EXTENDING INTERFACE DESIGN PRINCIPLES BASED ON SCALE TYPES

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Abstract

The purpose of this paper is to extend existing principles for interface design. Principles for efficient mapping between descriptive data and the dimensions of the graphical media used to present data to human operators are extended to principles for the mapping between prescriptive data and the physical dimensions used to present prescriptive data. This extension implies an extension of the notion of scale type, originally used to classify descriptive data, to prescriptive data.

Keywords: Information presentation, Scale types, Process control

1 Introduction

An operator supervising a physical system is concerned with two kinds of data: 1) *descriptive data*, i.e. values assigned to system properties in order to describe them, and 2) *prescriptive data*, i.e. values assigned to system properties in order to change (or prescribe) them. In Searle's' terminology, prescriptive data has a 'mind-to-world' *direction of fit,* meaning that the system data is supposed to match the actual state of the system. Descriptive data, on the other hand, has a 'world-to-mind' direction of fit, meaning that the state of the system is supposed to match the operators' intentions when acting on the system (Searle 1983).

For supervisory control it is important that the operator can bring about state changes in the system being supervised based on appropriate assessment of its state. In order to assess the system state operators need to draw on (descriptive) data (directly measured and derived from other data). Desired state changes are represented by prescriptive data referring to specific system properties. Often the operator cannot impose desired state changes directly but have to bring these about by changing the value of other properties, for which input devices are available (Petersen 2004).

In order to support supervisory control activity it is important that descriptive data is presented in a way that enables the operators to efficiently obtain an accurate picture of the state of the system being supervised. Zhang (1996) proposed a principle for accurate and efficient presentation mapping based on the scale type of (descriptive) data and the physical dimensions used to present data. This principle is further explained and slightly reformulated by Petersen and May (2006).

Similarly, it is important that the interface supports efficient and accurate input of prescriptive data so that the operator can impose appropriate state changes on the system being supervised. The present paper attempts to extend Zhang's presentation mapping principle for descriptive data to a principle for efficient and accurate presentation of prescriptive data based on the scale type of prescriptive data.

In this paper we abstract from the physical dimensions of manipulation of input devices (referred to as manipulator dimensions in Figure 1) as described by (Card et al., 1991) in order to focus on the physical dimensions used to present prescriptive data.

Supprimé : Figure 1

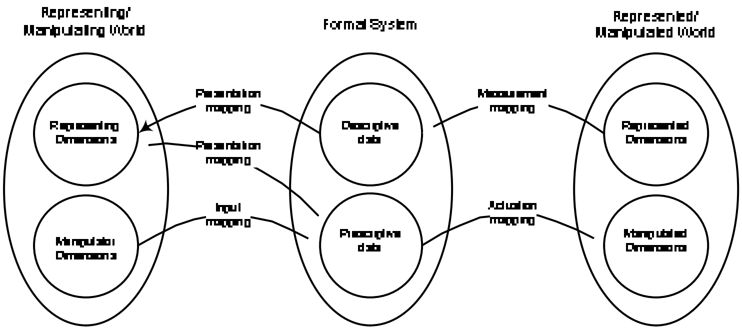

Table 1 indicates the empirical operations preserved for descriptive data on different scale types. Note, that the list is cumulative, i.e. that to the operations of a particular scale must be added all those preceding it. This means that all the operations that are legitimate for data on a ratio scale while only one operation is legitimate for data on the nominal scale. In other words, data on a ratio scale preserves the highest number of empirical operations. For this reason the ratio scale is often said to be the strongest whereas the nominal scale is the weakest.

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Table 1. Legitimate operations for descriptive data on different scale types.

Scale type	Legitimate operations
Nominal	determination of equality
Ordinal	determination of greater/less
Interval	determination of equality of differences
Ratio	determination of equality of ratios

When descriptive data is on an ordinal scale, for example, it is legitimate to determine the rank order of two indications, i.e. which one is greater (less). But it is not legitimate, however, to say anything about the difference between data values, let alone the ratio between them.

2.1 Scale types of prescriptive data

An extension of the notion of scale types to prescriptive data is based on a distinction between different rules according to which numbers or symbols can be assigned to real world properties (by means of *actuation*). In other words the scale type of prescriptive data denotes the *empirical change operations* preserved by the data prescribing real world properties, i.e. the operations that can be legitimately applied to data when imposing a change in the system property that data refers to. If, for example, prescriptive data is on an ordinal scale a change may be formulated in terms of ordinal changes like more/less. In this case, it is not legitimate to impose an increase/decrease of a certain amount, let alone an increase/decrease of a certain ratio, such as twice as much or half as much.

Table 2 indicates the empirical change operations preserved for prescriptive data on different scale types. Note, that the list is cumulative, i.e. that to the operations of a particular scale must be added all those preceding it. This means that all the change operations are legitimate for data on a ratio scale while only one type of change operation is legitimate for data on a nominal scale.

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Table 2. Legitimate change operations for prescriptive data on different scale types.

Scale type	Legitimate change operations
Nominal	imposing a different value (the possible values are not ordered)
Ordinal	imposing a lower or higher value (the possible values are not equidistant)
Interval	imposing an increase/decrease by a certain amount
Ratio	imposing an increase/decrease by a certain ratio

3 A principle for efficient presentation of data

Any *presentation* of descriptive data will be dependent upon some physical dimensions in a perceivable channel of communication (graphical, acoustic, haptic etc.) to instantiate the presentation for a human operator. When presenting information to human operators it is important to select an appropriate mapping between descriptive data and some dimensions of the presentation media.

Zhang (1996) has formulated a basic principle for efficient presentation based on the concept of scale types. This has been slightly reformulated by Petersen and May (2006), emphasizing that the dimensions used to present data must afford a set of perceptual operations that correspond to the set of operations that can be legitimately applied to the data being presented. In other words, the descriptive data and the dimensions used to present these data should match in scale type.

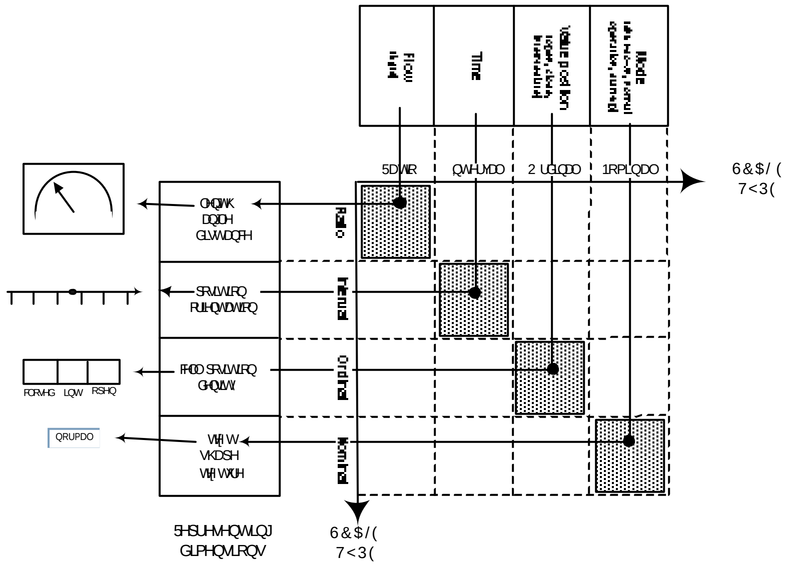

Figure 2. The mapping between descriptive data and representing dimensions.

Figure 2 shows the mapping between descriptive data and different kinds of representing dimensions of the graphical media. The representing dimensions are categorized with respect to their scale type.

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The diagonal in Figure 2 corresponds to the mappings where the scale type of data and the representing dimensions match. For mappings below the diagonal the scale type of data is stronger than the scale type of the physical dimension presenting it, i.e. not all the operations that can be legitimately applied to data are preserved by the representing dimension (as perceptual operations). The missing scale information is either lost or represented internally by the operator (Zhang, 1996). For mappings above the diagonal the scale type of data is weaker than the scale of the physical dimension used to represent it. In this case the representing dimension preserves all the operations that can be legitimately applied to data. But in addition the representing dimension affords (perceptual) operations that are not legitimate for data. This may lead to misperception and misinterpretation of the represented data.

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4 A principle for efficient input of data

Typically, the operators input of (prescriptive) data is presented by some physical dimensions which may or may not be identical to the dimensions actually being manipulated by the operator. When presenting prescriptive data it is important to select an appropriate mapping between prescriptive data and the physical dimensions that present these data in the interface. It is argued, that in order to ensure an efficient and accurate input of data, the physical dimensions used to present the prescriptive data imposed by the operator must afford a set of change operations that correspond to the set of change operations that can be legitimately applied to prescriptive data. In other words, prescriptive data and the physical dimensions used to present data should match in scale type.

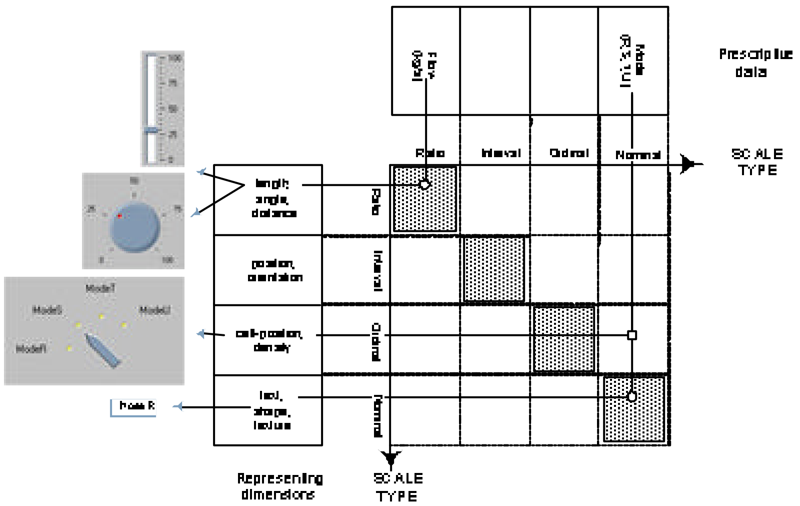

Figure 3. The mapping between prescriptive data and representing dimensions

Figure 3 shows the mapping between prescriptive data and different physical dimensions of the graphical media. The physical dimensions are categorized with respect to their scale type (i.e. the perceptual change operations they afford).

The diagonal in Figure 3 corresponds to mappings where the prescriptive data and the physical dimensions match in scale type. Both (prescriptive) flow data (on a ratio scale) and (prescriptive) mode data (on a nominal scale) are mapped to physical dimensions (length and text) that match in scale type. Two examples of interface components are shown (the slide knob control and the rotary knob control) that represent prescriptive flow data by means of the length dimension. In the case of the rotary knob control it is the length of the arc from zero to where the knob points. Also for mode data on a nominal scale an interface component is chosen that uses a physical dimension (text) with a matching scale type. For mappings below the diagonal the scale type of data is stronger than the scale type of the physical dimension used to present prescriptive data. This means that some of the change operations that can be legitimately applied to data are not afforded by the physical dimension (as perceptual operations). Zhang's distributed cognition argument that the missing scale information is either lost or represented internally by the operator applies also for the presentation of prescriptive data. For mappings above the diagonal the scale type of data is weaker than the scale of the physical dimension used to present it. In this case the physical dimension preserves all the change operations that can be legitimately applied to data. But in addition the physical dimension affords (perceptual) change operations that are not legitimate for data. This may lead to misperception and misinterpretation when imposing changes to prescriptive data. An example of this is shown in Figure 3 where prescriptive mode data is represented by means of a bend cell-position dimension in the rotary selector switch control. The problem with this way of presenting prescriptive mode data is that it might appear to an operator as if mode data can be subject to ordinal changes, e.g. when the

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current mode is ModeS then apparently a “mode decrease” can be obtained by changing the mode to ModeR (by turning the knob to the left) whereas a “mode increase” can be obtained by changing the mode to ModeT (by changing the knob to the right).

5 Conclusions

This paper described some preliminary results in extending existing principles for efficient mapping between descriptive data and basic interface dimensions to efficient mapping between prescriptive data and the physical dimensions used to present them. The notion of scale type, originally used to classify descriptive data, has been extended to prescriptive data. For prescriptive data the legitimate operations that characterize each scale type is formulated as change operations. The stronger the scale type of prescriptive data the larger the set of legitimate change operations.

6 References

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