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Proper Maps

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Abstract. GPS and digital mapping allow unprecedented accuracy, and the precision of digital storage has replaced the vagueness of the cartographer's pencil. We can dispense with sketch maps for tourism or how-to-get-here instructions instead using proper online maps. But a map is not just a miniature version of a landscape, but an instrument for navigation, education, stories, and experience – not all maps are 'proper' maps set on Cartesian grids. This paper discusses several maps of varying levels of propriety to explore the theoretical and practical world of cartography and suggest how digital technology can enable a diverse ecology of improper mapping.

Keywords: digital mapping, navigation, spatial cognition, cartography, human-computer interaction.

1. Introduction

I have been fascinated by maps since childhood; a love shared I'm sure by many readers of this article. Memorable maps for me included a large (~80cmx50cm) cardboard-backed map of the British Isles showing Heinz factories, which I got from a grocers where it had been part of a promotional display; a small metal globe perhaps 12 cm in diameter that I kept for years even after the stand had broken and from which I planned running around the world, swimming between Russia and Alaska via the Aleutian Islands; and a torn fragment of an ex-military map that later I worked out was part of Turkey, but fascinated me by its exotic names. Maps were the means to dream about far-away places or simply get around a sea-side town on holiday. Maps on the pages of an atlas, neatly folded out on paper or cloth, the printed linear route maps posted by the AA, or the model village that mirrored the real village (is this a map?), where you could walk giant-like along its streets and even gaze down at the model of the model village set inside – intimations of Borges [1] or Royce's "maps within maps" [2,3].

Not all of these are 'proper' maps in the sense of precise Cartesian projections – if there can even be a 'precise' projection of slowly shifting contents, eroding coastlines or meandering river deltas. Maps capture diverse human needs and aspirations, they embody political viewpoints, local knowledge and personal meanings; in Kitchin and Dodge's terms they are transitory, fleeting, contingent, relational, context-dependent

and "*enacted to solve relational problems*" [4]. The journey maps we'll see in Section 4 have a wide variety of forms, most not standard, and other projects such as Parish Maps [5] and Making Maps with Gaps [6,7] have found an equally wide variety. Digital mapping has made it ever easier to include a 'how to find us' map on a web page, but in the process runs the risk of eradicating the diversity of forms and the richness of locality and place by establishing a global norm, which, like Newspeak in 1984 [8], makes particular views unsayable. This paper celebrates non-standard and improper maps, the grounded reactions against the alienation of a view from afar, and asks how digital mapping can support diversity rather than impose homogenisation.

The next section will ask (but not answer definitively), "what is a map?". This is followed by two sections: the first theoretical introducing several lenses that we can use when thinking about maps and the second practical looking in detail at specific maps (digital and non-digital). Drawing on this joint theoretical and practical base, we will consider how digital technology changes our understanding of maps creating opportunities and challenges and then distil some of the lessons into concrete design advice

Note, this paper will focus on maps that are principally visual in nature as opposed to auditory or tactile maps. These non-visual maps are a critical area in their own right, especially when thinking about digital mapping applications, but it is largely beyond my own professional expertise and personal experience.

2. What is a Map?

It would be useful when writing about maps to know what actually constitutes a map and as the model village highlights, this is not clear cut. This section will not formally define 'map' – indeed the value of definitions lies less in the (usually flawed) binary distinction they create, but in the thinking that they provoke. However, we will briefly consider two key features (scale and abstraction) that in part explain a common understanding of the term. Both will recur later in the paper as we look at theoretical lenses and practical examples of maps.

2.1 Model or map

As suggested when thinking about a model village, it can be a little unclear what constitutes a map, even when thinking about 'maps' depicting geographic or topographical features let alone more abstract 'maps' of cyberspace [9,10].

As with many things it may be easier to recognise a map than to define the term. Flat sheets of paper that denote landscapes are clearly maps … although we will see at least one example later that perhaps pushes this definition. Three-dimensional relief maps are also common, both table-sized ones as found in visitor centres and wall mounted versions rendered in moulded plastic or laser-cut plywood. Note that while a flat map has to use contour lines or shading to represent height, 3D maps typically have to exaggerate height as using the same vertical and horizontal scales leads to maps that are neither visually impressive, nor helpful.

Scale matters here. In 2006 a Google Earth watcher spotted a vast 3D model of a landscape near the village of Huangyangtan in China 11] (see Fig. 1). The model was nearly a kilometre in size but represented an area perhaps 30 times greater with multiple mountains, valleys and lakes [12]. The purpose of it was never clear, but is it a map? The Google Earth images are map like, but then so are the Google Earth images of terrain itself. On the ground even a high tower would struggle to get a good view and the (assumed) military compound beside the vast model lies to one side only so it would appear the model is more to be walked around than looked at, except locally. Like the model village this pushes our idea of a 'map'.

Fig. 1. Area near Huangyangtan in China – Google Earth screen shot from [12].

2.2 Human scale

The model in China seems a little too large to be a map. In contrast table or wall-sized war room maps are unproblematic. The latter are large, but still 'human scale'.

There is an extensive psychological study of space (see also Section 3.4 below). This typically distinguishes the area immediately around our own body, which we can largely explore with our hands and within which we manipulate objects without moving location, and the larger space that we need to walk or otherwise move around. However, that larger space itself has two broad parts: there are the things you can see (vista space) and those out of sight (navigation). The distinction is more about the environment than the body: in a forest or building the former is small, but in an open plain it might extend many miles. Crucially these larger two (environment-dependent) scales differ in the way in which we perceive and navigate them. The vista space uses vision and, as a walked landscape, is effectively 2.5 D. The larger space is more a network of connections, paths, and landmarks between interconnected vista spaces, and is perceived through memory and mental 'maps'.

These three scales are summarised in Table 1. Note that while the body–large distinction is explicit in the psychological literature, the vista–navigation distinction is occasionally implicit but rarely if ever explicitly articulated.

Table 1. Three body scales from [13], Chapter 12 Comprehension of Space.

Scale	Representation	How sensed
body space	3D	proprioception
vista space	2.5D	vision
navigation space	network	memory and maps

If you are in hilly or mountainous country and unsure of where to go one automatically seeks higher ground from where one can see the lay of the land and plan a route. In a forest, the intrepid may similarly climb a tall tree, indeed 'lookout trees' are still used as part of fire protection in some forested areas. Gaining the high ground transforms navigation space into vista space.

It is interesting that some maps, especially tourist maps, effectively still use this 'hilltop' perspective rather than the standard bird's-eye view. Whichever projection we are using, maps of the wider landscape effectively do the same job as climbing the lookout tree. Most maps represent navigation space in vista space or body space so that it can be apprehended visually and/or (albeit less commonly) physically.

2.3 Abstraction

Another key aspect of the Huangyangtan model/map, but also of the model village, is that if something is too close to the real thing it no longer feels like a 'map'. Online Maps including Google and Bing use satellite imagery, but this is overlaid with schematics of towns and roads. This is well debated in the geographic literature not least Korzybski's "a map is *not* the territory" [14] or Borges' lampooning of the ultimate 1:1 scale map [1]; more broadly this connects with the idea of the 'infinite archive' [15] – when everything is in the archive it is no longer useful.

Selection and abstraction are thus critical to a map, and intimately connected with its *purpose*, which we'll revisit later in this paper.

3. Lenses

Let's look at a few theoretical lenses through which we can think of maps. 'Lens' feels an apposite word for looking at maps. As a child my parents had an AA Book of the Road, which, in addition to being a road atlas of the UK, was also full of information about nature, places and road signage. Free with the book was a torch and lens combination using which my mother navigated when we drove at night. Of course, the lens only magnified a small portion of the map, multiple lenses are always needed.

3.1 Form and function

While much debated, architect Louis Sullivan maxim "*form ever follows function*" is certainly one of the best-known design heuristics. Unlike modernist buildings, maps rarely entirely eschew ornamentation, even the functionalist military-originated UK Ordnance Survey (OS) maps have a photo on the cover. However, there is always a relationship between the form of a map and its function, the purpose for which it is intended to be used. Even for the precise military needs of destruction, the navigator in a Second World War bomber cockpit did not unfold a full sheet of an OS map, but instead had a linear map on a reel that could be wound on as the mission progressed. For long distance trails in the UK Harvey maps produce sheet maps, but where the sheet is a series of linear segments along the way.

The form of a map has at least three facets: the physical format (e.g. paper, cloth, plastic, digital, wall mounted or folded), the large-scale structure (e.g. 2D "God's eye view", linear) and fine scale details (e.g. contour lines or shading, roads, geology, buildings).

The purpose also varies tremendously. Maps can be used for navigation, getting from A to B, for simply getting a feel or understanding of the topography of area, for finding out what is there, say when planning a holiday or avoiding building a new house on contaminated ground, for virtual/vicarious tourism (like my childhood plans for walking and swimming round the world), or for defining space when buying or selling land.

Sometimes maps are produced for specialised purposes, for example geological maps which identify few if any towns or cities and rarely represent any above-ground features at all beyond coastlines. Similarly traditional tourist maps were often fish-eye projections that exaggerate (relative to standard mapping) the size of the centre of a town so that key features are easily found, whilst showing the periphery shrunken, where tourists were sparse. Others, such as OS maps, have to cater for a wide variety of needs inevitably leading to compromise.

3.2 Representation and semiotics

Both Borges imaginary 1-to-1 scale map [1] and Korzybski's "a map is *not* the territory" [14] were not so much about maps, but using maps as an accessible analogy for the models of science. It is clear to the everyday reader that a map *represents* the landscape rather than reproduces it. We do of course normally expect that the map does in some way *faithfully* represent the real, fictional or virtual landscape. Korzybski considered two trivial linear maps of Paris, Dresden and Warsaw.

(a) Paris – Dresden – Warsaw
(b) Dresden – Paris –Warsaw

The first has structure similar to the actual locations of the cites, whereas the latter has "a *structure not similar* to the territory", and thus potentially misleading. This was then used as a way to talk about the verisimilitude of language and mathematical abstractions. However, even this simple example demonstrates the complexities of maps for different purposes. If Air France were the dominant airline in Europe, then map (b) might well be the more useful representation for the frequent flier. John

Speed's 1610 map of Wales has a coastline that looks not very different from a modern 'proper' map, whereas the interior looks more like maps of centuries earlier, towns placed alongside vaguely meandering rivers with schematic mountains between. However, the purpose of the representations were different: at sea straight lines and compass directions are critical, whereas inland it is the routes along valleys that matter – within the same map the appropriate verisimilitude varies.

Within human–computer interaction, we expect user interfaces to be designed respecting the needs, goals and capabilities of the user. One of the key differences between Saussurean and Piercean semiotics is Pierce's addition of the 'interpretant' the way that a sign has an impact on the person perceiving it. Part of the complexity of writing a text, designing a computer application or drawing a map is that the author is not present at the point of interpretation, there is no dialogue, no feedback or opportunity to correct misinterpretations, the object: the book, code or map stands in for the person who produced it.

At their simplest, maps are a communication about the landscape between the cartographer, who knows about it, and the cartographee (the user of the map), who needs that knowledge to find their way or for some other purpose. The gulf of time and distance between the two means that the cartographee needs to understand the symbols on the map and the cartographer must both choose these to be comprehensible (with a map legend of course) and also envisage the potential ways in which the cartographee will use the map in practice.

However, maps do more than communicate; they change the world. Speech-act theory identifies some kinds of utterance as *performative*, they do not just describe what is but make it so; examples include naming a ship, declaring a couple are married or swearing in a new president [16,17]. Similarly maps have been used to declare borders and areas of influence from Pope Alexander VI carving out South America between Spain and Portugal to the 49th parallel between Canada and the USA [18]. Even without such grand strokes of the pen every map enforces a certain reality whether it is the name of the waters between Mexico and the USA or which named features appear first as one zooms into a Google map.

3.3 Stories and journeys

Stories are often intimately connected to maps fictional and factual, think about Arthur Ransom's maps of sepia-tinted Lakeland – the places marked are both the locations of incidents and connections to places far off. My memories of the Heinz map of Britain include not only the Heinz factories, but also images of gurning, Westmorland wrestling and other local customs and landmarks. Often these stories are about journeys, the road movie dates back at least to the Argosy and Exodus in Western tradition, and in Australia the story is the map, the way in which land is experienced and navigated.

Arguably the use of a map to tell a story or the story to be the map are simply examples of function and form. However, they are special in that while intimately describing locations and topography (for example the land journey of the Argo over the central European watershed), this is not what they are *about*. Stories are about people and culture.

Geographers have long debated the relationship between space and place [19] and this has also found its way into the human–computer interaction literature [20]. The meanings of the terms are somewhat fluid and differ between authors, but broadly 'space' is about Cartesian location and extent, whereas 'place' captures rich human social and cultural connotations.

Writers have worried about the way malls, out of town cinema complexes and massive travel hubs have eroded this sense of place. Fifty years ago, Relph [21] introduced the term *placelessness* – "*the casual eradication of distinctive places and the making of standardised landscapes that results from an insensitivity to the significance of place*" and Auge [22] talks about *non-places*. In fact, for those who work in them these 'non-places' have a rich social significance and many people will tell you about their favourite motorway services – humans can even stamp an identity on supermodernity! Perhaps more resistant to this place-ing of space have been the hi-rises and edge-of-town estates that replaced the bulldozed slums of the 1960s and 1970s, and which are often feared as seed beds of crime and even terrorism … the modern equivalent of "here be dragons".

Individuals, organisations and governments have reacted to this loss of place and the UK has funding initiatives towards 'place-based' research and action. We'll see examples later of the way that maps can help create a sense of place, but this should be set against the way that the ease of digital mapping has replaced the local tourist maps that were once common and in so doing potentially dis-placed the communities.

Elledge [23] draws a related distinction explicitly between states (political institutions) and nations (cultural, social and sometimes linguistic) and implicitly (because he is writing about often shifting borders) the physical patch of land on/within which they reside. For example, the UK is a single state comprising four nations (Wales, Scotland, Norther Ireland and England), the internal borders between which (their physical location) has shifted within my own lifetime. Elledge's 48th border in his 'History of the World in 47 Borders' [23] relates to Poland, which has been an identifiable nation for many hundreds of years, but has had periods when it has been amalgamated within or divided between multiple states and its current physical location is by no means where it has always been. Similarly, based on an artistic exploration of maps used in the reporting of current and recent wars, Jöns Mellgren notes how maps offer a "*fantasy of objective knowledge*" as they use hard borders to represent the inevitable fuzziness of front lines [24].

There are also related connections between journeys and routes/paths, although different in that the journey is about a specific individual or groups traversal of a route, mor akin to an event that happens at a particular location. We can of course now record every journey we take on running/walking apps maybe saving them and publishing them for others to follow, creating routes from journeys. However, there is also a space/place-like distinction when we look at paths. There is the line on the map, the tarmac, gravel or mud on the ground, the Cartesian coordinate in the GPX file. However, the Camino de Santiago is more than dashes across a map or scallop shells along the way, it is history, spirituality, personal stories, places where new friendships were forged or simply momentary human contact as one pilgrim greets another.

Ingold, inspired by his early studies of Skolt Sami reindeer herders, sought to privilege lines, the trails across the ground, as more than connections between places,

but instead the primary form of lived experience for those who travel them [25]. Indeed, we all live our lives in movement and only become associated with a specific spot when buried. Ingold distinguishes human 'wayfinding', which creates a *meshwork* of journeying, from point-to-point connection, but does not name the distinction between the inhabited (in motion) path that is a social nexus (albeit sometimes fleeting) in contrast to the line on the ground that the inhabited path follows. Just like places, these inhabited paths may actually change their cartographic line, for example, the Wales Coast Path has altered its route due to changing public access agreements and physical erosion. Perhaps we need names for these place-ish and space-ish paths.

3.4 Psychology and neuroscience

There is and extensive literature on the psychology of spatial navigation. This was revolutionised by the use of virtual reality enabling realistic environments to be designed and reproduced without experimental subjects moving more than their fingertips, and hence allowing extensive laboratory and web-delivered studies limited only by one's Mechanical Turk budget. Technology has also been critical in the neuroscience of navigation enabling maze running experiments with live electrodes mapping the lab rats' brain activity, in some cases at the level of individual neurons, and a little less invasively for humans with brain scanning and scalp-worn EEG. Bond's 'Wayfinding' [18] is an excellent introduction to both areas.

As noted earlier the psychological literature tends to conflate the vista space, which can be apprehended visually, and navigation space, which is traversed by paths. Experiments tend to create wall-rich and maze-like within-building or urban environments, so effectively operate in navigation space. The literature does identify two key *styles of navigation*, one more route-focused based on landmarks and sequential steps, the other involving mental maps, usually assumed to be bird's eye – the former can be thought of as a raw mechanism for navigation space, whereas the latter is projecting this distant space into vista space or body space as discussed in Section 2.2. Linear and 2D maps can be seen as supporting these two navigation styles respectively, although it should be noted that while individuals may favour one or other navigation style, most people are able to switch between them quite fluidly.

The most common task in experiments is to take subjects through a labyrinthian VR simulation and then ask them to point to the start, or some other place they have explored. Sometimes this is made slightly more ecologically valid by asking them to take a short cut. The ability to do this is usually taken as an indication of a good mental map, but there are other strategies such as 'seeing through' walls. Try this at home or your office, sit in a room and look in a direction; can you imagine what is straight in front of you? You are probably mentally turning the walls to glass rather than looking at a mental plan of the building. Note also that these experiments rarely involve actually turning or walking, so one's ability to perform 'path integration' (internally keeping track of location through dead reckoning) is severely hampered.

Of course, most maps do take the bird's eye view analogy, but these different methods of navigation can suggest alternative projections, for example augmented

reality allowing someone to see through the buildings in a manner similar to Saul Steinberg's View of the World From 9th Avenue [26].

Experiments on rats have found a rich collection of neural mechanisms to deal with the exploration and navigation of space, which are assumed to have human analogues. This includes 'place cells' in the hippocampus that fire when the rat at a particular location, but have no geometry in relation to one another and 'grid cells' that are laid out in honeycomb-like hexagonal patterns. It is tempting to think 'place' and 'space', albeit this is an over-simplification as the cells are re-used and re-mapped (*sic*) when the rat enters or leaves a space. This said, place cells are thought to be related to the memorisation of events and there must be longer-term variants of these transitory structures, which would have a place-like nature. Furthermore, it is known from memory research that crossing thresholds (such as doors between rooms) traverses 'event boundaries' so that things memorised in one setting are retrieved less well in others [27]. This corresponds very closely to the save-reload nature of place-cells.

4. Maps in the wild

This section looks at some examples of maps that are to different extents proper or improper. It starts with some hand drawn maps as this introduces a vocabulary which is useful when we consider other maps.

4.1 Tiree Journeys

While giving a keynote at ACM CVE 2000 [28] I asked the participants to draw how they got to the conference. I had prepared a slide to show afterwards with five kinds of drawing I was expecting and a gap for the unexpected. The expected categories were:

- *cartographic (isomorphic)* – 'standard' Cartesian bird's eye view maps
- *cartographic (homomorphic)* – a map but where distances and features may be expanded/reduced
- *schematic* – some level of direction layout, but with no attempt to make a 'proper' map and usually just picking out key features for the journey
- *linear* – the route straightened, similar to some road maps, usually with key places marked
- *episodic* – similar to linear, but focused more on the incidents and events which made up the journey

I've repeated the exercise several times since and, with one exception, all the drawings have fallen easily into these categories. Fig. 2 shows examples of some of the drawings produced after such an exercise at a Tiree Tech Wave in 2011 [29,13].

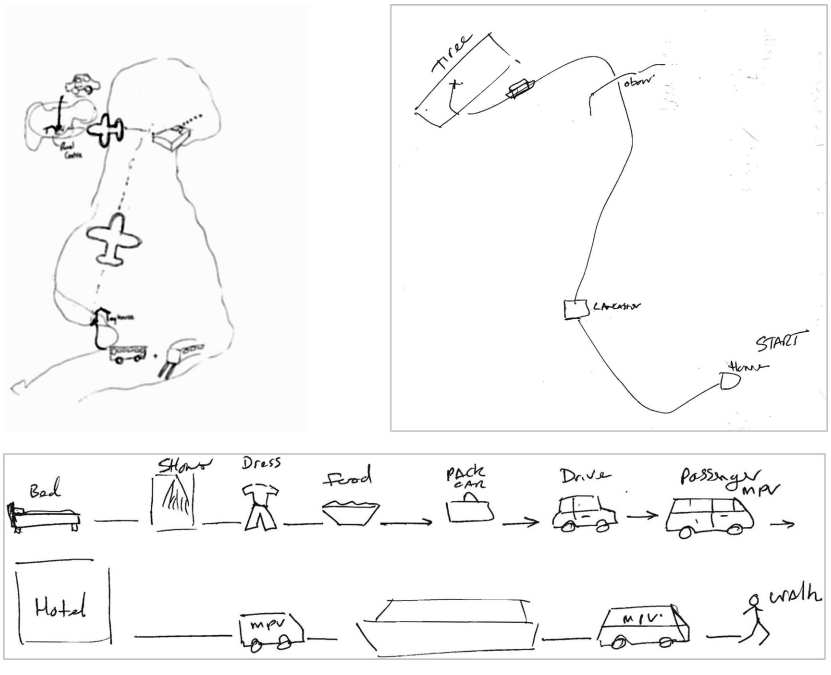

Fig. 2. Journeys to Tiree Tech Wave, November 2011 [29,13]: (top left) cartographic (homomorphic); (top right) schematic; (bottom) episodic.

At the top left of Fig. 2 is an example of a cartographic (homomorphic) map. The shapes are very simplified, but clearly trying to create the overall coastline of the mainland of Britain; the island of Tiree is in the current overall location, but about 20 times larger compared to the rest of the map. The map also shows the key waypoints along the way and the modes of transport.

At the top right is a schematic map, a line denoting the journey that swings to represent the direction of travel. Again the distances are shrunk/stretched with the few miles from home to Lancaster (where the artist met colleagues) of similar length to the 250-mile journey from Lancaster to Oban. Note that this person's route led through Glasgow, but that was not marked as it did not have significance for the journey.

Finally, the map at the bottom is purely episodic; indeed bed, shower, dress are all activities at the same location, so that the drawing is almost purely a timeline of events. While this does not seem like a 'map', it is reminiscent of songlines that weave Aboriginal knowledge of the land in parts of Australia.

Note that while the wording of these tasks tried to avoid terms like 'map' or 'route' so as not to influence the drawings, they were very much focused on the journey to the event. Different instructions might well elicit different outcomes; indeed, Bond documents examples of maps that Londoners drew as part of a project [18]; they are all variants of the cartographic (homomorphic) form.

The one time that a journey drawing did not conform to the expected categories was a sort of 'time tunnel', an image like a long alleyway with key landmarks placed om either side, rather as if one had looked along the route through the wring end of a telescope. This shared aspects of Steinberg's View of the World From 9th Avenue [26], but with a focus on the journey, so more an extreme version of an episodic map.

4.2 Frasan – opening up the archive

Fig. 3 (left) shows Frasan a mobile app that brings artifacts from An Iodhlann, the Tiree island historical centre, out into the landscape [30,31,32]. Three hundred and fifty items were chosen from the An Iodhlann archive, mainly based on their visual nature (so as to be interesting on the app) and where it was possible to geolocate them.

The app is a straightforward map interface that tracks your location with GPS and offers lists of artefacts that are either near your current location or at a location chosen on the map. There were practical difficulties because, at that time, there was no usable mobile signal on the island and open mapping did not support off-line use necessitating bespoke map software in a very limited (5Mb) total memory footprint.

Fig. 3. Frasan: (left) mobile app using high-resolution OS open-data mapping; (top-right) tourist base map of Tiree (top-left) decorative mural of Tiree.

When zoomed into maximum resolution, Frasan used OS Open Data maps, as seen on the phone screen, with features drawn as icons on this. However, when zoomed out more local mapping was used. On the right of Fig. 3 are two maps, the upper is the underlay of the map used for tourist leaflets. This tourist map is a 'proper' map, a *cartographic (isomorphic)* representation largely identical in shape to the OS map at the same scale except it is oriented to True North rather than OS Grid North. Note that the flattening of maps means that the grid squares on the north-western fringes of the OS Grid system are several degrees away from North-South. In addition, to the morphing required to flatten the curvature of the earth, it is not a perfect ellipsoid and so latitude-longitude is based on approximations to this leading to multiple versions. In particular in the area of Tiree OS latitude-longitude differs from GPS latitude-longitude (WGS84) by about 100 metres [33,34].

In addition, the tourist map shows fewer roads than the standard map. This is a deliberate choice in order to channel tourists away from smaller roads where they might interfere with farming. Note that this embodies two aspects that can be lost when using global mapping systems:

- *local knowledge* can be critical in determining sensible routes
- the *stakeholders* are wider than the direct map user

The second map (Fig. 3, bottom left) is even more interesting. It is a mural painted on the wall of an island shop and reproduced in postcards. It is recognisably the same island, but more bulbous in the central section; that is a *cartographic (homomorphic)* representation. The roads shown are largely similar, but as the map is designed for decoration, they are not placed in exactly their coordinate positions (if that even makes sense give the shape of the map). In order to be able to place the GPS marker, key positions were identified (mostly coastal features and road junctions and bends) and these were used to create a Delaunay triangulation and a piecewise rubber-sheeting transformation [35]. Normally rubber sheeting is used to transform one map to be overlaid on another, here the map image was used directly but the current GPS coordinates transformed to put the marker at the correct map location.

4.3 Walking through childhood

The map shown in Fig. 4 was first used during a keynote at a workshop on Spaces, Spatiality and Technology in 2005 [36]. The underlying map is a redrawn version of a street plan of Roath Park the area of Cardiff where the author was born and raised. It is a *cartographic (isomorphic)* representation. However, the critical aspect of this map are its annotations. It shows some of the early features that the author got to know as a very young child (approx. 3–4 years of age).

Some of these features are *patches*: rooms, houses, buildings, which correspond roughly to the kind of spaces of which a rat has a stable grid and place cell representation [18] and also to the areas that human memories are attached to in work on event boundaries [27] or (more roughly) *nodes* in Lynch's elements of urban legibility [37]. Also marked is a *path*, a route along the back lanes that the child took to nursery and later infant school. The neurological mechanisms for storing paths are less clear, although it seems likely they relate to episodic memory and storytelling.

Fig. 4. Map of Roath Park showing earliest remembered places and routes, from [36].

This childhood representation of larger space is effectively *network space*, the mental map (as in 2D bird's eye view) came later. Critical changes came as paths were recognised connecting previously isolated patches and the first time when it became clear that there could be multiple paths to the same location – opening up the earlier more domocentric model with tentacle like paths reaching out from home. In the keynote and papers about this map, the steps of spatial cognition development were used as analogies for the way more mental concepts form and link [36,13], a connection which is not merely a metaphor as it is likely that our brains have reused and adapted spatial mental structures for more general purposes.

4.4 Digitally performing Wester Hailes

Our next map is produced by slightly older children. Wester Hailes is a council estate at the edge of Edinburgh, which persistently ranks amongst the lowest in Scotland in measures of deprivation and has nearly 45% of children living in poverty. Napier University has a longstanding engagement with the community particularly involved with digital projects that offer a sense of agency and placemaking to young people. As part of her doctoral research, Tanis Grandison and colleagues worked on a project to help school children engage with their area and allow their voices to speak about it [38,39].

Fig. 5. Map of Wester Hailes with exposed wiring to audio triggers [38,39].

Part of this work involved walking the ground, recording the children's stories about the places as a form of community psychogeography. Back at school the children made a large-scale table-top map (Fig. 5). The basic layout is a *cartographic (homomorphic)* representation, hand drawn and roughly similar to a standard map. The pictures of key places on the map are drawn by the children.

Also clear in the figure are the exposed wires along the roads and circuit boards and speakers at the edge of the map. The pictures are each touch-operated switches which play edited versions of the children's stories about the places. The purpose of this map is not to navigate (it is hard to carry around!), but to be an interactive experience for the children and others, which is both engaging and celebrates a sense of place and local identity.

4.5 Wales a personal view

The final map (Fig. 6), was produced for the author one of his daughters prior to him starting his round Wales walk in 2013 [40,41]. The basic outline is vaguely 'Wales shaped', but simplified and with Liverpool looming large across the northern coast, so very definitely *cartographic (homomorphic)*. However, the details inside are most interesting. Rather like the journey maps in Section 4.1, the map does not pick out the main cities or roads, but instead focuses on specific places and events that have shared family significance. These are often represented as small pictograms and illustrations, which connect to the oldest traditions of mapping going back to Mappa Mundi and even Egyptian garden plans, but also to modern tourist maps [42].

Looking at the locations marked, Cardiff is there in approximately the standard location, but within its bounds are particular locations such as Bangor Street (which is also in Fig. 4), where the author grew up. Similarly, Liverpool is in roughly the right

position, but substantially enlarged fitting to its importance as the place where the daughter had gone to university and lived at the time. Along the western shore are a number of places from family holidays in her childhood, but with an order that, like Korzybski's Dresden–Paris–Warsaw map [14] would be unwise to follow as a navigation aid. Of course, this is not a map intended to put in the author's rucksack to guide his route around Wales, but a map of memories of shared significance.

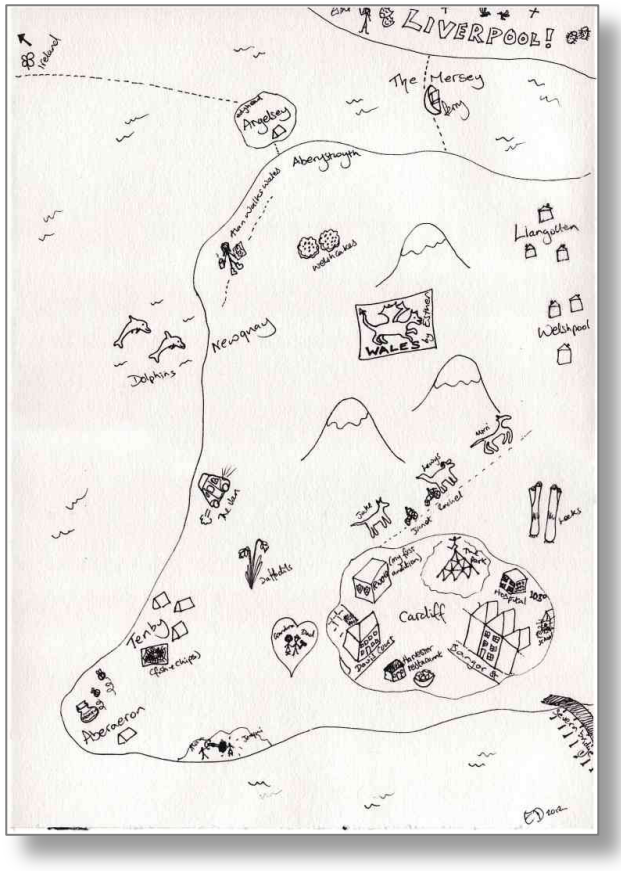

Fig. 6. Wales map of shared significance, © Esther Dix 2013.

5. Going Digital

In the 1990s Common Ground organised a project Parish Maps, which encouraged communities to create maps of their local areas; the wide variety of materials and forms can be seen on the Common Ground website [5]. A collection of essays was published as one of the outcomes of the project, and in this Barbara Bender laments that:

> "*Post-Renaissance maps cover the surface of the world with an homogeneous Cartesian grip*" [43]

This was written well before the rise of digital mapping, which has all but eradicated the variety of local mapping that used to be evident in the UK. However, it does seem possible for reimagined digital mapping to run alongside and indeed enhance a rich ecology of personal and community mapping as well as offering a opportunities for cartographic experiences that are more suited to the diversity of people and purposes who use maps.

5.1 Starting simple – add interaction to anything

A static map tries to match form and function, but a single map may be used for many different purposes, thus forcing a compromise layout. A similar problem arises in information visualisation, but even adding a simple interactive element can radically change a visualisation, often by allowing the static trade-offs to be dynamically changed [44]. Many of the heuristics that arise from this can be applied to maps.

Highlighting and focus. There was a style of old seaside tourist information board that showed a large-scale map with a series of labelled buttons below; if you pressed a button labelled 'cafes', corresponding lights would shine at all the café locations. While some mapping interfaces allow one to show or hide layers, this interactive highlighting of significant features is not common. However, it would be very easy to show a whole map, but fade areas distant from a route, or show all features as grey icons and then colour those of a particular kind on demand.

Accessing extra information. This heuristic is already well managed within digital mapping. Clicking or hovering over feature for additional details is common, indeed Frasan operated in precisely this way. The Wester Hailes map does a similar thing, but with additional auditory information.

Overview and context – zooming and fisheye views. Zooming is ubiquitous in digital mapping and in some navigation systems picture-in-picture techniques are used to show both the whole route and the current portion. In older paper tourist maps, fish-eye views were often used where the centre of the town was grown relative to the periphery. We saw also that the hand-drawn maps in Section 4.1 exaggerated the scale of areas which were important or where a lot of things happened. A simple geometric fisheye lens projection creates views that are aesthetically and practically too distorted to use, but so called 'fisheye' views in information visualisation [45] usually operate in a more semantic fashion showing areas of interest in full detail and then shrinking or eliding items that have less interest. In a related domain, Robert Pepperell created a series of non-perspective egocentric paintings inspired by Ernest Mach's "Analysis of Sensations" [46,47]; this was later developed into a computational technique called Fovography that generates immersive 3D experiences [48]. One could imagine taking similar inspiration from crafted town plans to create algorithms for effective fisheye layouts.

Same representation, changing parameters. One of the key parameters of a map is the scale and of course this is changed by zooming, but there are other parameters that are normally fixed at design time, but which could be made dynamically selectable. In 1969 the Ordnance Survey transitioned from heights shown feet to metres, so that old maps use feet and newer ones use metres, but this could easily be selected at viewing time. Similarly contour lines on 1:25,000 OS maps are shown at regular 10m intervals, meaning they can be unreadably crowded in mountainous areas, but unusably sparse on plains, it would be easy to dynamically change the contour distance. Perhaps most useful for general navigation (especially those with aging eyes) would be to be able to change the font size of labels!

Same data, changing representation. Most digital maps use 2D Cartesian layout, but, as noted earlier, paper road atlases often have additional linear maps showing motorways and other long-distance routes. Similar techniques have been used for digital maps, in particular StripeMaps uses 'torn' fragments of standard maps to create a roll down view on a smartwatch screen [49], not unlike the WWII bomber navigator's map roll. It would be possible to switch between this and the standard view or to the linear height graphs created by many fitness apps.

Linking representations – temporal fusion. On larger screens it is often possible to link multiple visualisations either by simply swopping between different views, or linking them together more intimately. This can be done with two parallel visualisations such as sliding a location marker on a height-distance graph and seeing the corresponding point on a 2D map. It can also be used for overlaid maps, for example fading back and forth between geological and agricultural land-use maps to help understand the relationship.

5.2 Pushing the bounds of normative mapping

The above techniques have all been described in terms of normative (proper) mapping. However, we have seen examples of digital technology being used for less conventional maps, which may be used instead of, or alongside more conventional representations. So often digital technology is suppressing these more individual or local understandings of space, but could be used alongside to preserve a sense of place and celebrate local knowledge.

In Frasan rubber-sheeting was used to allow the locations of features and the user's current GPS coordinates to be plotted on the hand-painted map of Tiree. It would similarly be possible to imagine the linear route maps in Fig. 2 alongside a standard 2D map in a linked representation as describe above. While the Wales map in Fig. 6 is too non-standard to be transformed using rubber sheeting, this might be possible for the periphery and definitely possible to allow selection of features in the Wales map to connect with a conventional map at the relevant location. Thinking about the adding of personal stories to standard maps, or sensed location, there is a long-standing strand of research concerning various forms of location-based annotation or narrative [50,51,52,53].

The time tunnel representation discussed in Section 4.1 also seems both possible to emulate digitally and potentially a useful navigation aid. At its simplest images along a route could be rendered on along virtual walls allowing linear perspective to create the pathway. More interesting would be to use a form of semantic fisheye and choose less images from the further distance so that they need not be shrunk as greatly and then gradually reveal details as one moved along the path. More prosaically, guide books often show a succession of photographs at key points of a trail, so that these could simply be portrayed alongside or inset onto a navigation map when approaching a waypoint.

The Wester Hailes map highlights the potential to use digital technology alongside physical representations or in the physical world. For example, one could draw a route in marker pen on a (plastic coated) paper map and then scan this into a navigation app which would recognise the base map and use it to geolocate the marked route and then use this as the route to follow on the digital map.

GPS allows connections to the physical world without changing anything on the ground enabling, for example, navigation apps or augmented reality overlays of historical scenes [54]. However, it is also possible to modify the physical environment, including QR codes or other forms of markers [55]. Sometimes this can be used as an alternative to the use of GPS for geolocation or as a way of alerting the user to the presence of digital material, but can also be used more richly. For example, in a hospital there are sometimes coloured lines on the floor that can be followed between frequently accessed locations. However, there are only so many colours and so much floor space, so it is not possible to have every possible link. Imagine instead having coloured lines that run for a distance and then end at junction points; you tell the hospital navigation app that you want radiology and it says "follow the blue line", as one approaches the junction point it then says "now follow the red line", or silently changes the colour of the screen. This allows the person to focus on walking, not constantly monitoring the screen or having disturbing navigation prompts at every turn.

5.3 Scaffolding spatial skills

In a 2013 paper, whilst in the midst of a one thousand mile walk around Wales, the author wrote:

> "*How can we create digital interactions that harness the power of GPS and global mapping and yet still invite a personal encounter with the path beneath our feet?*" [32]

This feels more urgent today than it did twelve years ago. This navigation deskilling is a key theme in Bond's Wayfinding [18] both because of the need to have a sense of place in a global world, but also because the development navigation skills are intimately tied to other cognitive processes. Bond highlights successful systems that focused on offering a safety net for exploration rather handholding direction, for example a "get me home" button that provides you a safe route back to where you came from hence giving you the confidence to wander and even get lost.

The comparison between the OS app and conventional navigation apps is instructive here. In its basic mode the OS map simply shows a map, your current

location and the direction the phone is pointing (if equipped with a compass). This is not unlike navigating with a paper map and compass leaving you the choice of where to go next, thus building a sense of where you are and how the map relates to the landscape. If the map fails, just as if your paper map blows away in a gale, you have a strong situational awareness rather than simply following instructions. The OS app does also have a path following mode, but that simply highlights the path and gently tells you when you go off path rather than giving turn by turn guidance – again scaffolding spatial skill acquisition.

However, it would be possible to imagine applications that combine aspects of the two. Some map applications offer ways to create your own routes. On such a route or others one could mark sections that are well known and therefore only require warnings if one is going seriously off track (where 'seriously' depends on the terrain), whereas other sections might be marked for Google-style directions. Alternatively one could mark waypoints at places on the path where one might want to take more care about navigation, and where the app should provide some sort of notification – however, it is still up to you to work out what to do next.

5.4 Maps and data

Digital mapping is built upon data, both the data about the landscape and increasingly also from the users of the apps. The latter is sometimes explicit, for example user contributed trails or Open Street maps, but also implicit, such as the speed of movement of the users that helps build a picture of current traffic conditions. In some way data can be seen as neutral, something that can be used in different representations and contexts. However, the choices about what is collected and how it is stored at the very least makes some applications easier than others and potentially makes assumptions about or alters the nature of reality.

Digital mapping can change the balance of roles within mapping. For a printed map, as discussed in Section 3.2, the cartographer uses their knowledge of the landscape to create the map which the cartographee interprets to help with their goals. User contributed content allows the cartographee a greater role in the process, perhaps creating content for other users or even a backchannel to the cartographer. In the Frasan app we considered adding a "what's this?" function, so that the user could take a geolocated photograph of something they have seen with a query, so that a local expert (or indeed another user) could explain.

Imagine an open navigation application where a town could add its town plan, so that visitors could use this instead of the standard map but otherwise have a well-known interface. This could extend the to the algorithmics of the application such as the heuristics in the 'antisocial hiking' app to allow one to avoid other people while enjoying nature [56], criteria selection as in FlexRoute for pedestrian navigation [57], or routing that avoids residential streets. The latter is not just about opening up the roles of contribution, but also recognising that the stakeholders of a mapping application are not simply the cartographer and the cartographee, but also those who are affected directly and indirectly by the navigational and other choices made because of the application.

As noted, one of the advantages of data-oriented mapping is that data can be presented differently. In Frasan the locations of objects are geocoded using WGS84 latitude–longitude, but these can be transformed into the coordinate system of the 'wonky' Tiree map. However, sometimes the data itself needs to more deeply reflect the contingent and locally understood nature of the world. At a numerical level the movement of landmasses due to continental drift is one of the reasons that OS latitude longitude is needed alongside WGS84; if you measure the corner of a building with high GPS accuracy and then repeat the measure a few years later, the coordinates would change by several centimetres – the earth quite literally moves beneath our feet.

It is easy to forget this in the hubris of digitalisation. GoogleEarth KML exports show a purported precision (if not accuracy) to molecular scale (10s of nanometres). In Frasan we used KML exports or Google Maps locations from geocoding, but then added a precision flag that could be 'bin sized' (~1m), 'house sized' (~10m) or 'township sized' (~100m). Of course, our measure of vagueness itself had to be discretised to fit a digital footprint but reflected to some extent the varying meanings of 'here'.

Note that this single vagueness metric itself covered several different things. Partly it is about *accuracy*, which for planning a building could be about the accuracy of a GPS reading, but for historical building it might include real uncertainty about the exact location. Objects and features also have *extent*, which in some databases is encoded as a shape or polyline, but very often as a single point, for example in Geonames Manchester (the UK city) is placed at (WGS64) lat/lon (53.48095,-2.23743). However, the KML file includes a 'range' field of 24053.685084375007 (yes all the digits!) which is the distance from which the feature should be viewed [58], so giving some sense of size. However, there is also often a sense of actual *vagueness*, if a tourist says "I visited Manchester" this would generally be taken to mean the central area, whereas if you said "my friend lives in Manchester" this probably means the wider conurbation. Indeed there are multiple entries for Manchester, UK in Geonames, corresponding to the different administrative regions, but all would be approximations to the real meanings of the spoken terms.

6. Design considerations

Hopefully, the examples given have already inspired you to think more widely about maps. If you are creating an application or web site that may include some form of mapping, don't just reach for Google Maps, Bing Maps, or Open Street. This may be the right option, but think first:

- ***think purpose*** – Who will use the map? What will they be doing? Remember maps are more than navigation.
- ***think message*** – Beyond the function purpose, what does the map say to the user and the community or organisation behind the map? This includes factors such as seriousness vs playfulness, local identity and empowerment, and personal stories.

- ***think form*** – Maps need not be Cartesian with top-down view. Consider linear maps, panoramas, fish-eye maps expanding critical parts, or more side-on-views as you might get from a hillside viewpoint.
- ***think local*** – Are there existing maps used by the community or organisation, perhaps used in leaflets, posters and information boards? If not maybe commission or draw your own – there is no shame in tracing and then modifying!
- ***think context*** – If the map is to be used in a physical setting can you connect it better? If on a web page or application, consider how it relates to the rest of the page.
- ***think interactive*** – Don't be outfaced by the software or electronic expertise required by some of the examples; you can do a lot with hand-crafted images and hotspots. On the web the `<map>` tag is there precisely for this and many image editing or web design tools provide easy ways to use it.

On the last point, it would be nice if all of the digital maps we have discussed were easy to include without specialised knowledge but, sadly, this is not the case at present.

7. Final words

There is a clear danger that, left to its own development, digital mapping creates a single 'proper' form of map that at best homogenises culture and at worst leaves our geospatial lives in thrall to a distant technological elite. Writers such as Bender, Kitchin and Dodge have long warned about this, even for pre-digital mapping [43,4]. The issue is not so much the will to resist, but how to do so. Happily, we have seen examples where digital technology can work alongside non-standard mapping and also opportunities to extend this. Note this is not to decry the transformational opportunities of conventional mapping, but to allow opportunities for local or dissenting voices and unexpected purposes.

A key lesson of design is that if something is easy to do, people will do it. It is very easy to embed a Google map, but far harder to create something more bespoke. This is why it is important for those creating digital mapping software to consider the data structures, mapping toolkits, information architecture and technological infrastructure, and to develop these so that it is as easy to create a peronal or local map as a global one. Providing this freedom will enable rich forms of local and individual expression and also alternative views that enhance democracy as well our aesthetic life.

The web page for this paper includes links to demos, examples and related information: https://alandix.com/academic/papers/proper-maps-2025

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