How to Choose Element Sizes for Novel Interactive Systems

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Abstract
Interfaces for many new interactive systems lack useful adaptation towards the properties of those systems. Users and designers used to use the same system. This is often no longer the case and it is hard for designers to know what implications their design decisions have. We study the two main components of interaction performance, input and perception, with regard to how performance can be transferred from a reference system to a target system. We show how to calculate element sizes that allow near identical perceptual and input performance across systems.

Author Keywords
Interface design;Multi-display design;Interface adaptation

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

Introduction
For many years, interface designers have used the same screens and input devices that users would use: a desktop computer with mouse and keyboard. Therefore, the design of interfaces was an intuitive process, designers developed a feel for sizes of buttons, text and images that would be usable for the user. In recent years we have seen

an enormous variety of new screen sizes along with many new input modalities. Interfaces for these novel interactive systems, however, are still designed on regular desktop computers. This results in many suboptimal and sometimes unusable interfaces as it is not immediately apparent to designers what implications their design decisions will have for the user.

Related work

Gajos et al. [5] showed how traditional desktop user interfaces can be adapted for users with motor and vision impairments. The interface is automatically adjusted to the users motor abilities, adjustments for vision impairments can be made manually by the user. New devices always raise the question of suitable sizes for optimal legibility again. A study of multiple age groups in [3] determines an optimal font size for the small screens of personal digital assistants. Input performance has been studied in detail [4, 6]

Interaction performance

The interaction performance for given interface elements allows to judge how well an interface will work for a given interactive system. For the prediction we need to study the factors that influence the interaction performance: perception and input.

Perceptual performance

The visual acuity can be used to calculate the smallest distance between two lines that are still distinguishable. The ISO standard 9241-303 [2] uses this fact to make recommendations about font sizes for good legibility. The two relevant parameters are the viewing distance d and the visual acuity δ which is $0.3°$ for normal sighted persons. With this knowledge the suggested font size h and can be calculated (Equation 1).

$$h = 2 \cdot tan(\frac{\delta}{2}) \cdot d \quad (1) \qquad w_t = d_t \cdot 2^{\frac{a_t + b_t - t_r}{b_t}} \quad (2)$$

Using the physical display size along with its resolution, an optimal font size can be calculated as described above for any display for a fixed viewing distance. This calculation is limited to fonts and can not easily be extended to graphical interface elements as they are often much more complex and many additional factors play a role in the perceptual performance. Unfortunately many of those factors are hard to measure or user specific. To overcome this problem, we introduce the concept of a reference system.

Reference System

A reference system is a set of display and input modality that serves as a reference for the designer when creating interfaces for other interactive systems, typically a desktop computer. This concept allows to only compensate for the factors in which the systems differ while others like context knowledge or familiarity of icons will remain the same. The factors, relevant to the perceptual performance, that change from the reference system to a target system are: physical size, resolution and distance. This allows us to calculate sizes of interface elements that will have the same visual properties on any target system as on the reference system. With knowledge of the pixel density of each display we can convert between pixel and physical size. Solving Equation 1 for the visual acuity and using the given variables, physical element size and distance of the reference system, it is possible to calculate the necessary visual acuity to perceive the element on the target system with the ease indented by the designer. To validate the hypotheses of the reference system, we conducted a user study with the goal of automatically calculating sizes for both text and graphical elements that would yield the same perceptual performance on two target displays as on the reference display.

	LCD	Galaxy Nexus	Nexus 7
Text	23,83	23,17	23,08
Icons	7,42	7,5	7,33

Table 1: Average durations for both experiments for each display

	Source	SS	df	MS	F	p
Text	Between	4.05	2	2.02	0.05	0.95
	Within	1436.25	33	43.52		
Icons	Between	0.16	2	0.0833	0.03	0.97
	Within	102.58	33	3.10		

Table 2: Anova results for the perceptual performance tests

Experimental Evaluation of the Reference System

ISO 9241-304 [1] describes a setup for measuring perceptual performance in which users have to count the occurrences of a target character in random text. We created another experiment of the same style using 80 icons instead of 306 characters and users had to count the occurrences of a target icon instead. Figure 1 shows example screens for both experiments. As a reference display we used an LCD screen with a diagonal of $60.96cm$ and a resolution of $1920px \times 1080px$ at a distance of$60cm$. As target displays we used a Samsung Galaxy Nexus smartphone with a diagonal of $11.81cm$ and a resolution of $1280px \times 720px$ at a distance of $25cm$ and a Google Nexus 7 with a diagonal of $17.78cm$, a resolution of $1280cm \times 800px$ at a distance of $40cm$. The participants, two female and ten male, aged from 14 to 52, all with normal or corrected to normal sight, were asked to count target occurrences on every display.

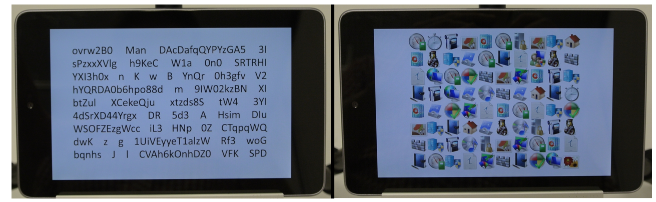

Figure 1: Example screens for the character and icon experiments

Table 1 shows the average performance in seconds for each of the three displays. For both text as well as graphical elements, the time it took users to locate all target elements is within an aberration of less than one second and the difference is not significant (One-way ANOVA results are given in Table 2). This allows us to calculate sizes for user interface elements, relative to the reference display that result in near identical performance on a target device.

Input performance

Input performance has been studied in great detail. Most prominently by Fitts resulting in Fitts' law which has been shown to reliably predict input performance. If we solve Fitts' law in the Shannon formulation for the width of an interface element, we can calculate the minimum width of interface elements if we have interaction time and distance to the target. While the actual distance to a target depends on the application context and layout, we set d to be the diagonal of the display. As Fitts' law assumes direct movements toward the target this is the maximum distance and therefore the worst possible case. With this maximum distance, t is the maximum input time. It allows to set an intuitive upper boundary to the required time for a single input task. In the context of the reference system this allows the designer to get an intuitive feeling of how big user interface elements have to be for target systems to achieve the same performance as the reference system. Using the reference systems screens diagonal as the distance we can calculate a time limit t_r for a given element size. With this time limit and the diagonal of the target systems' screen d_t, Equation 2 allows the calculation of an element size that will yield comparable performance to the reference system. The system specific properties of the input modality are a_t and b_t for the target system.

Evaluation of the Input Performance Adaptation
To validate the proposed calculation to retain input performance across systems, we conducted an experiment. We asked 10 users (8 male), aged from 21 to 42, to click 30 squares of $100px$ in size on a $60.96cm$ ($1920px \times 1080px$) LCD Monitor with a mouse as our reference system. We then calculated the necessary size of the rectangles to achieve the same performance on two target systems: a $221.3cm$ ($1280px \times 800px$) SMART 685i3 Board with a touch sensitive surface as input and a $132cm$ ($1920px \times 1080px$) TV screen with a gyro mouse as input. We asked users to click on 30 rectangles on these systems as well. The rectangles were placed randomly and displayed one by one. Table 3 shows the average performance for each device in ms. The aberration is within $70ms$ and shows that the calculated sizes result in a comparable performance across all systems with no significant difference (One-way ANOVA tests are given in Table 4).

	LCD	TV	SMART Board
Element size	100px	197px	27px
Input performance	797.2	857.3	855.7

Table 3: Average input performance for each system

Source	SS	df	MS	F	p
Between	23456.06	2	11728.03	1.55	0.23
Within	203897.8	27	7551.77		

Table 4: Anova results for the input performance test

Conclusion
We have introduced the concept of a reference system to design interfaces for novel, interactive systems. We have shown how to calculate element sizes to retain both perceptual and input performance on a given target system. In two user studies we have experimentally validated those calculations for multiple target systems.

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