Poking Fun at the Surface: Exploring Touch-Point Overloading on the Multi-touch Tabletop with Child Users

Dan Fitton
ChiCI Group
University of Central Lancashire
Preston, UK
DBFitton@UCLan.ac.uk

James Thompson
ChiCI Group
University of Central Lancashire
Preston, UK
JEThompson@UCLan.ac.uk

Janet C Read
ChiCI Group
University of Central Lancashire
Preston, UK
JCRead@UCLan.ac.uk

In this paper a collaborative game for children is used to explore touch-point overloading on a multi-touch tabletop. Understanding the occurrence of new interactional limitations, such as the situation of touch-point overloading in a multi-touch interface, is highly relevant for interaction designers working with emerging technologies. The game was designed for the Microsoft Surface 1.0 and during gameplay the number of simultaneous touch-points required gradually increases to beyond the physical capacity of the users. Studies were carried out involving a total of 42 children (from 2 different age groups) playing in groups of between 5-7 and all interactions were logged. From quantitative analysis of the interactions occurring during the game and observations made we explore the impact of overloading and identify other salient findings. This paper also highlights the need for empirical evaluation of the physical and cognitive limitations of interaction with emerging technologies.

Surface, Multi-Touch, Interaction, Children, Child-Computer Interaction.

1. INTRODUCTION

With the availability of commercial products such as the Microsoft Surface 2.0 and SMART Table, flourishing 'DIY' communities, and dedicated conferences there has been huge interest in the potential of multi-touch interactive tabletop technologies. The majority of early work in this area, perhaps naturally, focused primarily on the underlying multi-touch technology itself (Han, 2005) and impressive applications to showcase it. More recently there has been exploration of the new collaborative possibilities that tabletops afford, both with adults and children. Within the IDC community this has included exploration of new kinds of tabletop game for younger children (Marco, Cerezo and Baldassarri, 2010), digital storytelling (Di Blas, Paolini and Sabiescu, 2010), decision-making support (McCrindle et al., 2011), and exploration tabletop based classroom environments (Wang and Ren, 2009).

This new type of collaborative multi-touch technology is wildly different from the traditional single-user WIMP interaction paradigm that is well understood within the field of HCI. Work has begun to explore characteristics and limitations of interaction with a multi-touch tabletop but this is far less established. Work to-date has considered the implications of finger size for interaction (Wang and Ren, 2009)(Mansor, De Angeli and De Bruijn, 2008), the new possibilities for multi-touch gestures (Wobbrock, Morris and Wilson, 2009) and the terminology we might use to describe them (McKnight and Fitton, 2010). The majority of work exploring on interactions on multi-touch tabletops within the context of younger users has focussed primarily on collaborative learning (e.g. (Rowanne et al., 2009)(Martínez et al., 2011)).

In this work we design and evaluate a game (Surface Pipes) on a Microsoft Surface 1.0 to explore the condition of 'overloading' in a collaborative multi-touch game for children. In the context of this work overloading is used to describe the situation where a group of users cannot physical touch all the required points on a multi-touch tabletop (either individually or collaboratively). The motivation for this work was to explore the characteristics and limitations for children interacting with a multi-touch tabletop. An understanding of the new kinds of interactional limitations inherent in multi-touch tabletops is naturally very valuable to interaction designers and user experience professionals. An understanding of overloading is especially useful when considering collaborative applications and engaging games for child users, where overloading may be avoided or exploited for a desired effect. For example, a designer with an understanding of overloading could allow interaction in a game to become 'frantic' without frustrating the users with impossible interaction scenarios. Child users are also particularly interesting in this work as physical and cognitive development vary the point at which overloading occurs between age groups.

The Surface Pipes game used in this study randomly generates points of different size which must be touched till the game ends, more points are scored for touching the larger sized points. The game continues generating points beyond where it would be possible for all points to be touched simultaneously by the players. We were interested to discover how children cope with overloading and whether they would manage to collaborate or use strategies to score the maximum number of points.

We now give an overview of related work in this area, then present and overview of the game. Next we describe the studies that were carried out with 42 children from 2 different age groups. We then present and discuss the results, followed by concluding remarks.

2. RELATED WORK

While many novel surface-based applications have been developed ((Marco, Cerezo and Baldassarri, 2010), (Di Blas, Paolini and Sabiescu, 2010), (McCrindle et al., 2011) and (Wang and Ren, 2009) being a small sample of those existing) empirical investigation of the characteristics and limitations of interaction in this context has received comparatively little attention. At the lowest level of interaction, the physical characteristics of finger contact with tabletop surfaces have been explored in the context of adult users (Wang and Ren, 2009), which highlighted the challenge of accurate target selection. Similar work has highlighted the challenge 3-4 year olds have achieving a selection and drag task on a tabletop (Mansor, De Angeli, De Bruijn, 2008), and the lack of correlation between target size and success. Interestingly, many surface applications designed for child users leverage tangible objects placed on a tabletop for interaction instead of finger touch (e.g. (Marco, Cerezo and Baldassarri, 2010), (Di Blas, Paolini and Sabiescu, 2010) and (McCrindle et al., 2011)), which are less problematic than fingers to track and afford simpler interactions. Several works have explored techniques to provide insights into how tabletops are used by adults, primarily in the context of collaboration; for example (Tang et al., 2010) explores the traces of collaborative interactions, (Martínez et al., 20011) records and visualises the collaborative activities taking place and provides insights into the patterns of actions carried out by users. Much work at the Open University in the UK has focussed on child users collaborating around tabletops, for example (Read, 2011) explored the effect of multi-touch (vs. single touch) on collaboration within a group and the influence of a user's spatial orientation on the areas of a tabletop used (ages 7-9), and in (Rowanne et al., 2009) video footage of users was analysed to provide insights and identify four key aspects of collaboration. None of the related work to-date we are aware of has explored the situation of overloading users.

3. OVERLOADING THE SURFACE

The aim of this work was to explore the condition of 'overloading' in a multi-touch game for children. We were particularly interested in any interesting behaviours that might emerge through collaboration and to find out if the players were able to collaborate to ensure they achieved the highest possible score. Once each user has placed an index finger from each hand on the surface, a new touch point arising requires a judgement of whether to reposition an existing finger (which can be done very quickly) or to use free fingers in an attempt to touch this new point (slow and error prone).

The approach taken was to design a game that

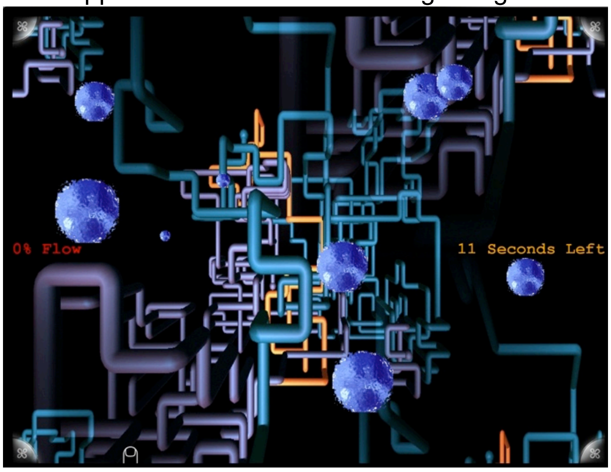

Figure 1: *Screen Capture from Surface Pipes Game*

would, through a gradual increase in the number of required touch points, create an overloading situation (the game is discussed in more detail in the following section). All interactions made during the game play were logged and the gameplay was videoed.

3.1 'Surface Pipes'

The game developed in the work is called Surface Pipes and the idea behind the gameplay is that the players have to hold their fingers down over leaks in water pipes. The 'leaks' appear in random locations at a predefined interval until the game ends, the leaks also have a randomly generated size within a defined range. The players must hold their fingers down on the leaks until the game ends (a game lasts 1 minute and 20 seconds). The score represented the amount of water lost and the aim of the game was to 'save' as much water as possible, thereby achieving a low score. The size of a leak was related to the amount of water escaping, therefore allowing a large leak to continue would increase the score more significantly than a small leak. The random sizes of the leaks were controlled to ensure some level of comparability between different games. The random locations of the 'leaks' allowed users to practise playing the game without any possibility of learning where the points would appear. The background to the gameplay is a collection of pipes rendered in 3D and the 'leaks' appeared as animated circles of rippling water as shown in Figure 1, water sound effects were also played during the game. The screen also showed the amount of time remaining before the game ended and a '% Flow' to help indicate how much water was being lost through the leaks, 100% being no loss and 0% all water lost through leaks.

Figure 2: *Children Playing 'Surface Pipes'*

3.2 The Study

The game was evaluated with children from two different schools in the UK. This included 23 year five (10-11 years) children and 19 year three (8-9 years) children, the gender mix is shown in Table 1. The year three children had visited the lab previously and used the Microsoft Surface. This study was one of a set of activities run in a MESS day format (Read, 2011), where a whole school class visited the lab and moved between different activities in small groups. The small groups varied in size between 5 and 7 children and the composition of groups was chosen by the class teacher. The study was carried out in an evaluation lab with the light dimmed to improve contrast of the display on the Microsoft Surface. At all times a teacher and a researcher were present. The children were seated around the Surface initially but typically stood when the game became challenging. During the game every touch point was logged and the sessions were videoed using 3 fixed cameras. A score was shown at the end of each game.

On entry to the lab the children were given an introduction on how to play the game, the objective and how the score was calculated. The room was arranged with light coloured chairs along one side of the Microsoft Surface and dark coloured along the opposing side (the chairs were office-type swivel chairs on castors set to their lowest height). The group was then divided in half based on the colours of the chairs the children were seated in. One half was then allowed to have a single practice game while the other half watched, they then switched over (so the other half now played a practice game while the others watched). During gameplay the researcher remained silent but on completion of the practice games the researcher reminded the participants that a lower score was better and this resulted from saving the most water. Once the practice games were complete the whole group then played the game together.

4. RESULTS

We now give an overview of the scores each group of users achieved then a more detailed analysis of the interactions that took place. The results of the practice games are not discussed in this paper.

4.1 Results Overview

Table 1 shows the breakdown of age and gender mix from each group along with the score from the

Table 1: Results from Surface Pipes Game

Group	Age	Male	Female	Score	Accuracy
C	***10-11***	***0***	***6***	***5,819***	***78%***
D	***10-11***	***0***	***6***	***6,652***	***64%***
	10-11	***6***	***0***	***10,260***	***62%***
E	***8-9***	***3***	***4***	***10,934***	***72%***
G	***8-9***	***4***	***2***	***13,062***	***51%***
B	***10-11***	***3***	***2***	***16,146***	***69%***
F	***8-9***	***6***	***0***	***17,973***	***51%***
			Mean	***11,549***	***63.9%***
			Std. Dev.	***4,538***	***10.2%***

game and the accuracy (the percentage of total touch points recognised by the Microsoft Surface that were on the area of a leak). The data is ordered by ascending score as this gives a measure of the success of a group in playing the game (the lower the score the more successful the group). The majority of groups consisted of 6 players, with group B having 5 players and group E having 7 players. From Table 1 it appears that the two all female 10-11 years groups C and D performed far better (lower score, more water 'saved') than the other mixed or all male groups in the other age groups. Averaged over the whole game groups G and F jointly had the lowest accuracy (51%) and similarly poor scores, both groups were in the same age group with the same number of members and scores above the mean. The best performing group C has the highest accuracy (78%), followed by the modal scoring group E (72%).

From observations of use, children typically use the index finger on the dominant hand first, followed by the index finger on the remaining hand. The children then attempted to use their remaining fingers by spreading them out where possible but this often resulted in an unreliable 'touch' on the tabletop due to the shallow angle of the finger giving low finger pressure (children had to rotate and stretch their hands in most cases). As a new 'leak' appeared participants often instinctively moved their dominant index finger to it, occasionally multiple participants would do this simultaneously and the first users to reach the point most often remained. In the worst performing groups with the highest scores (B and F), the males in the groups competed to be the first to touch new points that appeared and did not make efforts to communicate within the group (except for general exclamations of exhilaration or dismay). In groups C and D (the highest performing with the lowest scores) the participants worked cohesively and communicated continually and reorganised themselves in response to new points emerging or members of the group struggling with awkward or unreliable positioning of their fingers. The group with 7 players (E) scored slightly lower than the mean (10,934 compared to 11,549), while the group with only 5 players (B) also performed poorly (ranked 6 out of 7 by score).

4.2 Discussion

Accuracy has no causal relationship with score, an accuracy of 100% could be achieved by touching a single leak for the duration of the game (which would result in a very high/poor score). However, accuracy does provide insights into the way the game as played. While group E has the second highest accuracy their score was almost double that of group C, meaning that group E were touching less leaks than group C and the leaks that group E were touching were smaller than for group C (ie even though group E's accuracy at touching leaks was high they were less successful at preventing 'leaking' during the game).

The ability to continue playing when the group is 'overloaded' (ie more touch points than hands) was due to the participants spreading their fingers out in order to touch other nearby leaks. At this point all participants were touching the surfaces often with both hands and two key problems were occlusion and coordination. With many hands touching the

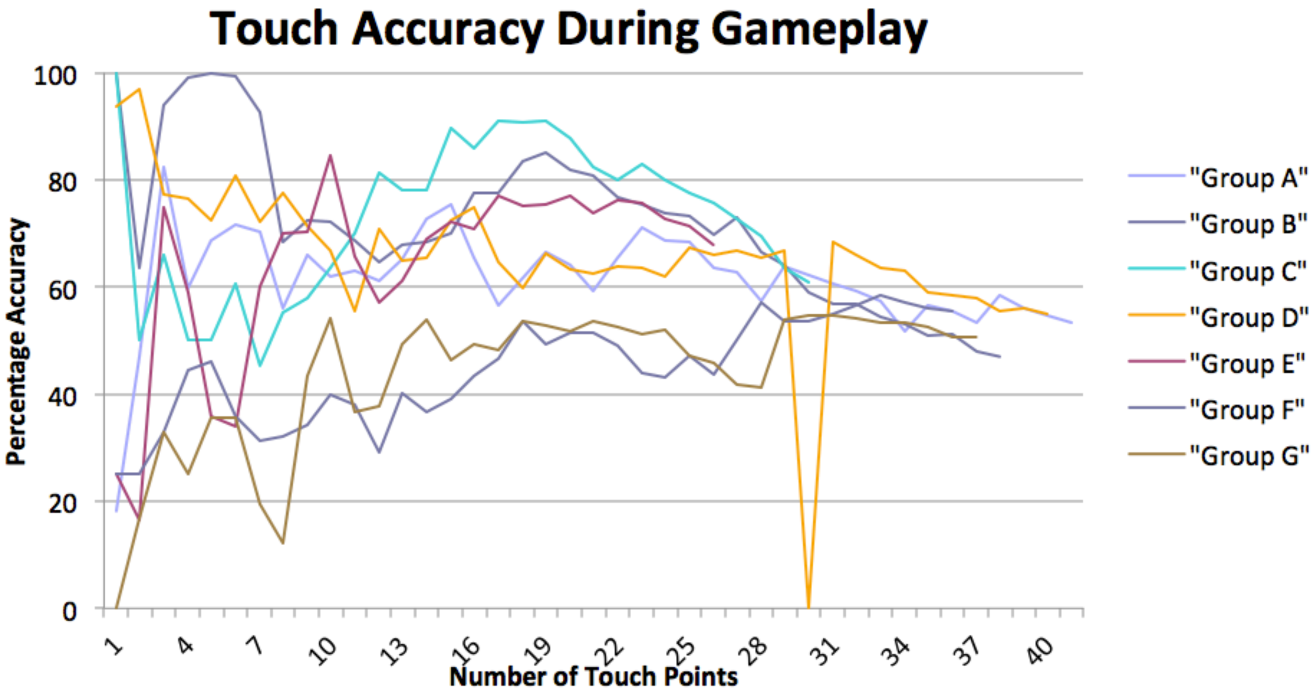

Figure 3: *Touch Accuracy During Gameplay*

surface parts of it were obscured, making it harder for participants to notice when new leaks appeared. Often when a new leak appeared it was within finger spreading range of two users who then had to negotiate who would attempt to touch it. Often this was communicated through initiating movement (ie the first person to initiate movement towards it 'claimed' it) as the participants found it challenging to refer to a specific leak unless they could use a unique characteristic (e.g. 'that big one' or 'that small one'). Often children struggled to maintain multiple-touches reliably when spreading out their fingers and would often be surprised to notice leaks reappearing if the position or pressure of that finger was unintentionally changed.

Figure 3 shows the mean accuracy for each number of simultaneous touch points throughout the entire gameplay for each group. The x axis of Figure 3 is the touch accuracy (percentage of the touch points registered by the Microsoft Surface that were on a leak) and the y axis is the total number of touch points registered. From Figure 3 we can also see the maximum number of simultaneous touch points registered for each group (the point at which the plot ends), the lowest being group E with 27 and the highest being group A with 42. It is interesting to note that group E had the highest number of members. Group D shows an anomaly where the only occurrence of 30 simultaneous touch points was where none were on target. An accuracy of 100% means that all touches recognised by the Microsoft Surface were stopping leaks (the players had no other reason to touch the surface during the game). Figure 3 shows that for each group the accuracy was highly variable until around 30 touch points, where the variance between groups A, D, F and G is at its lowest (around 10%) with a mean accuracy of slightly above 50%, which is beginning to tail off for all groups.

One would expect to see a high accuracy until the number of touch points exceeds the number of available participant hands (as index fingers are typically used to interact), which would be 12 touch points for most groups, with the spreading of fingers then causing reductions in accuracy past this point. This is not the case and the accuracy is highly variable for 1-30 touch points for all groups and shows no clear patterns, the only clear trend shown is the reduction in variance past 30 touch points described previously. At 23 touch points we can see the accuracy for the majority of groups beginning to trend downwards (A, B, C and E in particular) and overloading is assumed to be occurring. At this point each participant would be maintaining between 3 and 4 touch points with both hands, this corresponds with observations made during the study that participants were able to successfully maintain 2 touch points with the dominant hand but often struggled to maintain multiple touch points successfully with the other hand.

It is interesting to note that average accuracy was rarely above 80% for any group over the duration of the game, and groups G and F didn't manage an accuracy greater than 50% even with a very small number of touch points. From observations made during the study this lack of touch precision was attributed to three key factors; problems with target acquisition in a time pressured gaming scenario, finger drift during gameplay as users focused on re-positioning fingers and the same or other hand, unreliable touch recognition.

5. CONCLUDING REMARKS

This work has explored empirical evaluation of interaction with a multi-touch tabletop in the context of groups of child users. The aspect of interaction explored is the situation of 'overloading' where the number of touch points which require interaction exceeds the number of human hands available for interaction. The investigation was carried out using a simple game which gradually introduced additional points that need to be touched (in order to succeed in the game) at random locations. Two measures were used to quantitatively evaluate performance, a score generated by the game (lower numerical scores being better) and the touch accuracy (total number of touch points detected vs. number of touch points on target). Groups participating in the game were also observed by a researcher and video recorded from 3 angles.

The study provided valuable initial insights into how child users deal with overloading within the context of a game, such as:

- The instinctive but problematic use of finger spreading,
- The high variance and unstable nature of touch accuracy along with key contributing factors,
- An indication of overloading occurring when user have to maintain between 3 and 4 simultaneous touch points using both hands.

The results from the study have highlighted the need for further investigation (both quantitative and qualitative) to more clearly understand key issues such as the extreme variance in touch accuracy and the very high performance of the closely-collaborating all female groups of 10-11 year olds. The study was carried out with a Microsoft Surface 1.0 and it would, of course, be desirable to carry out comparative studies on alternative hardware such as the Microsoft Surface 2.0 and SMART Table. This work also highlights the importance of empirically studying the interactions with interactive tabletops and the unique findings that it offers. It is hoped that these early findings, in addition to providing the basis for future work, will help to inform designing creating tabletop applications for child users within similar age groups.

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