Rich digital collaborations in a small rural community

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Abstract In this chapter we describe experience in the design and installation of a low-cost multi-touch table in a rural island community. We will discuss the creation of the table including: pragmatic challenges of installation, and then re-installation as the physical fabric of the multi-purpose building (café, cinema, meeting area and cattle market) altered; technical challenges of using off-the-shelf components to create state-of-the art multi-touch interactions and tactile BYOD (bring your own device) end-user programming; design challenges of creating high-production value bespoke mountings and furniture using digital fabrication in an environment that could include sewing needles, ketchup laden sandwiches and cow manure. The resulting installation has been used in semi-in-the-wild studies of bespoke applications, leading to understandings of the way small communities could use advanced interactions. More broadly this sits within a context of related studies of information technology in rural developments and a desire to understand how communities can become users of the rich streams of open data now available, and, perhaps more important, offer ways in which small communities can become empowered through the creation and control of their own data.

Keywords: touch-table, rural community, open data, research in the wild

1. Introduction

The widespread availability of touch and gesture sensitive displays has begun to transform many areas of life. In train stations large interactive timetables can be interrogated and in the museum and heritage sector touch-tables and other tangible technologies are emerging from research labs. Sometimes these displays are used in isolation, but they also may be used in conjunction with users' smartphones [12], or in assemblies of displays [38]. To some extent the use of touch and multi-touch technology in smartphones has both commoditised the underlying technology and changed public expectations about the nature of a display. Furthermore, many researchers have demonstrated the value of collaborations around large-scale touch-tables and similar surfaces [31], part of a broader research agenda looking at more 'natural' approaches to interaction incorporating, touch, tangible and other interaction modalities [41]. Unfortunately, large touch surfaces are still expensive, which restricts their use.

In this chapter we describe the design and installation of a low-cost multi-touch table in a rural island community. This demonstrates how existing technology can be used in a creative way to spread the benefits of interactive surfaces. In addition, it allows us to see potential uses and issues once the falling cost of dedicated multi-touch tables become more widely available.

We discuss the creation of the table including: (i) pragmatic challenges of installation, and then re-installation due to alterations in the physical fabric of the multi-purpose building (café, cinema, meeting area and cattle market); (ii) technical challenges of using off-the-shelf components to create state-of-the art multi-touch interactions and tactile BYOD (bring your own device) end-user programming; (iii) design challenges of creating high-production value, bespoke mountings and furniture using digital fabrication in an environment that could include sewing needles, ketchup laden sandwiches and cow manure.

The resulting installation has been used in semi-in-the-wild studies of bespoke applications, leading to understandings of the way small communities could use advanced interactions. More broadly this sits within a context of related studies of information technology in rural developments and a desire to understand how communities can become users of the rich streams of open data now available, and, perhaps more importantly, offer ways in which small communities can become empowered through the creation and control of their own data.

In the rest of this chapter, we first introduce the physical context of the installation: the Island of Tiree; its community: the Rural Centre within which the display is installed; and the potential for open data in small communities. We then describe the two phases of design and deployment of two versions of the interactive display, which differed in terms of the kinds of technology offered (multi-touch, tangible), the physical constraints (5 metre vs. 2.4 metre mounting), and production values ('DIY' installation vs. digital design and fabrication). Three semi-wild studies were conducted with these installations; we present some of the results and explore wider issues thrown up by the experiences during deployment and use.

2. Context – Tiree island and community

2.1 Demographics and economics

Tiree is a small island off the west coast of Scotland. It has a land area approximately the same as Manhattan and a population of about 650 (c.f. Manhattan 1.6 million). By SIMD (Scottish Index of Multiple-Deprivation) metrics it is one of the most deprived areas in Scotland, alongside poorer parts of major urban areas [27], and is in the most deprived area in terms of access to services [1,2].

Despite these gloomy statistics Tiree is a strong, resilient community with a school that caters for children to the end of secondary age (on many islands secondary pupils have to go the mainland weekly only returning home for weekends). Alongside tourism, rural industry is central, with one of the most well preserved crofting systems (small scale farming) using methods that help protect a rich natural environment.

Economic and social development are important issues for the island, particularly as the population shrank by about 15% between 2001 and 2011 censuses. Population decline puts various services at risk. Of particular concern is the continued viability of the school, and with it, the attractiveness of the island to families. In 2010 the island community built a 950KW wind-turbine 'Tilley', one of the most efficient in the world due to Tiree's near constant wind. The income from Tilley helps fund other community projects, such as a feasibility study into the potential for a community purchase of land, large parts of which are owned by an historic estate.

The island has workable, albeit problematic, broadband infrastructure, about half of which is delivered by commercial 'copper' phone lines, and the remainder by a community company 'Tiree Broadband', which uses wireless links to reach outlying areas. Digital access has been identified as a major issue in Scotland, for both economic and social inclusion reasons, since there is a strong correlation between digital access and other deprivation factors [24,32]. Without specific government action, digital technology tends to increase existing inequality. The Scottish Government have therefore instituted a programme to ensure optical fibre connectivity across the country, and, as this chapter is being written, the island is being connected through fibre to the mainland broadband networks.

2.2 Tiree Tech Wave and Tiree Rural Centre

Tiree Tech Wave is a twice-yearly maker/meeting event on the island. It attracts technologists, artists, product designers, and others interested in the way technology can be used in interesting and innovative ways, with a particular slant on rural issues. The Tech Wave is partly aimed towards participants: offering them a space to think innovatively, inspired by a wild and open environment; and partly towards the community as the long-term sustainability of remote communities will almost certainly involve increasing digital technology. Bridging the two is an education mission, helping participants to understand the information technology challenges for those at the physical margins.

The Tiree Tech Wave has led to numerous collaborations and other research benefits for participants, but also a number of more specific projects. One of these was *Frasan*, a Nesta funded mobile app [14] for the heritage centre, *An Iodhlann*, which houses 15,000 archive items. Another was OnSupply, a project led by Lancaster University looking at awareness of renewable energy availability [35]. In addition, there have been several projects connected with communications and data.

The Tech Wave is held in the Tiree Rural Centre, a building constructed as the cattle market. It is typical in rural areas to see buildings that are multi-functional. As well as the cattle sale ring, the Rural Centre includes a café, meeting space, public WiFi, and a tourist information point. The cattle sale ring itself converts into the island's cinema and lecture hall.

2.3 Open data islands and communities

Many governments across the world have embraced open data [29] and in the UK the government-funded Open Data Institute promotes open data practices across civic society [28]. As well as national and governmental data, many large cities have adopted open data policies, and this has even extended to smaller local authorities [27]. However there are barriers, not least the expertise to use open data effectively. Ian Bartram, global manager for analytics at Gartner:

"*I don't know if any public sector has necessarily cracked the nut on attracting the right skills and capabilities," … "The commercial sector has, because they've got the dollars to spend*." [22].

The 'Open Data Islands and Communities' report [15] asks how open data could be made to work for smaller communities. There are many potential benefits:

(i) easing communication within and between communities (see Fig. 1, flows 3 and 4);

(ii) using public data for local action, external funding bids, and negotiation with external commercial or public bodies (flow 2); and

(iii) perhaps most important of all, creating data locally that may be combined and used by others, shifting the community citizens from being simply data subjects to active data providers (flow 1).

However, the barriers are higher still than for local government since it would be rare to have suitable expertise in a community of a few hundreds or thousands of people. Various projects have addressed this on Tiree, in several cases leveraging the expertise brought by Tiree Tech Wave. These include a unified SMS and social media portal for local youth work, a public 'ticker tape' display in the Rural Centre café, an internet enabled shop 'open sign', and a web dashboard.

The Tiree touch-table project is set within this context. Two studies were focused particularly on flow 2, the 'obvious' open data flow, using multi-touch interactions on a large projection to visualise and interact with existing data. However, even here we shall see that participants opened up discussion to look at wider flows. The final study, using tangible interactions, focused much more on the means for participants to create their own data flows.

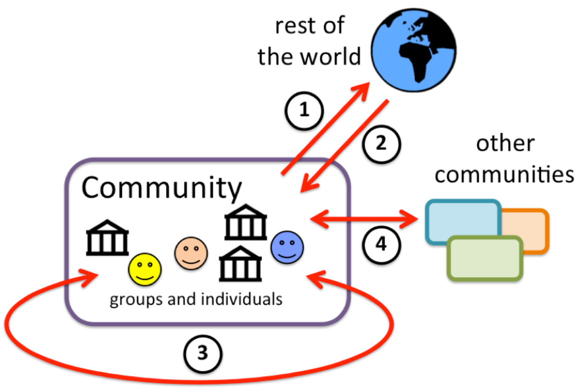

Fig. 1. Open Data Islands and Communities – data flows.

3. Design and Installation – Phase 1

3.1 Touch-table software and hardware

Various technologies have been used to enable touch and multi-touch surfaces. Electrical solutions, such as the capacitive displays in most smartphones, that embed electronics into the display surface do not scale well [42]. Optical solutions found in many large commercial and DIY surfaces make use of interference of infrared light on a semi-transparent surface detected by a rear-view camera [19]. While the latter can scale to very large displays, they are bulky and need surface instrumentation (e.g. special semi-transparent material with a fixed projector and infrared camera).

In 2010, Andrew Wilson from Microsoft suggested that new publicly available depth-sensing cameras, such as the Microsoft Kinect, could be used as inexpensive touch sensors [42] to overcome the limitations of capacitive and other optical approaches. An initial calibration phase provides a 3D map of the fixed surfaces, so when a finger, hand or pointer is detected in contact with the surface using depth estimation, it is interpreted as a 'touch'. Because it is a full vision-based method, any number of touch points can be tracked simultaneously (see Fig. 2).

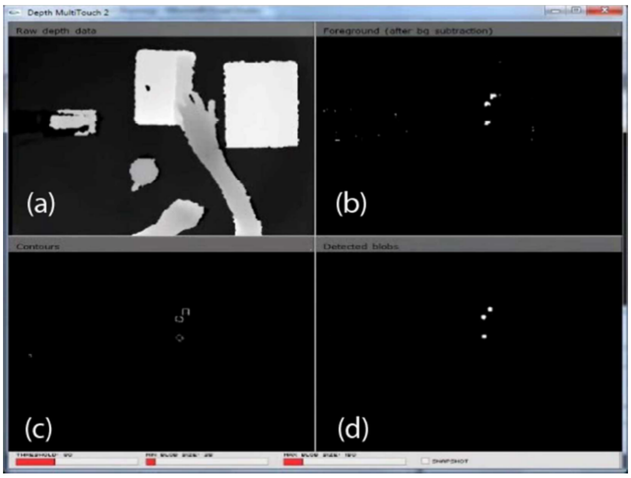

Fig. 2. TESIS using depth information to enable touch input (a) raw depth map; (b) subtract background and threshold to points within small distance of surface; (c) transform to connected regions; (d) recognized touch points

TESIS (Turn Every Surface into and Interactive Surface) was developed using this principle at the DEI Lab at University Carlos the III of Madrid [3,4]. TESIS had three advantages over touch-tables available at the time: cost, portability and the flexibility to make ad-hoc use of existing surfaces.

As well as using an off-the-shelf sensor (the Kinect), TESIS made use of open source software components: (i) openNI [30], which interprets the Kinect depth data; (ii) openCV for touch recognition; and (iii) openFrameworks for tracking fiducial markers to allow forms of tangible interaction such as the ReacTIVision amoeba codes [33]. In addition, openCV provided support for the TUIO (Tangible User Interface Object) protocol [23], an open protocol (and the de facto standard) allowing device-independent access to tangible and multi-touch tabletops. The openNI framework was chosen because it was well documented and offered support to different depth sensors. It also integrates better with other open-source software than the official MS Kinect SDK and benefits from a large community of developers.

The initial physical deployment used a micro-projector and Kinect co-mounted on an adjustable desk lampstand. The stand allowed the projector and Kinect to be positioned above any surface, transforming it into an active desktop, not unlike Wellner's [40] early DigitalDesk envisionment. One of the authors, AM, brought this to the Spring 2012 Tiree Tech Wave, giving rise to the idea of a permanent installation in the Rural Centre.

3.2 Physical installation

Many meetings at the Rural Centre take place in the 'foyer', an area that also serves as a tourist information and WiFi access area during summer months, and seemed the ideal spot to deploy a large version of TESIS. A large table is usually positioned towards the centre of the area, directly below the apex of the roof, which is about 5 metres from floor level. This meant that a large projector could be situated well out of the way, and connected to the girders that formed the ridge.

The deployment was carried out over a week by two of the authors, AB and AD. Part of the time was dedicated to software installation, running and testing at ground level, but the majority of the time was spent creating a platform to be installed at the 5 metre ridge. To ensure a strong light contrast, a 3500 lumen projector was chosen which was correspondingly heavy. This had to be mounted together with a Mac mini to run the software and the Kinect. The projector was mounted horizontally so a mirror was arranged off one end of the platform.

A critical design consideration was safety. Both adults and children use the area and the fear of a heavy projector or sharp-edged Mac mini falling on a child's head led to deliberate over-design. As the projector platform was quite sizable (about 70cm square, see Fig. 3 left), it needed to be designed to be bolted in position.

Fig. 3. Phase 1, (left) projector platform being constructed, note mirror cantilevered from the platform, and (right) installation at 5m apex of Rural Centre roof.

Another practical design consideration was the height of the Kinect. While the projected image could be adjusted to be table size, from a distance of 5 metres, the Kinect's effective range was only about 1.5 metres above a standard table height. Because Kinect precision deteriorates exponentially with distance and empirical tests demonstrated that a bigger distance would not provide the required precision, the Kinect had to be suspended half way down from the roof apex where the rest of the equipment was mounted. A long, adjustable T-piece was constructed from timber with the Kinect mounted at the lower end. Adjustments in increments of 10 cm were possible, partly to allow us to experiment with different heights, and partly because we wanted to make it possible to store it out of the way to avoid accidental damage (recall that this building is a work place including its designed purpose for cattle sales).

The eventual design was somewhat 'Heath Robinson'[1], but the lengthy preparations proved successful and the entire assembly was installed, deployed and tested in one day at the end of the week.

[1] W. Heath Robinson (1872-1944) drew images of complex machines with a superfluity of levers, cogs, wheels, and pulleys, to perform mundane and often not very useful purposes. These are called Rube Goldberg devices in the United States.

4. Design and Installation – Phase 2

4.1 Physical re-design

After completion of phase 1, the Tiree Rural centre gained funding for the installation of a false ceiling in the foyer area to make it warmer and more suitable for meetings. This was good news for the Rural Centre, but meant that the projector installation had to be completely removed and re-designed for a ceiling height of 2.4 metres Staff and students from the Cardiff School of Art & Design (CSAD) took on the re-design and installation of TESIS' next iteration at a subsequent Tiree Tech Wave event. The re-furbished Rural Centre had a more sophisticated feel than before, meaning that the previous utilitarian approach would no longer fit in either sense of the word. What was now required was something more akin to a fully developed product. This was a challenge. Tiree is located 550 miles (885 km) from CSAD's well-equipped base, and the available manufacturing facilities limited. Lateral thinking was required in five major domains: cost, understanding, time, design and manufacture.

Cost: A large part of a design project's costs lies in the designer time required. This project was no exception. However, CSAD used the touch-table project as a teaching tool. This made both economical and pedagogical sense, so it was written into the Product Design MSc for 2014-15. Material costs were met by Tiree Tech Wave and manufacturing costs could be kept to a minimum provided we could work out how to construct and install the designs in a remote area with very limited resources.

Understanding: The next issue was how to give students an insight into how people live on Tiree, including the community use of the Rural Centre and the space itself. The only effective solution was to bring them to the island. CSAD Product Design students are taught ethnographic research principles along the lines advocated by Hammersley and Atkinson [18] and Squires and Byrne [36]. They put theory into practice by conducting interviews with members of the community. Their key findings were:

1. The centre is used in multifarious ways and configurations;
2. The table in particular must be robust and should seat 12;
3. The projection module must not get in the way when offline;
4. There needed to be a way to link a laptop to the projection module;
5. The table should accommodate storage;
6. The table and projection module needed to allow vertical and horizontal projections

Time: Tiree Tech Waves last for four days; not long to research, design, prototype, test, complete and install two designs. By bringing the efforts of six students and three members of staff to bear we used a lot of people hours in a short space of time. This was further enhanced by the student cohort who put in many hours of 'overtime'.

Design: The cohort was divided into two teams. A user-centred design approach was followed [26,43]. Our approach also emphasised the role of relaxation and play [25] and the importance of the physical prototype [17]. Using research insights to form an appropriate brief, both teams began by producing concepts individually.

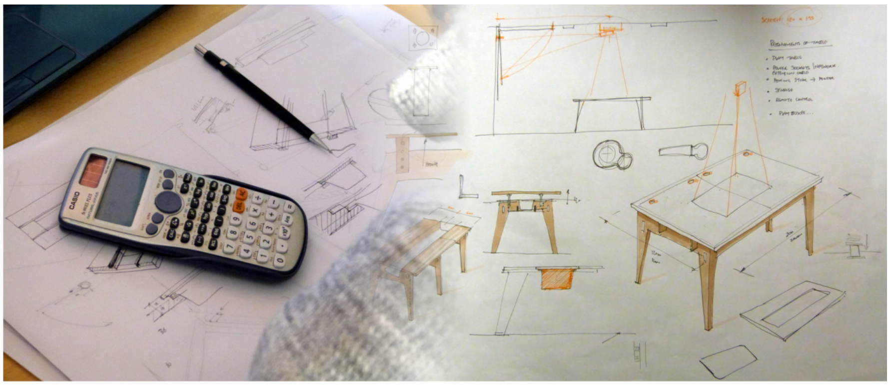

Fig. 4. Sketch development work.

They then brought their ideas together, consulted with the community to select the strongest proposals and refined them by combining the best features. Tasks were then divided amongst the team to maximise efficiency. Sketches and iterative prototypes were produced throughout (Fig. 4)

Manufacture: Prototyping facilities on Tiree are limited (see above). Our solution was to bring FabLab Cardiff [16] and its manager, to Tiree. There was an obvious limit to the number of prototyping tools that could be economically and practically imported, so equipment was limited to two 3D printers, a laser cutter, a small CNC machine, a CNC vinyl cutter, hand tools, battery drills, some electronics prototyping kit and a Perspex bender. Material included card, dowel, laser ply, Perspex and other plastics, MDF and modelling foam (Fig. 5). A small budget allowed for the local purchase of additional supplies.

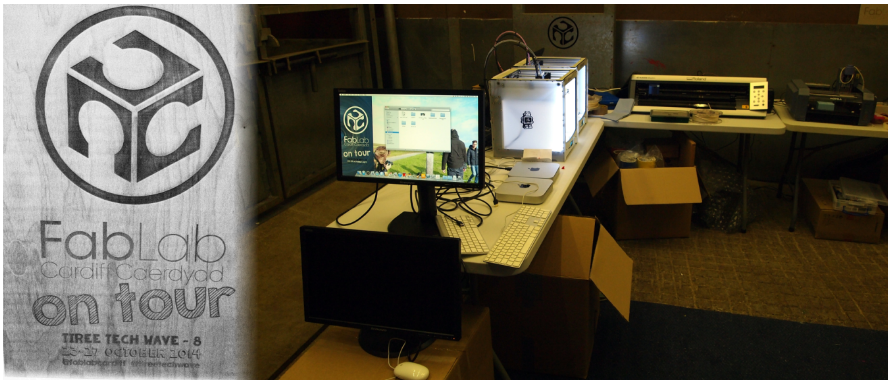

Fig. 5: FabLab Cardiff in the Tiree Rural Centre Cattle Market/Cinema

The manufacturing limitations had one immediate effect on the group designing the table: the CNC to manufacture it was too large to be transported. We reasoned however that digital files are scalable, so as long as the design was proven at scale, full size manufacture at a later date should be straightforward.

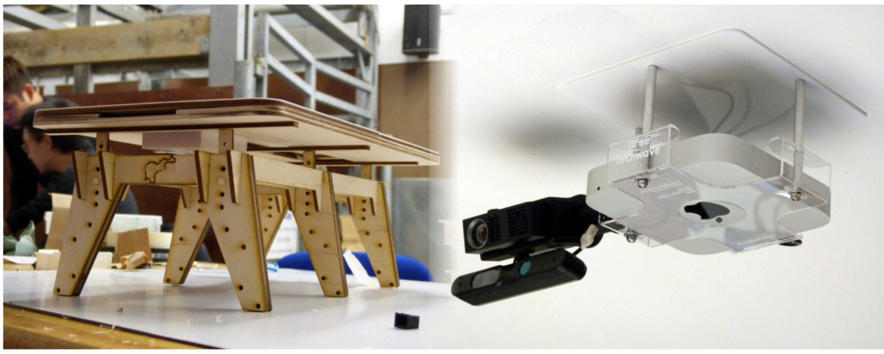

Fig. 6: Finished Table model and Projection Module

The finalised table design is a sturdy product designed for rough handling. It is height adjustable to allow seated or standing use, and the projection surface can be removed and wall-hung to form a projection screen. Removing the projection surface also exposes storage trays so that the community can keep frequently accessed items safely and neatly stored. The projection module is ceiling mounted with wiring fed into the loft. A pico projector sits to the side of the main chassis on a swivel joint that allows it to project downwards onto the table or horizontally onto a screen. The Kinect is co-mounted on the swivel to orient wherever the projector is pointed (Fig. 6).

Following modifications, the CAD files were used to produce a full sized variant of the table, which was assembled and installed during a subsequent Tiree Tech Wave (Fig. 7).

Fig. 7: The full-sized table in situ

4.2 Tangible software

With the second phase of physical installation completed and with the passage of time since the 2012 installation having given rise to a host of new software platforms, it was decided that the time was right to develop a second generation tangible software system. It was clear from the outset that the system had to be flexible. Unfortunately, due to their public and moderated nature, Pervasive Display ecosystems do not usually provide a wide set of general and unfixed features, even though their user base is heterogeneous time evolving. Enabling users to adapt a system themselves could promote more serendipitous and prolonged usage [21], fostering their appropriation in contexts where frequent supervision over mundane maintenance and upgrade activities is not feasible. We theorised that this would be the case with the Tiree Rural Centre, which is why an End-User Programming-enabled approach was chosen.

End-User Programming provides us with design guidelines to enable users to adapt software systems to their needs, allowing them to exploit the computational capabilities enjoyed by professional programmers. By employing it together with an easy to use interaction modality we designed a Pervasive Display system that can be deployed in public spaces to be used by non-experts to repurpose the system to their own needs.

We also chose to exploit Tangible User Interfaces (TUIs). TUIs consist of a set of physical objects that users manipulate to interact with a computing system. They are a popular choice for interaction with Pervasive Displays and have proven very effective in making highly abstract activities such as programming, more direct and widely accessible; thus our decision to deploy one here.

The end result was a successor system to TESIS called TAPAS (TAngible Programmable Augmented Surface). TAPAS is a TUI-based BYOD End-User Programming system [39] comprising a horizontal tabletop display and a RGB camera capturing the movements of the users' smartphones on the main display's surface using fiducials [5]. We decided to exploit smartphones since they hold users' preferences and can display a wide range of widgets depending on the required input (e.g. a virtual keyboard to input text).

TAPAS allows users to develop simple workflows by composing different available services, where the output of one becomes the input of the next. We used a puzzle metaphor to communicate the services' control-flow since it is familiar to end users [10]: each puzzle piece represents a service which could require inputs and produce outputs, the type constraints of which are displayed using shapes. The smartphone itself is associated with a circle halo with a hollow to accommodate the next piece, which moves alongside the smartphone on the tabletop projected surface. Joining a suitable piece to it will add the latter's represented function to the user's workflow. If a single piece requires additional inputs from the user, a dynamic widget will appear on the lower half of the smartphone screen (varying accordingly to the type of input required, e.g. list menu or keyboard).

5. Studies

The software and hardware setups were tested through three studies, the first two using the phase 1 installation (TESIS) and the third after the phase 2 installation (TAPAS). Studies 1 and 2 described in greater detail elsewhere [7,8].

5.1 Study 1

The first study was with a small group of islanders who had responsibilities or interests related to future policy and investment in the island. They used the phase 1 installation as a large computer desktop display, showing a variety of documents, but principally a map of the island (Fig. 8).

Fig. 8: Participants gathered around the tabletop display. Sometimes they split into small groups to discuss topics.

The researchers began the session by giving a brief demonstration of the system, and introducing the topic of big data. Participants were also offered the ability to draw or write on the map (as it was projected onto a large sheet of paper, see Fig. 9).

Initially the group used the map to show where they lived, and to recognise key features and locations. Although perhaps a frivolous use of the system, it was important for participants to relax with the technology and get used to its features. They soon switched to an in-depth discussion of plans for a future island skate park using the system to plan the most appropriate location. Discussions included the availability of data concerning weather and how this might affect the materials used if it were to stand up to the harsh island climate. The participants also considered the way data could be aggregated to give a truer picture of island life.

The conversation shifted outwards, initially around comparisons with the neighbouring islands of Coll (similar physical size, but much smaller population) and Mull (substantially bigger size and population). The participants believed that a system such as this could potentially be used to communicate between related islands, where physical flights and ferry usually have to be via a hub port. They also considered its use with the diaspora, including the descendants of those who emigrated to Canada, Australia and elsewhere in the 19th century.

The participants drew on the map adding connectivity of roads, times and locations of shops, fast food, WiFi and 2G coverage (Fig. 9). This free form use, although not captured digitally, enabled us to understand the kinds of features that might be added.

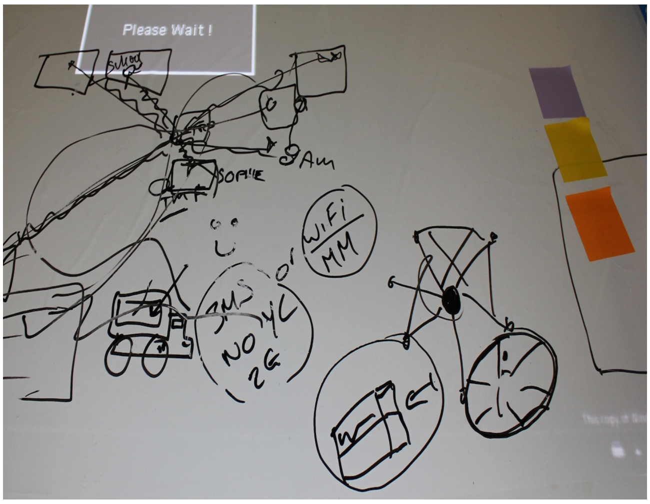

Fig. 9: Illustrations drawn directly on the projected surface (projection turned off)

The researchers introduced the issue of health planning and this led to further discussions and the need for effective data and figures on health on the island in order to prepare funding bids or similar projects. Currently this requires accessing information directly from the island surgery records with the aid of a local expert.

Fuel was also discussed, as it is particularly expensive on the islands. The researchers introduced the idea of community fuel purchasing, but the participants explained that the island garage is an important local business and so would be reluctant to introduce community-based competition. However, they were more interested in the use of data as part of an exploration of the additional costs of island living.

These discussions also led on to the way the island was sometimes asked for locally sourced information and the advantages if that information could be more readily available for external bodies, not only to ease this fact finding, but so that potential funders could more appropriately target the island. If such externally facing information were available the participants also wanted to be able to track where and how it had been used, reflecting concerns in the authors' own earliest writings on privacy and HCI [11].

5.2 Study 2

During Study 1, the participants suggested that the system would be useful during the launch of the Tiree Heritage app [14]. This involved using a full-screen version of a web browser to display the web-based application, which while designed primarily for small-screen devices adjusted to the larger screen and enabled shared discussions of what would otherwise have been individual interactions.. Touch sensing was turned off for this and replaced by a wireless keyboard and trackpad. This was partly because the calibration could still be quite fragile if the table was moved, and it would not be possible to maintain this in a fully 'wild' situation.

The evening launch event involved around 30 people who gathered round the table in small groups, often using the map-based information as a catalyst for conversation and collaborative reflection (Fig. 10). It was this reflection upon places, people and history that displayed the power of the TESIS system at a community level when used with local maps. It is also important to allow this technological appropriation, because as Bucciarelli [6] writes, "*…different participants in the design process have different perceptions of the design, the intended artifact, in process. […] The task of design is then as much a matter of getting different people to share a common perspective, to agree on the most significant issues, and to shape consensus*".

In the next section, we further discuss some of the issues raised, including the importance of local mapping.

Fig. 10: Discussion around the map at the *Frasan* launch.

5.3 Study 3

The last study utilised the new hardware/TAPAS software installation. To get some feedback on TAPAS we interviewed three interaction design experts in a controlled environment during one of the Tiree Tech Waves. The study lasted 45 minutes and involved two HCI experts and a product designer. We introduced the prototype and explained the rationale behind its design, including the scenarios we are targeting; we then gave a brief demonstration, going through examples of its usage in a real world scenario on Tiree. We then proceeded with semi-structured interviews focusing on TAPAS's strengths and weaknesses in relation to its interaction modality and applicability in a context like the Tiree Rural Centre, where tourists and locals often meet up to get information about what is going on in Tiree.

The designers liked the idea and the use of a smartphone for personalization and tangible interaction, and recognized the potential of a cheap, available and easily deployed system in a public space. They also liked that it can be left for long periods of time without the need to perform maintenance operations or bring in experts to add new features, since users can repurpose it themselves, a particularly valuable feature in a remote setting such as Tiree.

Some of the participants' suggestions focused on the coupling between data visualization and the dynamic widget: Due to the type of data currently handled (directory and library books listings) it makes sense to restrict user prompts to lists or keyboard input. Nevertheless, dealing with more structured data types – such as points of interest on a map requires more flexible and personalisable widgets based on the two-folded level of interaction between the user and data perspectives.

Finally, interviewees pointed out how the continuous back and forth interaction between the smartphone and large display might confuse users since switching between tangible and multi-touch interaction styles requires extra cognitive effort. Instead they suggested making the tabletop the main interaction focus by providing a mixed interaction modality with the smartphone used to assemble the workflow, but using a multi-touch-enabled widget on the tabletop surface once an input is required. So while it was agreed that the system has clear strengths, such as low cost, ease of prototyping in the wild and the flexibility of the architecture, there are also some major challenges to be addressed in term of interaction design requirements, like the flexibility and programmability of the widgets.

6. Discussion

6.1 Practical lessons

Many very practical issues drove aspects of the development of the Tiree touch-table installation. Some of these concerned the physical aspects of the space and equipment (5 metre roof, entailing heavy projector), some more to do with the social setting (crayons and cow dung), and some about the relationship between the two (young children below large equipment). This has led to issues of safety including the installation process itself as well as the protection of equipment (retractable arm for the Kinect).

This kind of issue will be familiar to anyone who has created long-term installations. Similar issues occurred in the Lancaster eCampus project where projectors were installed in an underpass at the University, but suffered continual problems related to access, safety and shear dirt [37].

The changes in the building are also quite a normal part of a real setting; social, organisational and physical settings all change over time. In this case the physical change meant changing equipment (lightweight LCD projector instead of large high-power one) and also production values. While the foyer area roof was effectively that of an agricultural building, a rough-and-ready install was sufficient; but once the new ceiling had been installed, a higher standard of design was required.

As this is a real setting there were diverse stakeholders. Although we did not produce a classic 'rich picture' [9], it is clear that there are a wide variety of uses of the space (cattle sales, information point, meeting area, WiFi access) and each has a range of users. The needs and expectations of the more 'official' members of the community in study 1 are different from the 'general public' in study 2 and the 'experts' in study 3. One example of this is the design of the table. The initial model in figure 6 has a single 8 foot x 4 foot tabletop (2.4m x 1.2m), but the final design in figure 7 consists of two square sections. The students' client for the design was one of the Rural Centre directors. He felt that a single large table was sufficient; however subsequent conversations with actual users of the area (some elderly) suggested that moving around a single large table would be very difficult. The final compromise was a two-part table on lockable castors where the two halves clip together. Again conflicting requirements from different stakeholders is far from a new lesson for any practical design project, but can often be ignored for small-scale or lab-based experiments. Even though the deployment is partly for research purposes, it must still meet professional physical and digital design standards.

6.2 From global big data to local small data

The touch-table and projected map in study 1 were initially presented as a way for small communities to be able to access big data (fig. 1, flow 2), for example, government open data. However, the participant discussions soon changed to looking at internal island data (flow 3), inter-community communications (flow 4) and the creation of data for external use (flow 1). This counter narrative of the importance of data, knowledge and wisdom of the community, was also evident in the physical marks they left behind.

The whiteboard markings in figure 9 are embodiments of local understanding linked to the external data and satellite view maps of the island. However, they are transient, ephemeral; the canonical external data persists, but the local knowledge is wiped with the cleaning of the surface. Although this may be all that is needed during a meeting, there often is also a need for a more persistent connection.

With a paper map, one might draw on the map, highlight areas, or add pins and thread to link points on the map with each other. With digital maps and data the 'external' view is privileged, being digital in many ways makes it more 'immutable' as well as more authoritative. For both maps and data we need ways to enable communities to easily annotate and augment 'official' big data with their own contextual small data. Semantic web technologies are a move in this direction in that they allow multiple statements to not just link to, but add data to existing resources in a way that is, in principle, on an equal footing [34]. To some extent, Linked Data, the more practical side of semantic web technology, has re-established a privileged source with more asymmetric relationships, but does still allow easy augmentation and linking [20]. None of this is yet in a form that is easy for ordinary users, however.

The map projected during the more formal sessions was a Google map, but on the wall is a large map of the island divided into 'townships'. This division of the land is crucial both for local understanding of identity, and also for the crofting: The crofts in a township share common grazing rights, but these are not part of the external mapping of the island. In contrast, the Tiree Heritage app (*Frasan*), projected onto the surface in the evening session, uses 'standard' mapping in detailed views, but for the overall island view, adopts hand-created maps used in tourist information. These local maps, like tourist maps elsewhere, emphasise certain features and may 'distort' geometry for cartographic or aesthetic reasons [14]. Local maps embody a sense of local identity, challenging the uniform view of 'standard' maps.

Finally, recall that the participants wished that they were able to provide island data to outside bodies, so that they might be more visible to potential funders. This reminds us that the power of data cuts two ways.

On the one hand the consumption, visualisation and analysis of data is often easiest for those with large budgets and available expertise; that is data consumption may reinforce existing power relationships.

On the other hand, the production of data is typically asymmetric, with the powerful, whether government or multinational corporations, in the best place to provide information. If that data is easily accessible, then it is that which will frame discourse. Even if the data is factually correct, the choice of what to provide, the methods of collection, filtering and presentation, all reinforce an external normative viewpoint.

Making local data available globally, especially if connected with others as part of the 'long tail of small data' [13] means that the voice of local communities is more likely to be heard. Of course, this small data form large numbers of communities becomes big data, allowing local knowledge to contribute to large-scale understanding. This poses technical problems, including the need to deal with heterogeneous datasets. Crucially these technical challenges need to be seen in the light of the social and political implications they entail, for example, the need for the tracking of provenance, as highlighted by the participants in Study 1.

7. Conclusions

A significant part of this chapter has focused on the practical issues of deployment and installation. Any in-situ long-term prototype has to deal with these kinds of issues, although they are perhaps particularly severe in a relatively remote location. Those deploying in the developing world often face harder issues, not least, lack of power. For Tiree the power supply is somewhat less stable than the mainland, but only with minor fluctuations and short outages. This is an issue we need to face however for future work. The aim is to have the table running permanently, especially through the summer months when the island has over 20,000 visitors.

During the studies we saw examples of all the data flows described in open data islands and communities; some existing, some potential. The tangible end-user framework, deployed as part of the phase 2 installation, has the potential to offer ways of manipulating external data and creating local data, but so far, has only been subject to experts' evaluation. More work is needed to make this useful for local needs.

There is always a tension when creating public installations between research goals and making it useful for those in the setting. When installing in a large municipal building, or university, the 'client' site often has a level of technical oversight. While there is frequently significant local expertise, this cannot be assumed. So when installing in local communities it is particularly important to be sensitive to local needs and not simply impose a solution because it is your latest, favourite technology. Of course this creates equal challenges in interpreting the research data as each setting is unique with specific stakeholders and issues.

We hope in the work reported here, and in our on-going research, that we can both be sensitive to the particular rich setting of Tiree, but also to learn more widely, socially and technically. In particular, we are aware that the regular presence of expertise in the Tiree Tech Wave is unusual, and so we wish to create reusable technology that can be easily re-purposed to other settings and communities allowing each to express, in their own unique way, what it means to be a small community in an age of global data.

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