

Goal-Snapping: An Empirical Evaluation of Object Snapping in Tangible and Multi-Touch Interfaces

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Abstract: We present “Goal-snapping”, a novel approach for applying snapping techniques to tangible and multi-touch interfaces. It can be used to support users in accomplishing basic tasks such as aligning, sorting or grouping of virtual objects. As using snapping on large surfaces poses challenges in interaction design, we identify and discuss according parameters in Goal-snapping. For sorting and aligning, we propose to use snappers that attract objects within a target zone and visually arrange them to present an overview. For exchanging objects among users, we propose that each user has a target snapper that acts as a goal to which objects can be flicked. A user study has shown that although participants embrace the use of snapping to automatically group objects in a sorting task, snapping does not accelerate the completion time and increases the error rate by accidentally snapped objects. In a long distance positioning task, the use of snapping significantly increases task completion.

1 Introduction

Tangible user interfaces (TUI) make use of real-world objects to interlink between a virtual and the physical world by allowing to detect physical artifacts (so-called props). TUIs can utilize a person’s interaction capabilities with real-world objects in order to manipulate digital information. Multi-touch interfaces allow to detect multiple simultaneous touches on a display. This enables to use specific multi-finger gestures and interaction techniques [LPS⁺06]. The combination of TUIs and multi-touch interfaces constitute the field of hybrid surfaces (for instance, in [TKR⁺08]).

Hybrid surfaces have a large potential for being employed in future living environments as they are able to seamlessly enrich peoples surroundings with ICT. For instance, elderly people can use this technology in order to communicate and stay in contact with family members as these user interfaces allow for natural communication and sharing of artefacts in remote collaboration ([MHPW06] gives an example). Families can gather around an

interactive surface integrated in a table in order to manipulate documents such as photos or play games ([SCH⁺06] provides an example). As these user interfaces possess the potential to make interactions more intuitive, more natural and easier to grasp, hybrid surfaces can provide in particular an easy access to complex information systems, their configuration and administration. Users could, for example, facilitate these interfaces to specify the security policies for their private IT-sphere through sorting priorities that are visually represented on a hybrid surface.

Sorting or grouping are basic tasks that need to be supported on such hybrid surfaces. Since these surfaces might become large or could be operated from a distance, an additional basic task will be long-range positioning that enables users to comfortably use the complete surface for sorting and grouping. In this paper, we introduce a new user interface (UI) technique we call Goal-snapping that can be applied with hybrid surfaces and provides a novel realization alternative for the three basic tasks mentioned. It contributes not only to the easy and safe usage of the private communication and information infrastructure; it mirrors also the abilities of self-organizing and self-adapting IT-systems as it supports users in organization and adaptation tasks.

Goal-snapping builds on the commonly used method of snapping. Snapping refers to different techniques in various application fields. In general, it has been introduced in [BS86] as application-based assistance to place and align virtual objects or cursors on a display and has since then been thoroughly investigated for mouse and keyboard-based user interfaces. Goal-snapping employs snapping in target zones that automatically attract virtual objects that remain within the boundaries of that zone.

We show how to employ Goal-snapping to assist users in sorting and grouping tasks on interactive surfaces. Target zones can attract objects that have been dragged or flicked to it and arrange them clearly in piles in order to provide an overview of the documents. We also show how to use Goal-snapping to facilitate long range positioning tasks. If several users work together with shared documents on the same surface, users might want to exchange documents with each other. Due to the size of larger interactive surfaces, users may not be able to reach all regions from their location. Thus, for instance, each user can have their own Goal-snapper to which other users can flick documents.

This paper contributes an in-depth consideration and evaluation of design and interaction issues of Goal-snapping. For evaluation purposes, we conducted a user study with 20 participants allowing us to give qualified statements about the impact of alternative design aspects on Goal-snapping.

2 Related Work

In the area of multi-touch and tangible interface computing, snapping can be used for different purposes. [NBBW09] empirically evaluates interaction techniques for translating, rotating and scaling single objects on a multi-touch surface. Here, snapping is used for a more accurate alignment of objects. Hancock et al. also present techniques for the rotation and translation of virtual objects on a tabletop system [HCV⁺06]. They discuss the role

of snapping and state that snapping could simplify the alignment of objects to one another. Still, they only discuss the possibility and suggest that it could be used in systems that employ any of their techniques. [SCH⁺06] introduces a technique to move virtual objects to related groups. Here, snapping is realized in combination with arrows that appear close to objects that can be added to a group. When tapping an arrow, the related object is moved to the according group. This concept is based on existing textual metadata, describing the photos and videos. Therefore, it assists the users by offering only certain target groups for an object. However, it does not support grouping and sorting tasks where no prior metadata has been defined. In [AB06] Agarawala et al. describe the use of snapping in a virtual desktop environment that can be manipulated by pen-based interaction. Objects on the virtual desktop can be grouped together by tossing them towards piles. Still, they neither describe their snapping approach in further detail nor do they evaluate it empirically. [RGS⁺06] introduces flicking as a long-distance positioning technique for a pen-based interactive surface. However, they do not investigate how flicking can be employed on multi-touch surfaces in combination with snapping.

3 Goal-Snapping

We now introduce the properties of our Goal-snapping concept. First, we give a definition of Goal-snapping and introduce the related terminology. In section 3.2, we discuss various design issues for a concrete realization of Goal-snapping.

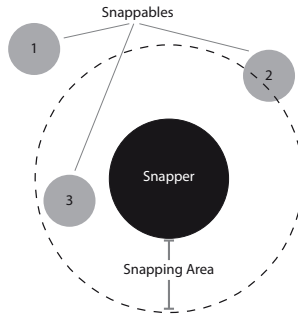


Figure 1: Basic Goal-snapping concept including a snapper object with it’s related snapping-area and snappable objects which can be snapped towards the Snapper

3.1 Basic Concept

For the basic concept of Goal-snapping we regard two different kinds of UI elements, namely “snapper” and “snappable”. Figure 1 illustrates this concept: Similar to the functionality of a magnet that attracts a piece of metal, a snapper attracts snappable objects.

If a snappable object comes within range of the “snapping area”, the snappable is being snapped by the related snapper. An essential aspect of Goal-snapping is that an object is either snapped by a snapper or not at all. This means that once a snapping is detected there is no way to interrupt this process. Furthermore, the snapping scope is locally restricted to the snapping area only. In the scenario in Figure 1, snappables 2 and 3 would be snapped by the snapper while snappable 1 would not be snapped.

3.2 Design Issues of Goal-Snapping

Our basic definition makes neither suggestions about how a snapper object is represented on a hybrid surface nor what further properties it may have. As a result, the introduced concept for Goal-snapping leaves space for various design decisions when considering a concrete realization. In this section, we identify several design parameters that have to be considered when implementing Goal-snapping and give design advices where appropriate.

3.2.1 Snapper Design

The snapper itself can be represented graphically or by a physical object. For instance, the snapper in Figure 1 is a graphical object that has a circular shape. Alternatively, a physical prop of an arbitrary shape (for instance, in the shape of a magnet) could be employed. In order to create snappers, there are several possible approaches. For instance, they could be created automatically when an application starts or manually by a user. A user could perform a gesture to create a snapper under their fingers. If a prop is employed, it can be simply put on top of the interactive surface to activate its snapping behavior. After the creation of a snapper, it could also be possible to move a snapper around or to change its size.

3.2.2 Designing the Snapping Area

Similar to the snapper, the snapping area can have different properties regarding size, shape and behavior. As a snapper resembles a magnet that attracts virtual objects, it is recommendable to use a circular snapping area to represent the snapper’s magnetic field that usually has spherical characteristics. The snapping area size defines the strength of the snapper’s magnetic field. Hence, the snapping area needs to exceed the snapper’s boundaries. At runtime a user could be allowed to enlarge or shrink the area. The snapping area needs not necessarily to be visualized. Basically, a visible snapping area could be useful as to ascertain users when they have moved an object into the boundaries. Alternatively, snapping areas could only be displayed at a certain moment. For instance, if a snappable approaches a snapper, the according area could be faded in. Furthermore, the area can be visualized with different aspects concerning alpha, color or texture. If an object enters overlapping snapping areas, the conflict to which snapper it will be moved needs to be settled. Normally, the object should be attracted to the snapper to which center it is nearer or which has the stronger “magnetic field”. Alternatively, snappers with overlapping areas

could reject each other like they had the same magnetic poles in order to prevent areas from overlapping. However, this will be rather complicated to establish if the snappers are physical props.

3.2.3 Designing the Snapping Process

This section discusses aspects of the actual snapping process that can comprise up to three phases. In the first phase, a snappable object is recognized, in the second phase the snapper attracts it and finally in the third phase – the after phase – the object may be automatically arranged and grouped within or manually removed from the snapper.

In the first phase – the recognition phase – of the snapping process the snapper will decide if an object that resides within the snapping area’s boundaries will be attracted to the snapper. In order that a snappable object will not be pulled from a user’s hand while dragging it, interaction with the object must be finished. Basically, each snapper attracts all kinds of snappables. For instance, if snappables are geometric objects like squares and circles with different colors, a snapper does not discern between shapes and colors it recognizes. However, it is conceivable that snappers attract only certain snappables. For instance, in a tabletop application in which different kinds of documents like photos and videos are used, a snapper could deliberately attract only photos and not videos. For instance, a tool set of prop snappers could be provided for a TUI that provides Goal-snappers with different behaviors. Alternatively, a user could configure constraints for a standard snapper to create custom behavior. If an object has been recognized in the first phase, the snapper attracts it in the second phase. In order to clarify the attraction process, the attraction process should be performed in an animated movement. In the third phase the snapper may automatically group, arrange and process snapped objects. For instance, if a snapper has attracted different kinds of documents like photos or videos, the snapper should group each kind of document in a pile. Within the piles, miniatures of snapped documents give a visual cue, which documents have been snapped. Additionally, miniatures provide interaction affordances that allow manual removing of accidentally snapped objects. Additionally, it is conceivable to provide a possibility to release all snapped objects at once, for instance, with a shaking gestures on the snapper. The snapper could be coupled with further program logic. For instance, it could be thought of a shrink snapper that automatically downsizes snapped documents.

Summing up, Goal-snapping brings the basic snapping concept to hybrid surfaces. Due to the extended properties of interactive displays, compared to a classical desktop, Goal-snapping also implicates a vast design-space for concrete application scenarios.

4 User Study

We carried out a user study to make qualified statements about the Goal-snapping concept. 20 subjects participated (13 male, 7 female), who were aged between 20 and 28 years (25.15 years in average). 95% were familiar with using touch sensitive interaction devices

like a touch pad, 100% were familiar with using single-touch display devices like a public ticket machine, 65% were familiar with using multi-touch display devices like multi-touch enabled mobile devices and 45% were familiar with hybrid surfaces.

We created two different test setups to consider different aspects of the Goal-snapping concept. The first task consisted of a general grouping task where objects had to be sorted into pre-defined target areas. The second task took place in the area of collaborative work and tangible user interfaces. Here, we analyzed how Goal-snapping can support the positioning of virtual objects over a long distance.

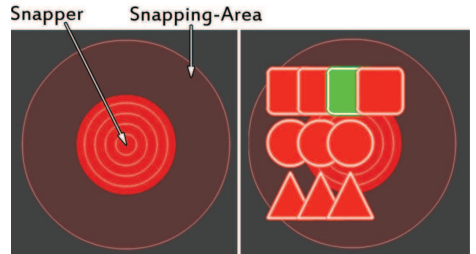
The study was carried out on a hybrid surface called “TwinTable” that we have developed (see Figure 2). Its projection area has a size of 80×45 centimeters where a full HD resolution (1080p) is provided. The TwinTable supports multi-touch and tangible interaction.

4.1 Test1: Evaluating Object Grouping

In the first test, we examined the performance of Goal-snapping for the task of grouping virtual objects into pre-defined target areas. For this purpose, we compared the grouping task for snapping and non-snapping areas and tested it with different combinations of interaction techniques.



(a) The Twin Table consists of a hybrid surface and a passive display



(b) Goal-snapping without (left) and with snapped objects (right)

Figure 2: (a) Our Twin Table (b) Our realization of Goal-snapping

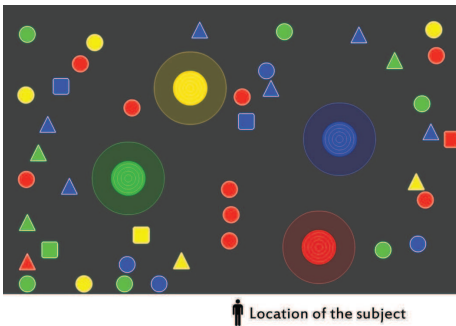
4.1.1 Snapping Design

We designed the snappers as circular objects with a circular, surrounding snapping area (see Figure 2). The participants generally could not move snappers. As long as a participant dragged an object over a snapper, it did not attract the object. Only if an object was dropped within or flicked to the boundaries of a snapping area, it was snapped. If the

snapping process had triggered, the object was arranged in the snapper according to Figure 2. As illustrated, snapped objects were stacked together and squares, circles and triangles were arranged in different rows. Snapped objects could also be removed from a snapper by using drag & drop interaction.

4.1.2 Test Setup

The object grouping test consisted of five different tasks. At the beginning of each task, four target areas in the colors red, yellow, green and blue and 40 objects each with a random color out of red, yellow, green, blue and a shape out of square, circle, triangle were automatically positioned at random positions on the surface. This initial arrangement of target zones and objects was realized in a way that none of the objects were overlapping each other. Figure 3 shows an example distribution of target zones and objects at the beginning of a task. The 40 objects had to be grouped into the four different target zones according to their color. The different shapes of the objects indicated diversity among them, but did not have to be regarded for the tasks. The test scenarios differed slightly regarding the characteristics of the target zones as well as the allowed interaction with the objects. As different characteristics of the target zones were “passive target zones” (areas that did not snap), “snapping target zones with visible snapping area” and “snapping target zones without visible snapping area”. These different target types are illustrated in Figure 3.



(a) A typical setup of target zones and objects right after the beginning of a tests scenario



(b) Passive target zone (left), snapping target zones with visible snapping area (middle) and snapping target zones without visible snapping area (right)

Figure 3: (a) Setup of the first test (b) Target zone designs for the user test

To evaluate the influence of flicking on grouping with Goal-snapping, either “drag & drop” or “drag & drop and flicking” interaction was allowed in the tasks. The subjects were allowed to use both hands and any number of fingers of each hand. This enabled to drag or flick more than one object at a time. If an object had hit the border of the interactive surface, it was automatically rebounded. The table in Figure 4 shows the five test scenarios.

The participants had to perform the tasks in random order to compensate for training effects. Prior to each scenario, the upcoming kind of target areas and the allowed interaction

Test Scenario	Target Zone	Drag&Drop enabled	Flicking enabled	Snapping-Area visible
1A	Passive	Yes	No	Not Available
1B	Passive	Yes	Yes	Not Available
1C	Snapping	Yes	No	Yes
1D	Snapping	Yes	Yes	Yes
1E	Snapping	Yes	Yes	No

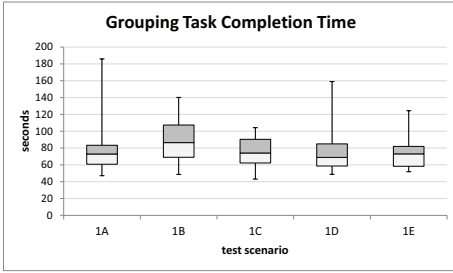
Figure 4: Properties of the five test scenarios for color grouping tasks

were introduced to the participants.

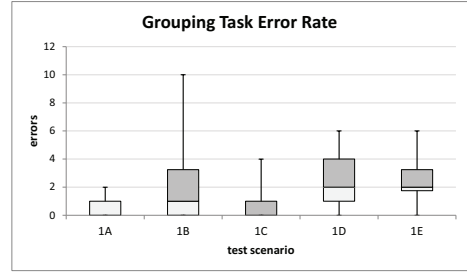
Within each scenario, the color grouping task could be performed with any of the enabled interaction techniques. The time to complete each task was measured. Although the snappers had different colors, each snapper attracted every object within its snapping area no matter which color or shape it had. The number of objects that were temporarily sorted into wrong snappers was recorded. After the five tasks participants had to fill-out a questionnaire. The questionnaire mainly consisted of questions that had to be answered based on a semantic differential scales and on Likert scales, each having seven items. Also, the different target area types had to be ranked by the participants according to their preference. Finally, the participants were asked to give additional textual feedback.

4.1.3 Results

Regarding the measured completion time, we could not make any significant observations about an acceleration of task completion caused by snapping as compared to non-snapping target zones. The completion times are illustrated in Figure 5. The data we gathered on accidentally wrongly snapped objects leads to more significant insights. Here, we could verify that with snapping target zones, flicking increases this error rate. This could be proved as well for the snapping target zones with visualized snapping area (binomial test, $p < 0.02$) as well as for snapping targets without visualized snapping area (binomial test, $p < 0.01$). The corresponding data is shown in Figure 5. Furthermore, we could perceive from the questionnaire that the subjects clearly preferred snapping target zones as compared to passive target zones for object grouping (binomial test, $p < 0.01$). Additionally, participants found the grouping of objects into snapping target zones more comfortable as compared to grouping into passive target zones (binomial test, $p < 0.01$). The visual feedback, that the snapping target zones offered, gave the participants a stronger impression of actually having added an object to a group (binomial test, $p < 0.01$). The automatic arrangement within the snapping target areas was perceived as more clearly arranged than the arbitrary arrangement within non-snapping target zones (Wilcoxon signed rank test, $p < 0.01$). We regarded flicking to be helpful for sorting objects into snapping zones if the participants chose one of the two most agreeing items of the seven items on the Likert scale. We could verify that flicking is helpful (binomial test, $p < 0.01$). However, it could not be verified that snapping was regarded as helpful for the grouping task.



(a) Completion time in seconds for the object grouping tasks



(b) Number of objects that were temporarily sorted to a wrong target group

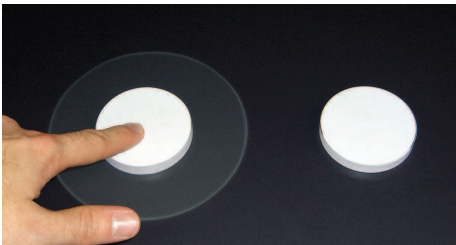
Figure 5: Measured data from the color grouping tasks

4.2 Test2: Evaluating Long Range Object Positioning

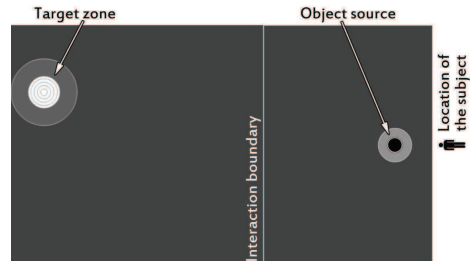
In contrast to object grouping, the second test focused on long range positioning of objects into a target that is out of a participant's reach.

4.2.1 Snapping Design

The snapping design for this test was almost equal as for the object grouping test. As it was not important to permanently group snapped objects, we changed their handling in the after phase. Snapped objects had been moved to the center of the snapper in an animated movement and were faded out afterwards. Additionally to the target zone types from the first test (Figure 3), we also employed props as snapping targets (Figure 6). These physically represented snappers were designed similar to virtual snapping zones.



(a) Physical props as snapping target zones – with and without a visualization of the snapping area



(b) The setup for the long-range positioning scenario

Figure 6: (a) Snapping Props (b) Setup of the second test

4.2.2 Test Setup

The setup for this test is illustrated in Figure 6. Participants had to flick objects into target areas on the opposite side of the table. In order that tall participants could not just bend over the table and drop objects into the target area, participants were not allowed to cross an interaction boundary with their fingers, which was located after one third of the surface. During each task, participants had 15 attempts to flick an object to the target. After every attempt, the target moved to a new random position on the far side of the surface. If a prop was employed, it was manually moved to the new position. In Figure 7, the five tasks are listed in a table. The tasks differed only in the target zone characteristics.

Test Scenario	Target Zone	Snapping-Area visible
2A	Passive	Not Available
2B	Virtual Snapper	Yes
2C	Virtual Snapper	No
2D	Prop Snapper	Yes
2E	Prop Snapper	No

Figure 7: Properties of the five test scenarios for long-range positioning tasks

Like in the first test, the order of the scenarios was randomized to compensate for training effects. We considered a passive target zone to be hit if the object stopped at least touching its boundary. In contrast to the grouping test, the rebounding of snappables from surface edges was disabled in order to make sure that the subjects had to hit the targets in a direct way. If the objects did not hit the target, they faded out at the position they stopped after flicking. For each task, the amount of objects that were successfully placed in the target area was determined. After the participants completed all tasks, they were asked to answer a questionnaire, which was structured accordingly to the object grouping test questionnaire in section 4.1.2.

4.2.3 Results

In this test, we could clearly measure a significant improvement of the hit rate within the snapping scenarios 2B (Wilcoxon signed rank test, $p < 0.01$), 2C (Wilcoxon signed rank test, $p < 0.01$), 2D (Wilcoxon signed rank test, $p < 0.01$) and 2E (Wilcoxon signed rank test, $p < 0.01$) as compared to the non-snapping scenario 2A. This result is also presented in Figure 8. In the questionnaire, the participants ranked snapping target areas over passive target areas concerning the time they needed to get accustomed to the positioning task (Wilcoxon signed rank test, $p < 0.01$) as well as to the easiness of the task (Wilcoxon signed rank test, $p < 0.01$). We regarded the subjects to evaluate the visualization of the snapping area as helpful if they chose one of the two most agreeing items on the Likert scale. However, it could not be verified that the participants found visible snapping areas helpful (Wilcoxon signed rank test, $p < 0.03$). Additionally, it could not be verified that the participants estimate a prop snapper's location better than the position of a virtual snapper.

In general, the participants preferred snapping zones to the passive target zones for long range object positioning (binomial test, $p < 0.01$). The question whether they preferred the virtual snappers or the prop snapper was not answered significantly. Concerning aspects between both tests, we can state that visible snapping areas were ranked more useful for long range object positioning than for object grouping (Wilcoxon signed rank test, $p < 0.03$).

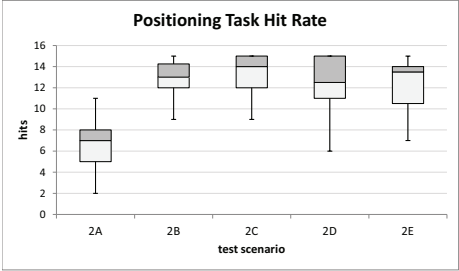


Figure 8: Number of hits for the long range positioning tasks

5 Conclusion

We introduce a basic concept for the use of snapping on hybrid surfaces, called Goal-snapping. It can aid sorting and aligning objects on an interactive surface by grouping them within snapping target areas. Goal-snappers can be employed in face-to-face collaboration on a tabletop setup to facilitate the exchange of objects between users over distances that are out of users' reach. This can be provided with a Goal-snapper for each user to which other users can flick objects. We carefully examined and described the design space of the basic concept which includes representation, visualization and interaction aspects of snappers, snappable and snapping areas. In a user study with 20 participants, we evaluated the usefulness and different design and interaction approaches for Goal-snapping in two scenarios for object grouping and long range object positioning. Although we figured out that Goal-snapping does not significantly accelerate the completion time for grouping, users prefer snapping target areas that automatically group objects as compared to passive target areas that do not snap objects. In terms of target area design, a visualization of the exact target area is more important for long range positioning tasks than for object grouping tasks. Although users regard flicking as helpful for grouping tasks, using flicking has the drawback of a higher rate of accidentally snapped objects. However, in the long distance positioning task, Goal-snapping zones significantly enhance the hit rate as compared to passive target zones. Additionally, participants agree that they find it easier to hit Goal-snapping targets than passive targets. The design choice to use a real world prop instead of a graphical representation does not significantly improve long distance positioning tasks.

Acknowledgements

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