Dealing with New Cognitive Dimensions

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Introduction

The core of the Cognitive Dimensions of Notations framework is the list of dimensions itself. This list has been gradually expanding – Thomas Green's early publications (Green 1989,1990,1991) described only a few selected dimensions, as did other researchers in early publications (Gilmore 1991). By the time the Green and Petre (1996) paper was published, 13 dimensions were listed. Despite the auspicious number, Green and Petre did not claim that the set of dimensions was then complete. On the contrary, Thomas and Marian have continued to encourage discussion of new additions. As it turns out, the process of defining new dimensions has slowed down. This may partly be because the existence of a definitive publication made the initial step of defining one more dimension a daunting one (perhaps the camel's back would break). More importantly, few researchers have seen the addition of new dimensions as an important end in itself. The 1996 paper, under the heading of "Future progress in cognitive dimensions", observed that the framework was incomplete – but not in the sense that more dimensions were urgently needed. Rather it emphasised the need for formalisation and applicability.

Nevertheless, new dimensions do get proposed from time to time. Some of these proposals have been published, but more of them exist only in the form of informal conversations with Thomas. I have recorded some of those conversations myself, and Thomas has also assisted me to list other dimensions that originate with other people. But it is neither necessary nor desirable for the development of the framework to depend on Thomas acting as a gatekeeper / coordinator for new additions. This paper therefore considers possible future approaches to the process of identifying and defining new Cognitive Dimensions.

Some examples

To start with, I list examples of a few candidate dimensions, taken from my notes over the last couple of years, together with suggestions from Thomas. Some of these have been published before, some are original and unpublished, most are appropriated from other research fields (in the sense that they are inspired by authors who did not consider themselves to be working on cognitive dimensions). None of them should be considered at this stage to have canonical status – in fact the question of how to assemble the canon is the main topic of this discussion paper.

Creative Ambiguity	The extent to which a notation encourages or enables the user to see something different when looking at it a second time (based on work by Hewson (1991), by Goldschmidt (1991), and by Fish and Scrivener (1990))
Specificity	The notation uses elements that have a limited number of potential meanings (irrespective of their defined meaning in this notation), rather than a wide range of conventional uses (based on work by Stenning and Oberlander 1995)
Detail in context	It is possible to see how elements relate to others within the same notational layer (rather than to elements in other layers, which is role expressiveness), and it is possible to move between them with sensible transitions, such as Fisheye views (based on work by Furnas (1986) and by Carpendale, Cowperthwaite and Fracchia (1995))

Indexing	The notation includes elements to help the user find specific parts.
Synopsie	(originally "grokkiness") The notation provides an understanding of the whole when you "stand back and look". This was described as "Gestalt view" by some of the respondents in the survey by Whitley and Blackwell (1997).
Free rides	New information is generated as a result of following the notational rules (based on work by Cheng (1998) and by Shimojima (1996))
Useful awkwardness	It's not always good to be able to do things easily. Awkward interfaces can force the user to reflect on the task, with an overall gain in efficiency (based on discussions with Marian Petre, and work by O'Hara & Payne (1999))
Unevenness	Because things are easy to do, the system pushes your ideas in a certain direction (based on work by Stacey (1995))
Lability	The notation changes shape easily
Permissiveness	The notation allows several different ways of doing things (based on work by Thimbleby, not yet published).

Where do they come from?

As is apparent from the above list, most candidates for new dimensions come from other research, whether or not the author is aware of the CDs framework. This is a good thing. One objective of CDs is that they should be credibly derived from psychological or cognitive science research. This is largely what gives them authority among notation designers (and the implication is intentional, through the use of the word "cognitive").

This suggests that an immediate point of good practice would be to encourage the participation of the original researchers in the process of defining new dimensions. We should aim for goodwill by promising credit via citation of the author's original work, and we should also give the author the opportunity to review the dimension derived from his or her work – both our characterisation of the dimension itself, and the way that it is related to the rest of the framework through profiles, tradeoffs, dependencies and design manœuvres.

A couple of candidates on the list are simply ideas that have been thrown into the CDs pot. (I think indexing was mine – Thomas suggested lability, though it may have come from elsewhere). In these cases, it is probably necessary to validate the basis for the dimension – either by finding supporting research, or by conducting new studies. This could be an activity of the wider community, if candidate dimensions were offered for general review.

Criteria for acceptance

What are the criteria that define a good (or even an acceptable) new cognitive dimension of notations? The process by which the current set were derived has been the subject of reflection, but not thorough documentation. This discussion will hopefully lead to further criteria, but I start with several that seem important.

Orthogonality

Most important, the term "dimension" was chosen to imply that these are mutually orthogonal – they all describe different directions within the design space. Furthermore, it is hoped that the trade-off relationships between them might be similar to those of the Ideal Gas Law – so that it is probably not possible to design a notation system that achieves specific values on any two dimensions, without having the value of a third imposed by necessary constraints. But these notions of orthogonality are intuitive rather than exact, and they are described in this way mainly so that designers recognise the nature of the constraints on their design. There is ongoing work on formalisation of dimensions that

should allow more precise statements to be made regarding orthogonality and trade-offs for a few dimensions, but I don't believe such analyses can be required when proposing new dimensions.

Instead, mutual orthogonality can only really be tested at present via a qualitative approach – going through all current dimensions, and checking to see whether any of them might describe the same phenomenon as that described by the proposed new dimension. This checking ought to be done by more than one person. It is so common for individual researchers to misunderstand the nature of one or two of the dimensions, that it is highly likely a proposed new dimension will simply be a rediscovery of an existing dimension (which the researcher had understood to refer to something else). It is also necessary to be aware that the new dimension might simply be the obverse case of an existing dimension.

One open question is how to deal with cases of aggregate dimensions. There are some cases that occur often, and are very serious, but don't get so much attention because they are not orthogonal to existing dimensions. One example is the combination of viscosity and premature commitment.

Granularity

The CDs seem to describe activities at a reasonably consistent level of granularity. It is probably a good thing that they should continue to describe phenomena at a similar scale.

They do not directly describe large cognitive tasks (design a system, write a play), but the structural constituents of those tasks.

They also tend not to describe low-level perceptual processes (although Thomas comments that I have moved in that direction more than he has done). But some things that are too low a level of granularity might include Gestalt phenomena, or observations related to individual motions (e.g. selection target size, as analysed by Fitts' law).

If they were to be characterised using GOMS analysis (which they are not going to be …), we might say that CDs do not apply either to leaf nodes in the goal tree, or to the whole tree, but to sub-trees.

Object of description

(This criterion was suggested by Thomas). There is an outstanding question regarding what it is that the dimensions are supposed to describe. Some possible options for suitable objects of description (no doubt not a complete list) are:

(i) structural properties of the information within the notation/device
(ii) the external representation of that structure
(iii) the semantics of that information
(iv) the relationship between the notated information and domain-level concepts – some of which are inevitably not notated

Depending on which of these are chosen, the CDs field gets bigger or smaller. Useful awkwardness and permissiveness are both defined partly by domain-level concepts, so they might not be members of the CDs list, if we restrict objects of description to (say) (i) & (ii).

In fact, considering the object of description might help to solve a continuing problem with useful awkwardness. In a tea-time discussion at PPIG 10 (Milton Keynes), Marian, Thomas and I concluded that useful awkwardness might be a kind of meta-dimension, in that almost all the other dimensions can be subject to useful awkwardness – it can be good for a system to be viscous, error prone etc., where that might assist the user in some higher goal. But is "meta-dimension" simply a slightly more serious kind of orthogonality? We never solved this.

Regarding the definition of a criterion for new dimensions … whichever subset of (i)-(iv) (or more) we choose, the proposed dimension should describe something that falls within that subset.

Effect of manipulation

(Also suggested by Thomas). It ought to be possible to consider each dimension and say 'if you change the design in the following way, you will move its value on this dimension'. That's a criterion of understanding how the dimension works, as well as the basis for design manœuvres. Thomas

suggests that creative ambiguity may be a case where we don't understand how it works (although I think Rachel Hewson would contest that). So the criterion is that when we define a new dimension, we should be able to say something about how to manipulate it.

Applicability

One of the desirable properties of a CD is that it should make sense to talk about it in a wide range of different situations. This has not always been achieved with the current set of dimensions.

Polarity

As CDs are not supposed to be either good or bad (more on this below), they should have interesting properties in both directions – i.e. both when present and absent. Error-prone-ness is not a very good dimension when considered from this perspective.

Choosing names

It is hard to find good names for new dimensions. "Grokkiness" (which persisted for almost a year) shows just how hard it is! Some of the criteria for good names include:

Length **(diffuseness?)**

It seems like one or two words should be enough (Closeness of Mapping is really on the limit).

Vernacular **(closeness of mapping?)**

CDs should sound both technical and approachable at the same time. They must sound sufficiently technical that they don't get confused with everyday meanings, and that they can be accorded some respect by notation designers (who are, in my experience, already sufficiently sceptical without the inclusion of funny-sounding names). In an effort to get something sufficiently technical, we have sometimes had mixed results, either by resorting to neologism (grokkiness) or archaism (synopsie).

There is also a problem of cultural specificity. It turns out that knock-on viscosity is unintelligible to Americans (recently reported by Margaret Burnett, and confirmed by several other delegates at VL2000). Some Americans guess correctly, but others think that it might have something to do with door knockers. They have suggested "domino" or "consequent" viscosity – is either of these too technical, or too approachable? (Left as an exercise for the reader).

Polarity

It gives a false impression of the CDs framework if readers treat the dimensions as representing "usability problems" rather than trade-offs. But this constantly happens, especially if the audience is already familiar with Nielsen's heuristic analysis of usability. We have partly caused the problem ourselves, because most of the names do imply negative consequences "Hidden dependencies" rather than "Visible dependencies", for example. There are several options for addressing this problem:

- Choose neutral names (desirable, but hard to achieve).
- Purposely choose names with alternating obverse polarities.
- Choose positive names if at all possible (to avoid the usability problem assumption).
- Provide dual definitions for all dimensions, illustrating positive and negative aspects.

With regard to polarity, it is also important to remember that dimensions only become evaluative when applied to some specific activity. For this reason, it should be possible to describe the characteristics of a dimension without any evaluative emphasis – evaluative observations should ideally be localised within the profile.

Supporting Apparatus

A cognitive dimension is more than just a name and a definition. All of the current dimensions are supported by a range of documentary and tutorial apparatus.

Examples

Each dimension is supported by examples of situations in which it can occur, with the consequences of that occurrence. There should be one "killer example" that immediately reveals to the reader the essence of the dimension. Ideally, examples should be drawn both from programming and other user interface domains.

Pictorial examples

In future, it would be very useful for every "killer example" to be supported by a pictorial illustration that can be incorporated in published papers referring to and citing the dimension. There is no real harm in repeating the same illustration, and a nicely illustrated example would help to promulgate CDs as a whole. Thomas and I have found that we lose our graphic files from one paper to the next, so it would be very useful to have canonical illustrations (archived and distributed via the CDs website) in GIF and EPS forms.

Impact

Different dimensions have different impacts on various activity types and profiles. Some kind of characterisation should be attempted.

Trade-offs

Should be noted. But if there is a specific trade-off that invariably occurs, that might be a sign that this dimension is only the obverse case of an existing dimension, rather than an orthogonal dimension.

Sources

Research sources should be cited, both as supporting evidence, and also to give appropriate credit to previous researchers.

Manœuvres and workarounds

It is valuable to have some observations regarding design manœuvres and also the ways that users might try to work around the effects of the dimension.

Meta-Vocabulary

This discussion paper has introduced a lot of new vocabulary. This is probably unavoidable, as we know that it is useful to have a vocabulary for use by designers when designing information artefacts. The information artefact that we are designing here is the CDs framework, so we need a vocabulary for designing it. It is tempting to use the CDs themselves for this purpose (and I have done so in a very small font in two places, after being unable to avoid the temptation), but this is not a good idea, as I previous persuaded Mark Simos (Simos & Blackwell 1998).

Some of the meta-vocabulary introduced (or repeated) here for describing the characteristics of new cognitive dimensions includes:

- Granularity – the scale of the phenomena described by a dimension.
- Polarity – the consideration of either the good or the bad consequences of a dimension.
- Obverse – the definition of a given dimension according to its other polarity.
- Orthogonality – the relative independence of a dimension from other dimensions
- Vernacular – the lexical origin and associations of a dimension name

There is also a growing meta-vocabulary that has been introduced in the CDs tutorial, as well as in recent research papers. For the record, CDs researchers should be able to define:

- Notation, Media and Environment
- Activities and Profiles
- Trade-offs, Design manœuvres and User workarounds
- Sub-devices and Layers

Presentation and Dissemination

Overall, the CDs express relationships between the structural demands of a cognitive task, and the structure of the notation used in that task, as mediated by some tool environment. Any extension that addresses this concern should be considered for inclusion in the overall framework, so nothing is sacred. Other areas for future consideration, in addition to finding new dimensions, include finding new types of sub-device (beyond the ever-present abstraction manager), and new types of activity (one that I found described in the Green & Petre (1996) paper while preparing this document is the need for "slicing" during system debugging).

There is a need for recording canonical updates to the framework. This can be partially catered for by maintenance of an archive site, but it will also be necessary to continue updating documents such as the CDs tutorial and questionnaire, as they are increasingly being used as primary sources. We have been careful to cite dated versions of the tutorial, but perhaps we should add an edition number. In fact the current versions on the site at the time of writing are inconsistent (as pointed out by Rachel Hewson, and one of my students) – the tutorial does not include the "search" activity, while the questionnaire does.

It also seems increasingly important to record common misunderstandings of the dimensions, as well as definitions of new dimensions (the American problem with "knock-on" is one example). There are times when carefully crafted positive examples, be they ever so good, just can't compete with "if you think this, you are wrong"!

As the number of dimensions grows, it is becoming crucial to identify a useful subset for new users (including undergraduate courses). Commercial users are already impatient with the size of the set that exists now. We could perhaps create a CDs-lite for commercial friends – perhaps with 7 plus or minus 2 dimensions. These might be selected as the most important, or possibly the easiest to understand. We might possibly adopt Jack Carroll's minimal documentation approach to presentation, so that people only have to deal with the dimensions that they need.

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