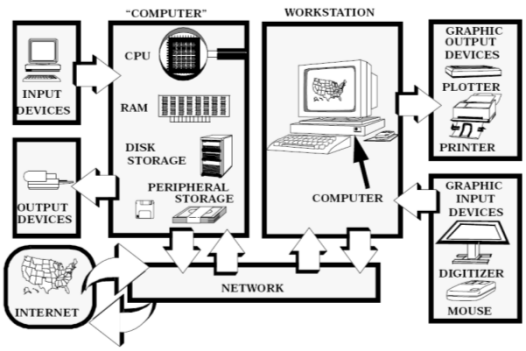
Geography 128

Lecture 6: Data Storage and Representation

Today's Themes

- How we represent the world makes a big difference in how we map it
- Technology impacts how the computer can store maps
- During the data capture and transformations errors abound: be wary!

Hardware for Computer Cartography

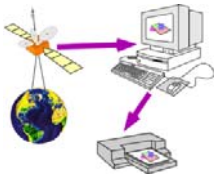


Clarke, K., 1995, Analytical and Computer Cartography

Input Devices for Computer Cartography

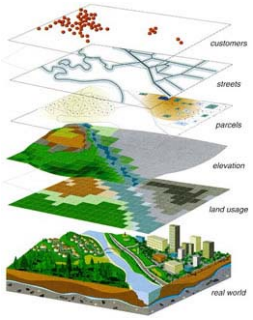
What is Geocoding?

- *"Geocoding is the conversion of spatial information into computer-readable form. As such, Geocoding, both the process and the concepts involved, determines the type, scale, accuracy and precision of digital maps"* – K., Clarke, 1995
- Geocoding involves capturing the coordinates, and sometimes also capturing the attributes
- Often involves address matching



What is Geocoding? (cnt.)

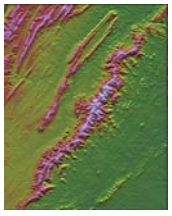
- Real world broken into phenomena, landscapes
- Phenomena can be broken down into cartographic entities
- Entities are geocoded to become cartographic objects
  - Geometry
  - Topology
  - Attribute



Two fundamentally different data models

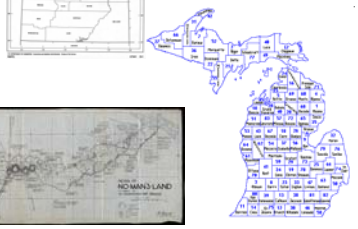
- Features
  - Objects
  - Entity-by-entity
  - Point/Line/Area/(Volume)
  - Based on coordinates with given precision

- Fields
  - Variable is continuous
  - Measurement can take place anywhere
  - Samples are used, sampling strategy matters



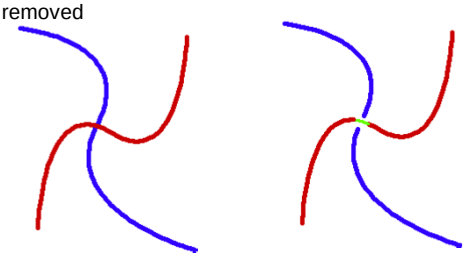
Common issues with Cartographic Data Models

- Holes
- Undefined areas
- Discontinuities
- Multi-values
- Uncertainty



Topology

Topology - The spatial relationships between connecting or adjacent map features (e.g., points, lines, and polygons) that remain when geometry is removed

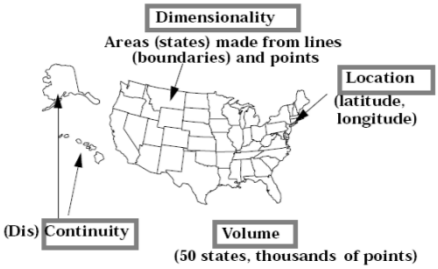


Non-topological Approach

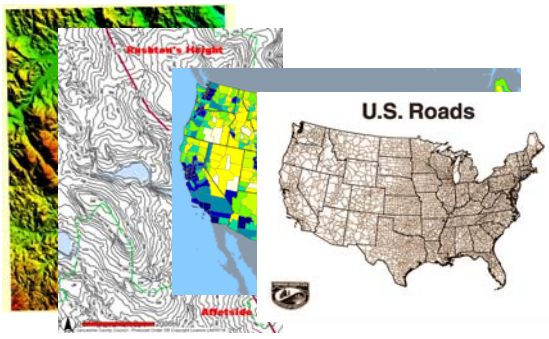
Topological Approach

Characteristics of Geographic Data

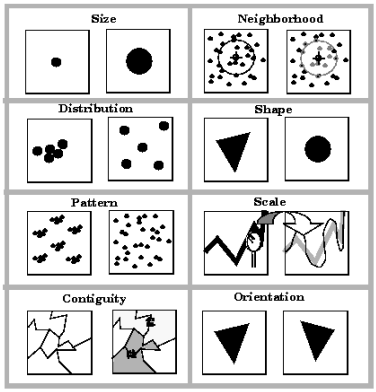
- Geocoding is the process of digital-encoding the fundamental characteristics of geographic data
  - Location
  - Volume
  - Dimension
  - Continuity



Continuity vs. Discontinuity

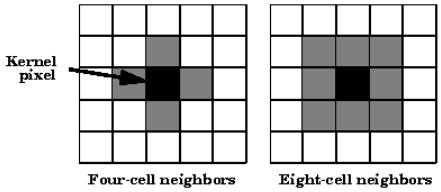


Fundamental Properties of Geographic Objects



Fundamental Properties of Geographic Objects (cnt.)

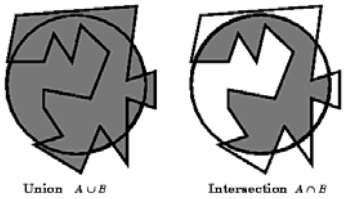
- Neighborhood



Fundamental Properties of Geographic Objects (cnt.)

- Shape
  - Lee and Sallee index

$$s = 1 - \frac{A \cap B}{A \cup B}$$



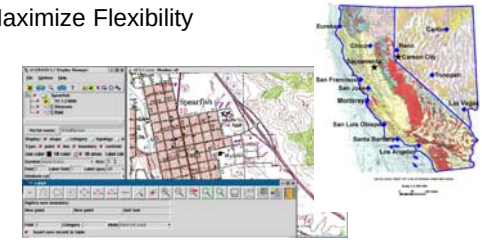
Punggye-ri Nuclear Test Facility in North Korea

Measure the Properties of Geographic Objects

	POINT	LINE	AREA	VOLUME
SHAPE	Feature type	Curvature	Shape measure	Dimension Resemblance to figure (e.g. cone)
CONTIGUITY	Link	Intersection	Shared boundary	Shared face
ORIENTATION	Of cluster or pattern	Bearing Trend	Of axis Of pattern	Dip, drift, trend, aspect
SIZE	Number	Length	Area	Volume Surface area
SCALE	Range at which object is a point	Range at which object is a Line	Range at which object is an area	Range at which object is a volume
NEIGHBORHOOD	Set of nearby points	Connected lines. Lines within a range	Contiguous areas Area within a range Connected areas	Adjacent voxels Overlapping volumes Shared faces
PATTERN	Pattern matching Fourier analysis	Curve measures Fractal dimension	Shape distribution Description	Fourier power spectrum Trend surface
DISTRIBUTION	Standard distance Nearest neighbor number Autocorrelation	Line density Length, Intersection frequency	Coverage Autocorrelation	Variogram

Goals of Geocoding Methods

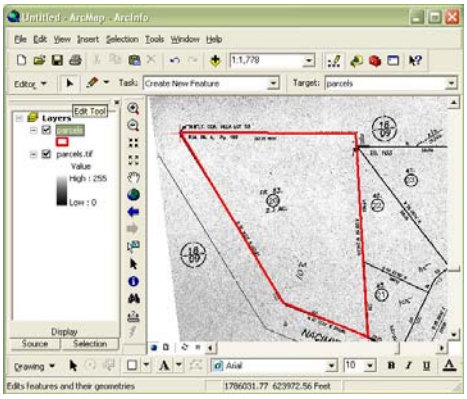
- Minimize Labor Input
- Detect and Eliminate Errors
- Optimize Storage Efficiency
- Maximize Flexibility



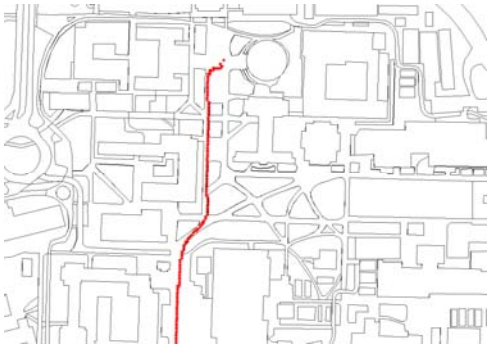
Geocoding methods for maps

- Digitizing
- Scanning
- Field data collection

On-screen digitizing



GPS navigation/tracks



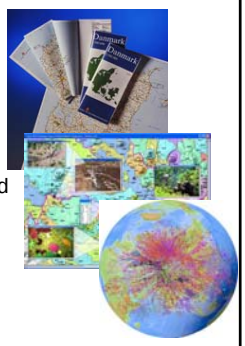
Address Matching

- Most GISs contain capability
- Start with 123 State St, Santa Barbara, CA 93101
- End with Coordinates

- May need to interpolate along blocks
- Street number range, left and right side e.g. 101-199

Storage Media

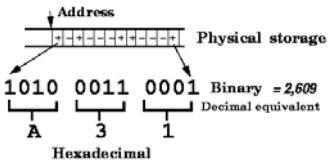
- Traditionally, the paper map has performed a storage function for spatial information
- Computer cartography requires information to be digital and stored explicitly
- Storage is increasingly distributed over networks
- Many mapping programs require local storage of data
- Cost and size restraints now less important

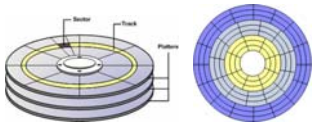


Evolution of Storage Media

Physical Storage

- Bit - the most basic information unit in a binary system (1 / 0)
- 1 Byte = 8 bits
- Binary (2-based), Decimal(10-based), and Hexadecimal (16-based) System
- Binary Operator – AND, OR, NOT
- Data on a disk -Sectors, Tracks, Platters
- File system – File, Directory





Maps as Numbers

- Map data is stored in the computer's memory in a physical data structure (i.e. files and directories).
- Files can be written in binary or as ASCII (American Standard Code for Information Interchange) text.
- Binary is faster to read and smaller, ASCII can be read by humans and edited but uses more space.

ASCII Table

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

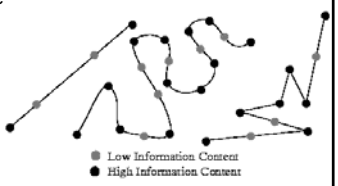
ASCII Table (extend)

128	Ç	144	É	161	í	177	▒	193	┴	209	╤	225	ß	241	±
129	ü	145	æ	162	ó	178	▓	194	┬	210	╥	226	Γ	242	≥
130	é	146	Æ	163	ú	179	│	195	├	211	╙	227	π	243	≤
131	â	147	ô	164	ñ	180	┤	196	─	212	╘	228	Σ	244	⌠
132	ä	148	ö	165	Ñ	181	╡	197	┼	213	╒	229	σ	245	⌡
133	à	149	ò	166	ª	182	╢	198	╞	214	╓	230	µ	246	÷
134	å	150	û	167	º	183	╖	199	╟	215	╫	231	τ	247	≈
135	ç	151	ù	168	¿	184	╕	200	╚	216	╪	232	Φ	248	°
136	ê	152	ÿ	169	⌐	185	╣	201	╔	217	┘	233	Θ	249	∙
137	ë	153	Ö	170	¬	186	║	202	╩	218	┌	234	Ω	250	·
138	è	154	Ü	171	½	187	╗	203	╦	219	█	235	δ	251	√
139	ï	156	¢	172	¼	188	╝	204	╠	220	▄	236	∞	252	⁻
140	î	157	¥	173	¡	189	╜	205	═	221	▌	237	φ	253	²
141	ì	158	₧	174	«	190	╛	206	╬	222	▐	238	ε	254	■
142	Ä	159	ƒ	175	»	191	┐	207	╧	223	▀	239	∩	255	
143	Å	160	á	176	░	192	└	208	╨	224	α	240	≡		

Source: www.LookupTables.com

Storage Efficiency and Data Compression

- Cartographic data sets are typically large
- Need to reconfigure data formats, structures etc.
- Seek to retain information content, lose volume.
- Is redundancy necessary?

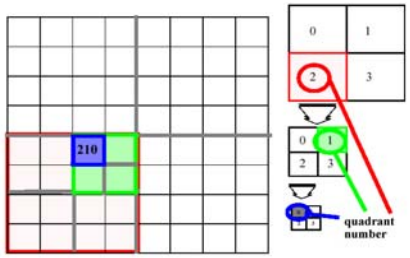


Storing Coordinates (Vector)

- Physical Compression
  - 4,513,410 m N;587,310 m E; Zone 18,N (32 characters, 15 digits)
  - 4513410 587310 (13 digits, one space) Need metadata
  - 98 96 7F 0F 42 3F (six bytes)
- Logical Compression
  - Drop last two digits (10 ASCII or 2 bytes per coordinate)

Raster data Compression

- Run-length encoding
- Quad-trees
- …

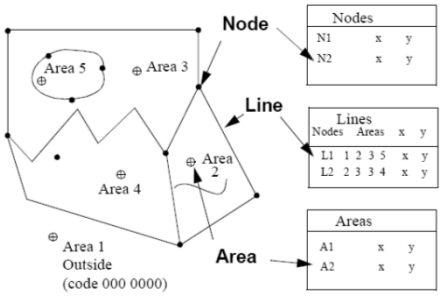


Data Storage Formats for Cartography - U.S. Geological Survey

- DLG – Digital Line Graphs (1:24,000; 1:100,000; 1:2,000,000)
- DEM – Digital Elevation Model (1:24,000; 1:250,000)
- GIRAS – Land-use and Land-cover Digital Data (1:100,000; 1:250,000)
- GNIS – Digital Cartographic Text

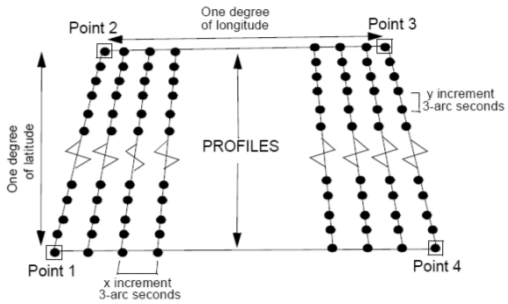
USGS science for a changing world

Data Storage Formats for Cartography - U.S. Geological Survey



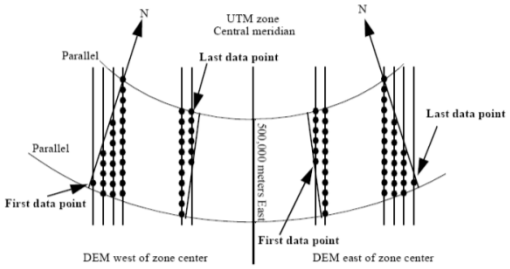
USGS DLG format

Data Storage Formats for Cartography - U.S. Geological Survey



USGS 1:250,000 3-arc second DEM format (1-degree block)

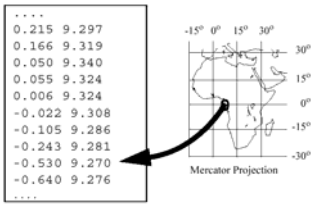
Data Storage Formats for Cartography - U.S. Geological Survey



USGS 1:24,000 30 meter DEM format (7.5-minute quadrangle)

Data Storage Formats for Cartography - CIA World Data Bank

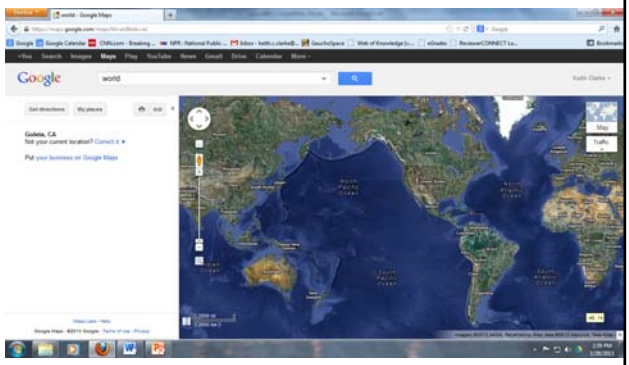
- WDB I (1:12M base, 100K points)
- WDBII (1:3M base, 6M Points)
- DCW 1:1M base- 4 CDs, 14 layers DMAs VPF



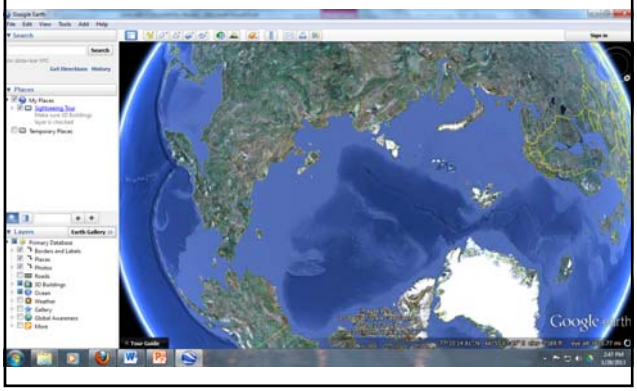
Storage Issues

- Compression: Lossy vs. Lossless
- Ease of Access (Time, # operations)
- Reliability
- Permanence
- Backup
- Redundancy
- Detail and Scale
- Tiling, Mosaicing and Joining “Seamless” Database
- Maintenance, management
- Metadata (embed vs. attach) e.g. GeoTIFF

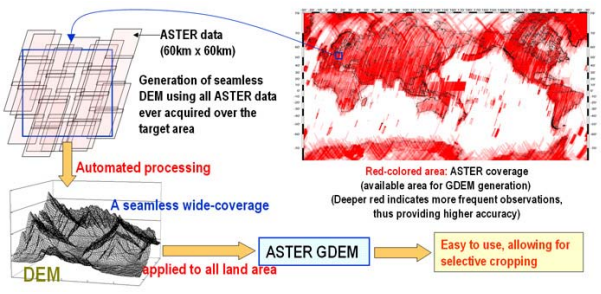
Web-Mercator



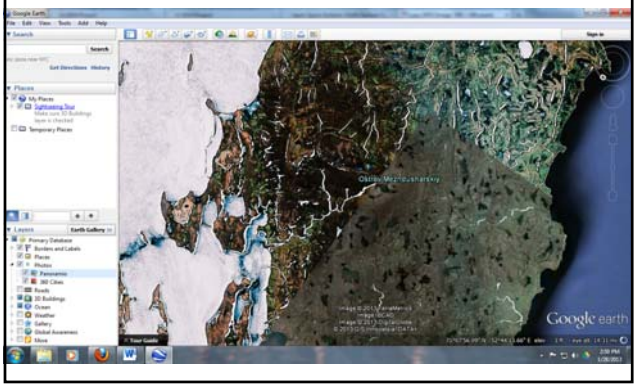
Tiles and Seams



Tiling: ASTER GDEM



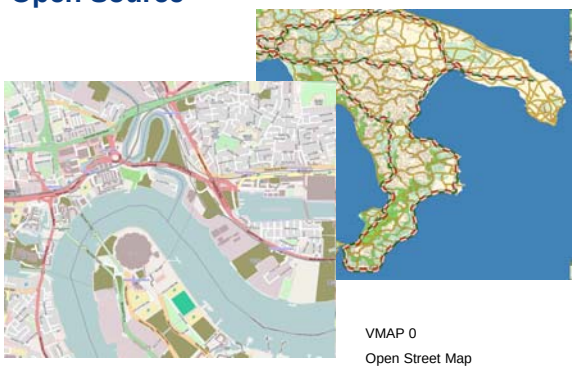
Discontinuity in Time and Space



Data unlimited

- Proprietary vs. Open Source
- Accessible (i.e. Discoverable) vs. Isolated
- Protected, e.g. Private, Sensitive, Classified, Denied, Watermarked, Steganography
- Web-accessible, web-enabled, clearing house
- NSDI, GSDI, Digital Earth

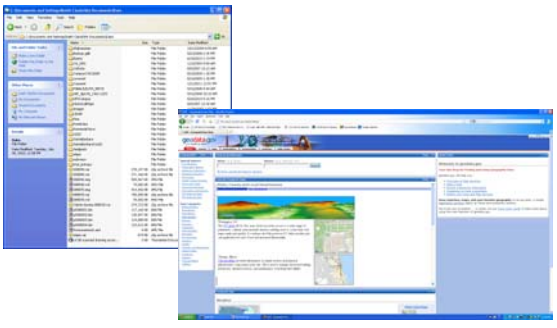
Open Source



VMAP 0

Open Street Map

Isolated



Denied Data

Hidden Data

Image of a tree. Removing all but the two least significant bits of each color component produces an almost completely black image. Making that image 85 times brighter produces the image below.

Image of a cat extracted from above image.

Cartographic traps

- Kerbela Street, Shrewsbury, England. Just off Meadow Farm Drive in Shrewsbury Google Maps shows a Kerbela Street, which does not physically exist at this location or even exist at all in Shrewsbury, according to Royal Mail.

AA in £20m battle over 'copied' Ordnance maps

Future Memory: Efficiency vs. Access

Whole internet on a disk?

Search systems: Information value vs. content

Dynamic and Real Time GIS