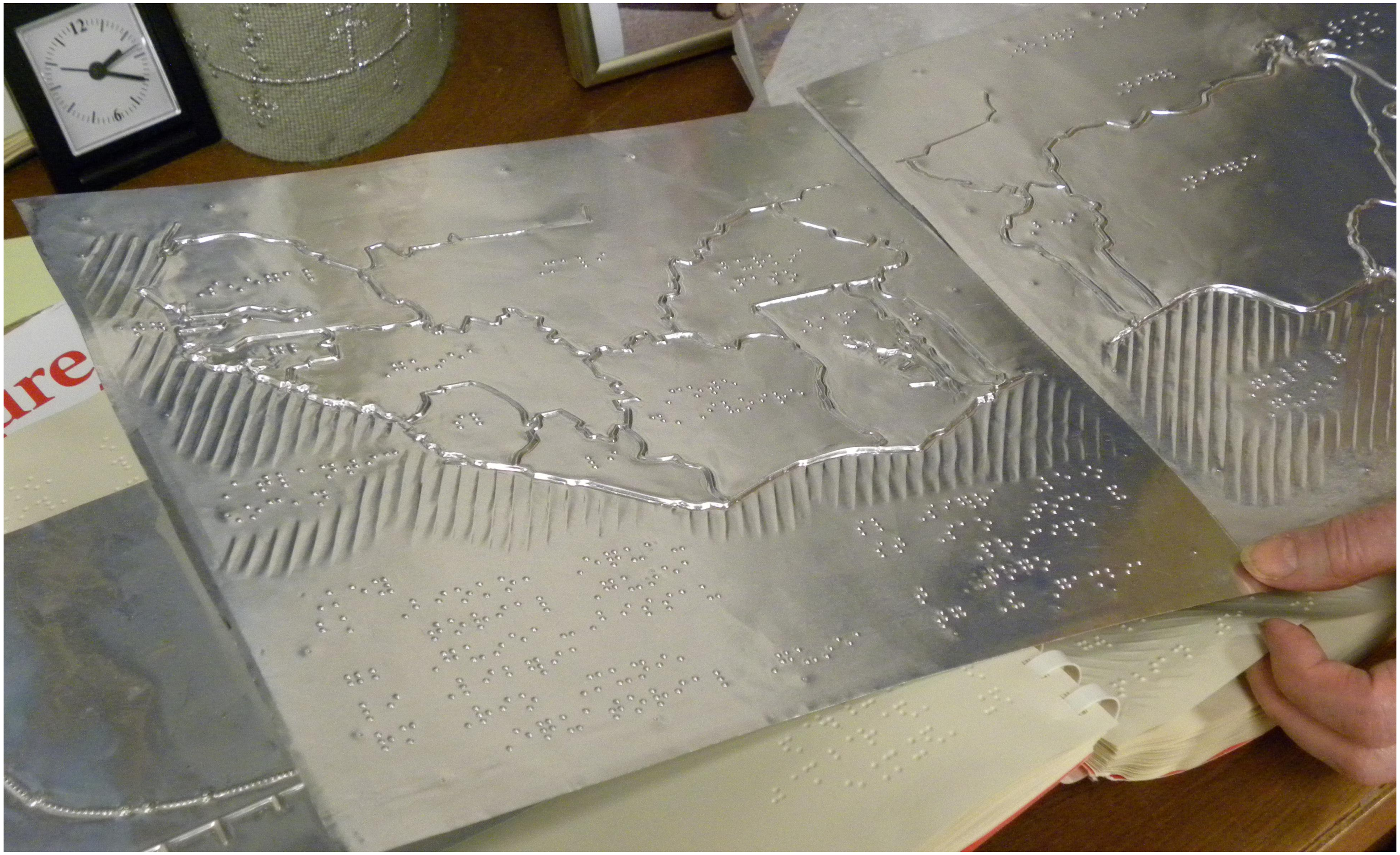
So things must be really simplified.

A tactile map



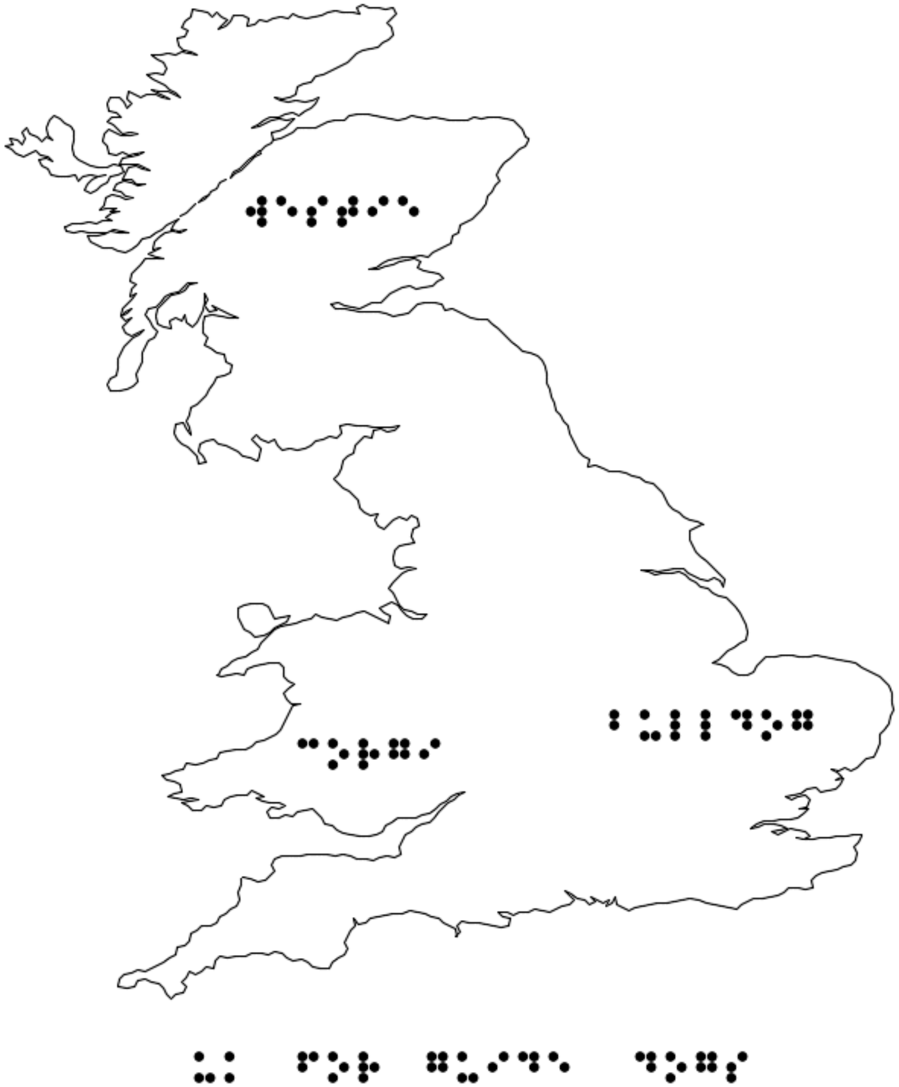
This map is roughly 22x11 (standard sheet size is 11x11, and this map is double page).

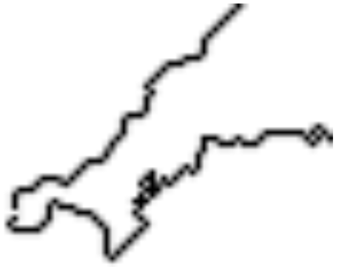
How these are made today



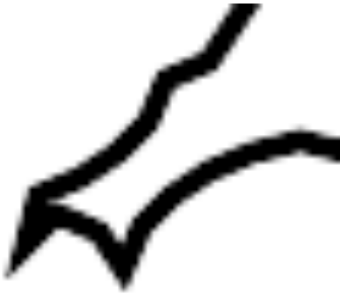
The map is hand-engraved into an aluminum sheet.

Comparing maps

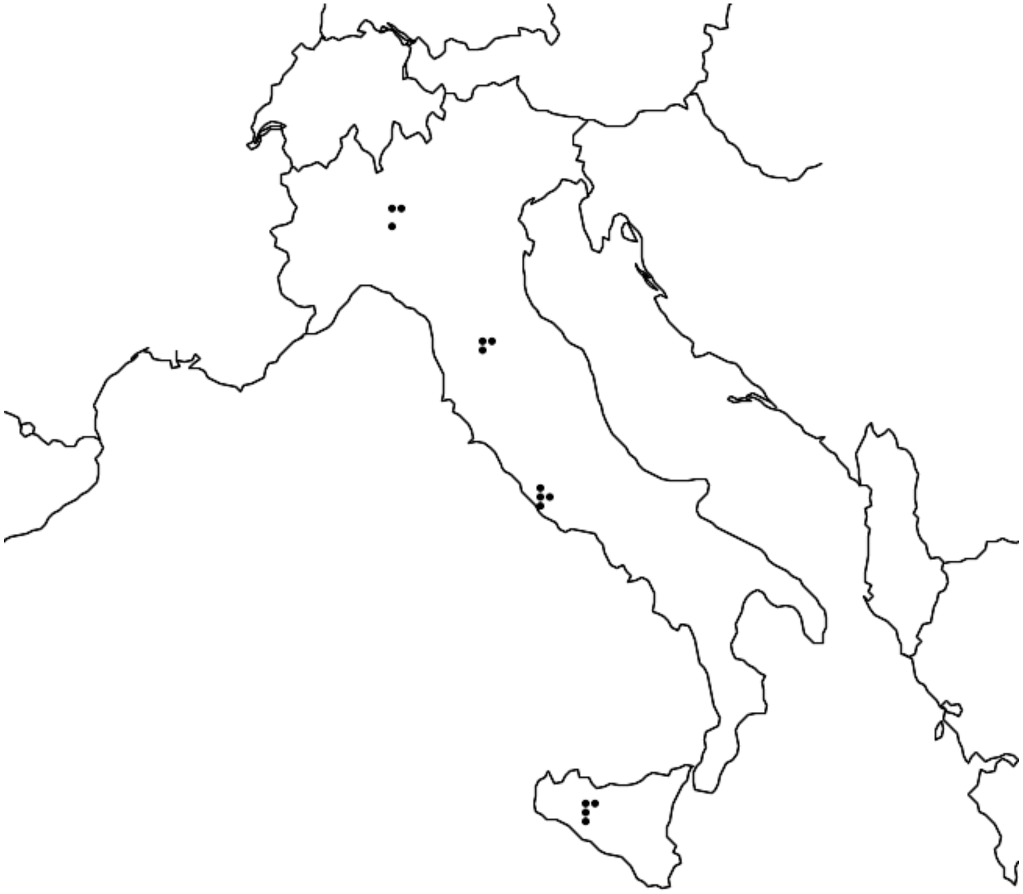




Cornwall, better resolution above, smoothed below



Simplifying maps



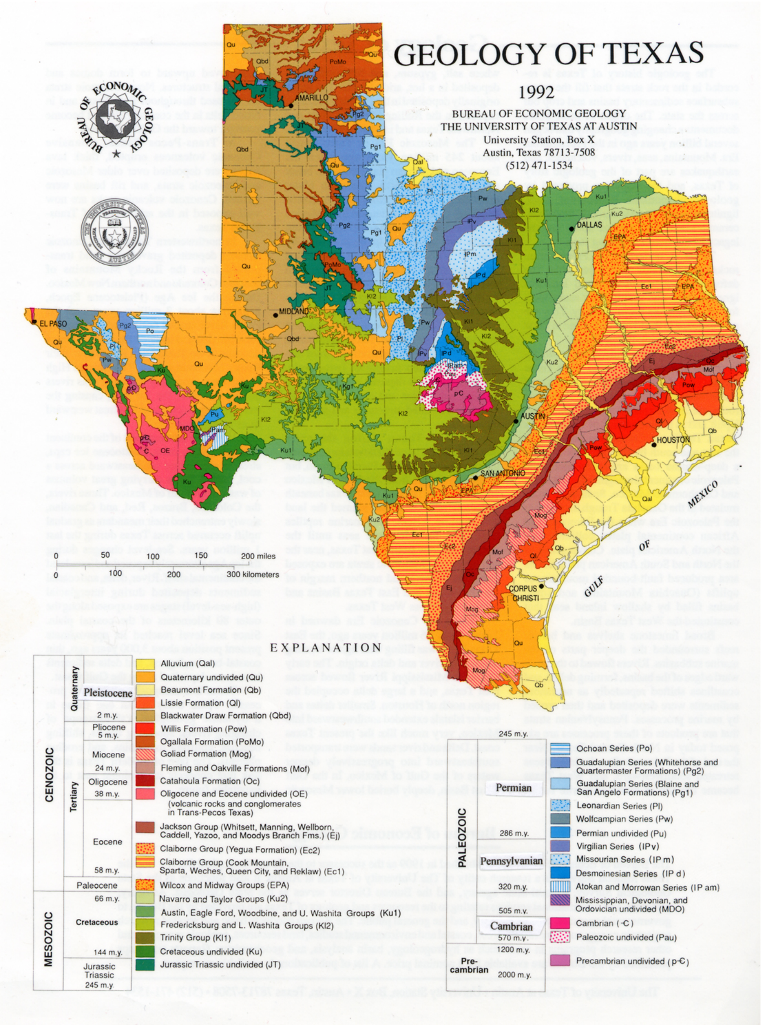
⠗ ⠗⠕⠍⠑
⠏ ⠏⠁⠇⠑⠗⠍⠕

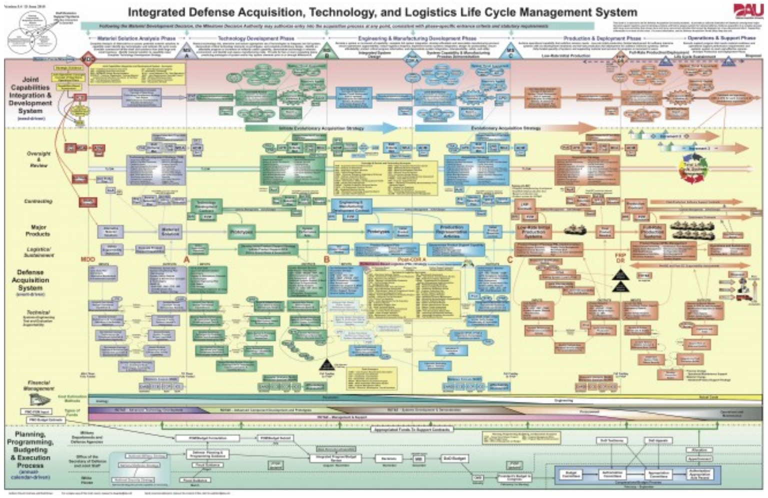
⠍ ⠍⠊⠇⠁⠝
⠋ ⠋⠊⠗⠑⠝⠵⠑

We have a model that lets us simplify maps. For example, choose a country, use fewer points on the outline, and give locations for four large cities.

But this is not so simple for other kinds of drawings.

What could you do with these?


GEOLOGY OF TEXAS
1992
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN
University Station, Box X
Austin, Texas 78713-7508
(512) 471-1534
BUREAU OF ECONOMIC GEOLOGY
AMARILLO
DALLAS
MIDLAND
EL PASO
AUSTIN
SAN ANTONIO
HOUSTON
CORPUS CHRISTI
GULF OF MEXICO
0 50 100 150 200 miles
0 100 200 300 kilometers
EXPLANATION
CENOZOIC
Quaternary
Pleistocene
Tertiary
Pliocene
Miocene
Oligocene
Eocene
Paleocene
MESOZOIC
Cretaceous
Jurassic Triassic
2 m.y.
5 m.y.
24 m.y.
38 m.y.
58 m.y.
66 m.y.
144 m.y.
245 m.y.
Alluvium (Qal)
Quaternary undivided (Qu)
Beaumont Formation (Qb)
Lissie Formation (Ql)
Blackwater Draw Formation (Qbd)
Willis Formation (Pow)
Ogallala Formation (PoMo)
Goliad Formation (Mog)
Fleming and Oakville Formations (Mof)
Catahoula Formation (Oc)
Oligocene and Eocene undivided (OE) (volcanic rocks and conglomerates in Trans-Pecos Texas)
Jackson Group (Whitsett, Manning, Wellborn, Caddell, Yazoo, and Moodys Branch Fms.) (Ej)
Claiborne Group (Yegua Formation) (Ec2)
Claiborne Group (Cook Mountain, Sparta, Weches, Queen City, and Reklaw) (Ec1)
Wilcox and Midway Groups (EPA)
Navarro and Taylor Groups (Ku2)
Austin, Eagle Ford, Woodbine, and U. Washita Groups (Ku1)
Fredericksburg and L. Washita Groups (Kl2)
Trinity Group (Kl1)
Cretaceous undivided (Ku)
Jurassic Triassic undivided (JT)
PALEOZOIC
Permian
Pennsylvanian
Cambrian
Precambrian
245 m.y.
286 m.y.
320 m.y.
505 m.y.
570 m.y.
1200 m.y.
2000 m.y.
Ochoan Series (Po)
Guadalupian Series (Whitehorse and Quartermaster Formations) (Pg2)
Guadalupian Series (Blaine and San Angelo Formations) (Pg1)
Leonardian Series (Pl)
Wolfcampian Series (Pw)
Permian undivided (Pu)
Virgilian Series (IPv)
Missourian Series (IPm)
Desmoinesian Series (IPd)
Atokan and Morrowan Series (IPam)
Mississippian, Devonian, and Ordovician undivided (MDO)
Cambrian (-C)
Paleozoic undivided (Pau)
Precambrian undivided (p-C)


Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System
Joint Capabilities Integration & Development System
Oversight & Review
Contracting
Major Products
Logistics/Sustainment
Defense Acquisition System
Technical
Financial Management
Planning, Programming, Budgeting & Execution Process
A
B
C

Remember that in the tactile space we don't have colors and textures (there is a small escape since there is a possibility of two different heights at each point).

Why is searching easier?

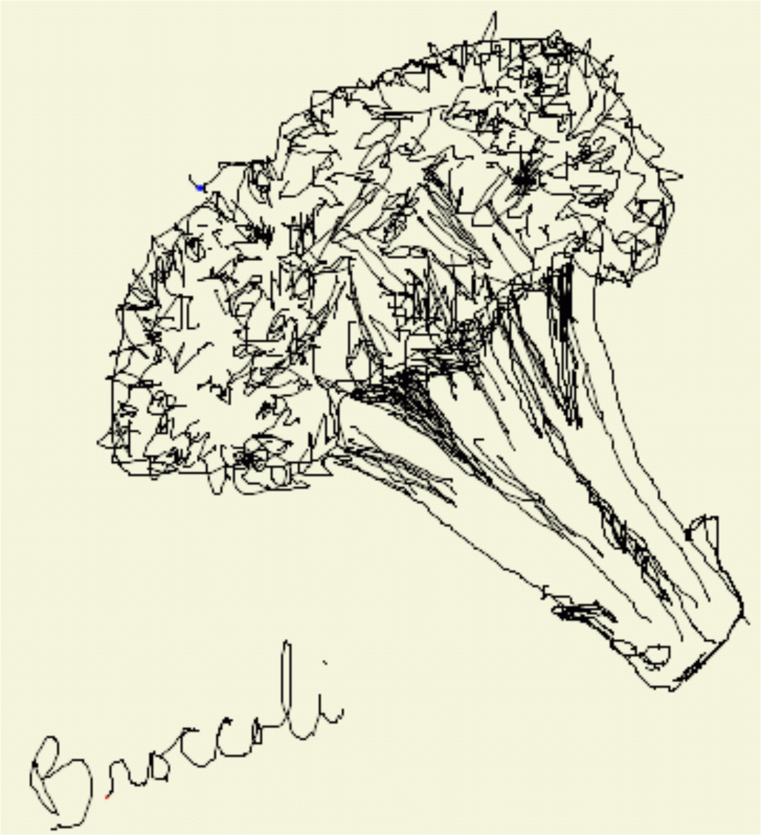
Nowadays, we can collect user observations: “people who looked at this image also looked at that one, or people who looked at text containing the words *cat* or *dog* then viewed the following images…”

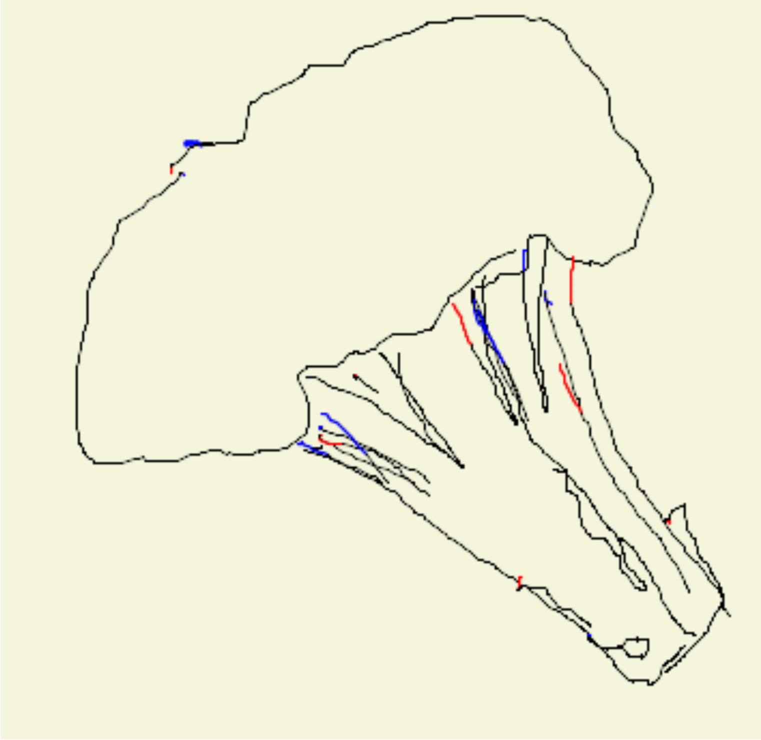
Summarizing is harder.

We don’t usually have a way to tell which features of an image somebody looked at – even eye tracking will not help when the problem is knowing what property at a particular spot (color, density, connectivity, etc) is most important.

The value of time data

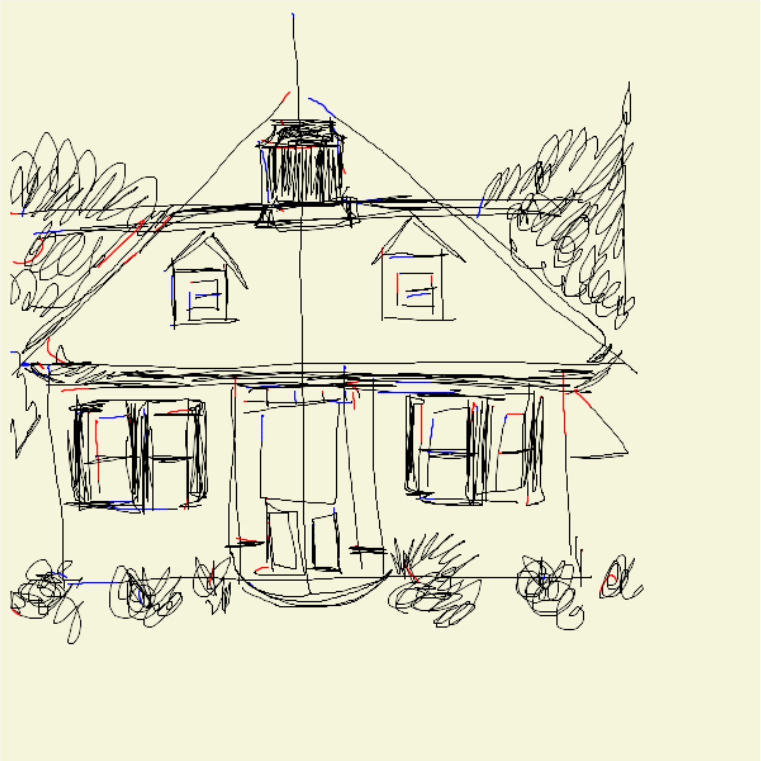
Sketches may give us a clue about what might be worth excerpting from an image. The right-hand picture is the first 10% of the strokes from the left-hand image.

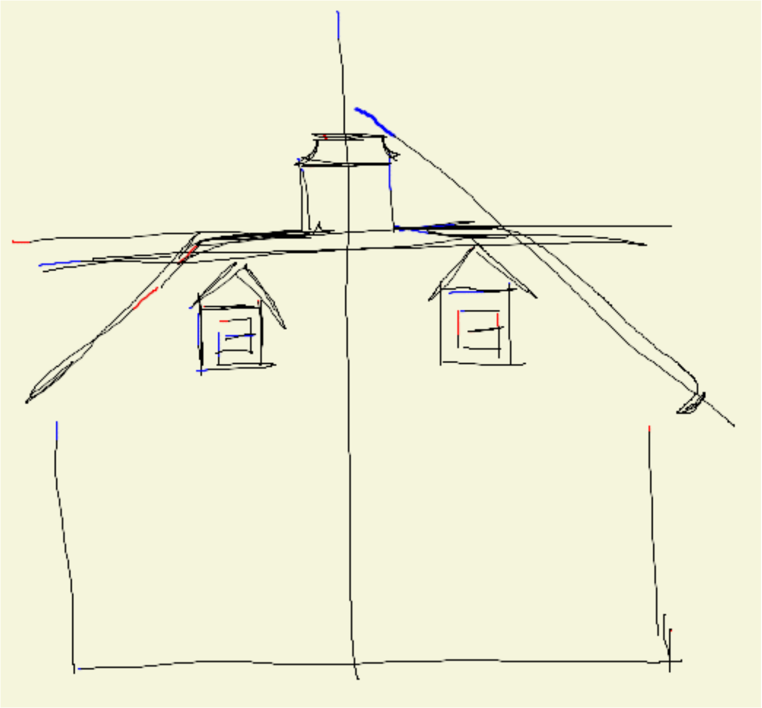




Another example

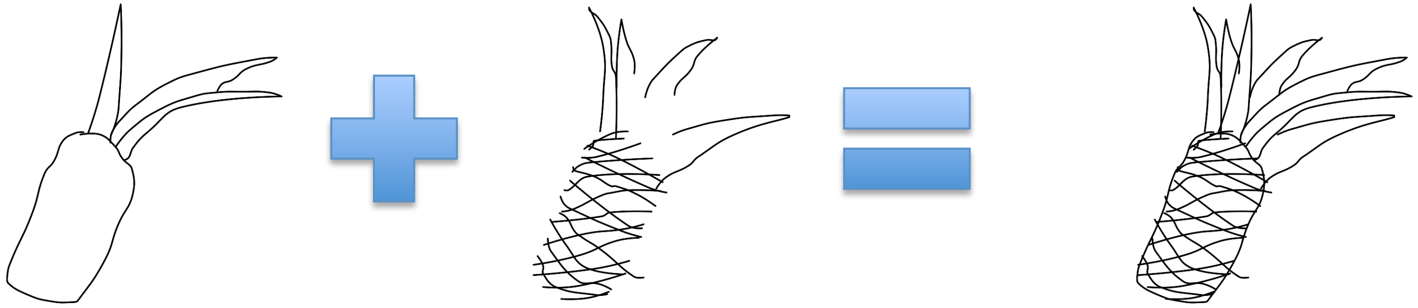
This time, the right-hand picture is the first 16% of the strokes from the left-hand image.





Recent dataset from SIGGRAPH

There are 20,000 sketches from "How do humans sketch objects" by Eitz, Hays and Alexa (2012) online; they were studying recognition rather than decomposition, and some of their sketches were made less carefully (which may not matter). The data include sequence if not timing. Again, the sketches typically start with the outside. The strokes in the left part are the first 10% of the strokes in the drawing.



Strategy for future

Suppose we try…

By having people sketch, define a set of examples of abbreviated images.

Then train an algorithm to abbreviate images.

Given simpler images, isolate segments that are more general.

What about the other hard cases?

I’m not a mathematician, nor a musician, so I’m not sure what to do about either theorems or scores. Theorems seem harder – you can’t just say “leave out the subscripts”. Music search is an active area; exact-match works (copyright infringement) and more technology is on the way.

Software has me baffled. There are no ambiguities, and the set of syntactic operators is usually fairly small, and the problem is just that the variable names are irrelevant. I can envisage searching for a sequence of syntactic structures, or using them as index terms, but no products yet. There is promising research at this conference; see poster by Tuarob, Bhatia, Mitra and Giles (Automatic Detection of Pseudo-codes in Scholarly Documents Using Machine Learning).

How are things changing?

In 1985 I gave a similar talk, at a SIGIR conference. At the time, drawing maps was new, so I talked a lot about maps. But the general problem is still the same. To quote from that paper:

“Today successful graphics routines contain a great deal of local domain knowledge. There is no analog of the simple keyword systems that handle textual documents in any subject area. Just as computational linguists have found that subject matter expertise is necessary to do really sophisticated processing of English, it seems also necessary to sophisticated processing of pictures; the difference is that we don't know how to do unsophisticated processing of graphics.”

Conclusion

I’m not denying progress. One step forward was SIFT features, and another was recognizing the power of visual dictionaries (exact matching).

But we still need better and larger scale methods for handling many kinds of visual information. And I look forward to methods that, without using words, will search across CAD databases, photographs, and paintings. There is research in this conference about higher level features – we need more of that.