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KEEP IT REAL: ON TOOLS, EMOTION, COGNITION AND INTENTIONALITY IN DESIGN

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1. Introduction

Tools support and assist designers and engineers in their daily interactions with real and virtual worlds, this paper looks at tools, in conjunction with the meta-cognitive aspects and intentionality of the user(-s). Most of our tools enable us to acquire a natural or synthetic extension of the physical and/or virtual realms and enhance the human capability and capacity in their interactions with these multiple realities. In the past forty years, what we have learned and embodied in our techno-design, e.g. [Duchamp 1934], [von Foerster 1973], [Varela et al. 1974], [Latour 1988], [Baudrillard 1994], [Heisenberg 1998], is that reality is constructed, and we build 'worlds' each on our different ways. We mirror that understanding in our virtual realities, and bring both ambiguity and sophistication to the idea with mixed reality technology [Ascott 2006]. In this blend of consensual realities, the habitual and the virtual are fused. Robust interaction design (IxD) is therefore crucial to support the way designers and engineers (people) interact and exchange information and communicate throughout the design process. Rationalizing and externalizing the thought process that led to the insight is necessary to communicate the knowledge with others and make it plausible for them. Brereton [1999] uses the term 'distributed cognition' as "the process of designing and developing design understandings". Distributed cognition during ideation and interaction with predetermined or loosely defined constraints is essential to manifest ideas, explore fuzzy-notions and stimulate inventiveness [Wendrich 2009, 2011]. Most computer aided design (CAD) tools do not fully support ideation, externalization and creativity processing, especially not during the early phases of design processing, e.g. [Sener 2002], [Wang et al. 2002], [Bilda and Gero 2005], [Wendrich 2012, 2015], [Liu et al. 2014], [Kosmadoudi et al. 2014]. We propose heuristic shape ideation to support creativity, intuition, tacit knowing and reflection-in-action. The paper concludes by the consideration of possible pathways for expanding the perspective of human-computer interaction (HCI) through the use of robust interaction design (IxD), gamification and affective computing.

2. Blended spaces and hybrid design tools

McCullough [1996] stated: 'We must look very closely at craft. As a part of developing more engaging technology, as well as developing a more receptive attitude toward opportunities raised by technology, we must understand what matters in traditional notions of practical, 'form-giving' work.' This will take some study of tools, some study of human-computer interaction, and some study of practicing the digital medium.' Duchamp [1934] denounced the superstition of craft, the artefact is a projection of a three-dimensional object that in turn is the projection of an (unknown) four-dimensional object. The artefact is therefore the copy of a copy of the idea. Ascott [2006] questioned what that real reality might be? The 'space' created by various blended realities (mixed realities) is malleable (though fixed in spectral terms), we react to it individually and idiosyncratically. Beyond merely a blended space, we accept our mixed realities as montage-like interpretations of realities and create illusions of realities that differ substantially from 'original' experiences. Mixed reality technology provide us thus with another skin, another layer of energy to the body, adding to the complexity of its field [Ascott 2005]. Human experience and meaning depend in some way upon the body, for it is our contact with the entire spatio-temporal world that surrounds us. Key question here is: Are embodied representations, our expressions developed from our bodily perceptions and imaginative systems of understanding adequately shared to be thought of as appropriate to knowledge? Or, are they too subjective, unstructured and unconstrained? To paraphrase Johnson [1987], "...there is alleged to be no way to demonstrate the universal (shared) character of any representation of imagination." According to Schön [1983] it seems right to say that our knowing is in our action and interaction. In the fuzzy front end of creative processes, ideas are often visualized in one's imagination and externalized through 2-D and/or 3-D representations. Our approach incorporates the human embodiment (human) and interactions in conjunction with blended environments (machine), hence, interactive hybrid design tools and environments (HDT-E). The centrality of human embodiment (Figure 1 right) directly influences what and how things can be meaningful to us, the ways in which these meanings can be developed and articulated, the ways we are able to grasp and reason about ideas, experiences, and the actions we take (Figure 1 left).

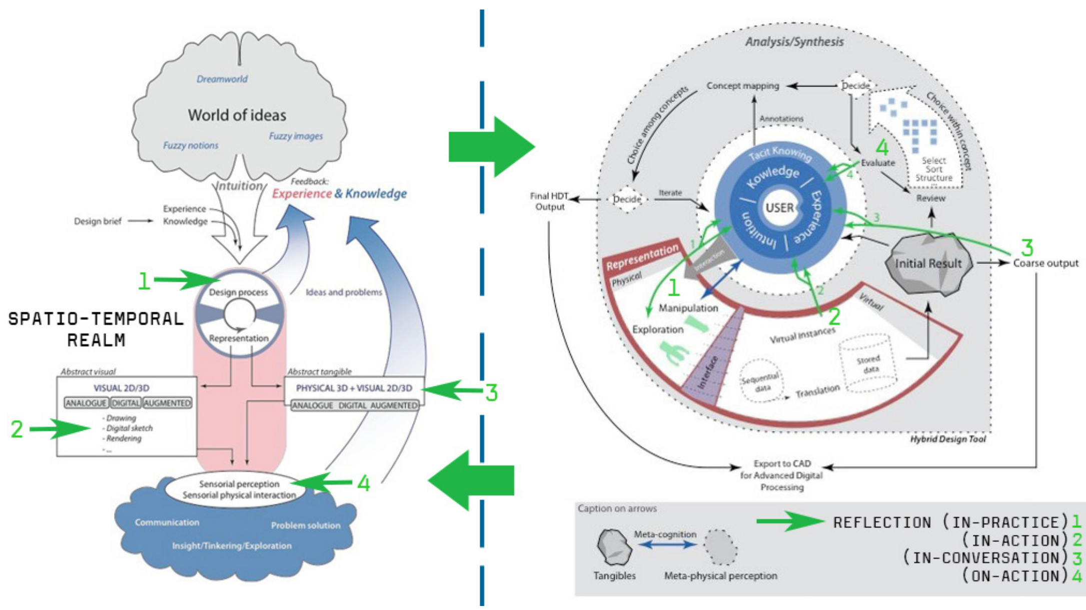

Figure 1. Hybrid design tool environment (HDT-E) and user engagement (UE) process flow

Embodied understanding is a key notion, we are never separated from our bodies and from forces and energies acting upon us to give rise to our understanding (our "being-in-the-world"). So, this "being-in-touch-with reality" is basically all the realism we need. This realism consists in our perceptions and sensorial understanding that makes us feel, touch, explore, and come-to-grips with reality in our bodily actions in the world. Moreover, we need to have an understanding of reality ample enough to afford us to fulfill a purpose or task nearly successfully in that "real" world. Polanyi describes the human body as an instrument, the only instrument that we normally never experience as an object. Because we experience our body in terms of the world to which we are attending from our body "…we feel it to be our body, and not a thing outside" [Polanyi 1966]. The HDT(E) holistic approach is based on the dynamic and agile development of HCI, along with the inclusion of meta-cognitive affordances, intuition, and bodily experiences. Miller et al. [2005] state that intuition comes in two types; either holistic hunches, or automated expertise. A holistic hunch is a judgement or choice made through subconscious synthesis of information drawn from previous experience and knowledge. Automated expertise happens when judgements or choices are made through a partial subconscious (autonomous, self-aware) process involving recognition of the situation. However, often it is the software alone that defines and determines how and what actions are possible within a virtual reality. As a result 3-D modelling tools (CAD) on a computer, not much unlike e.g. 'hammers', impose limitations to the solution space. These limitations have direct implications to the freedom of a designer, as well as the understanding of form and shape of virtual models [Kruiper 2015]. According to Dyck et al. [2003] current CAD systems do not have a strategy to communicate between the system and the engineer to enhance the UX. Games on the other hand "…communicate information to users in ways that do not demand the user's attention and do not interrupt the flow of work" [Kosmadoudi et al. 2012]. Humans excel at using resources, especially representational resources, in systematic but creative fashion to work their way to solutions. They are good at using and manipulating structures and constructs [Kirsh 2005].

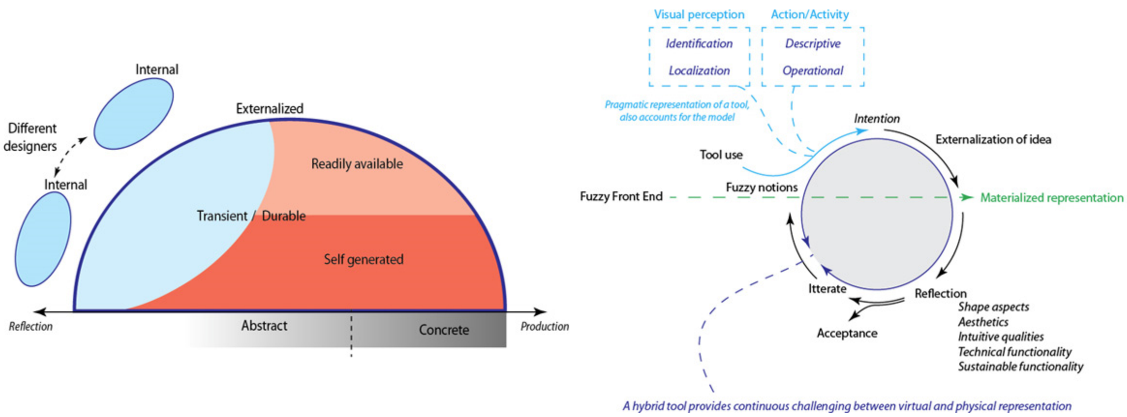

Figure 2. HDT(E) fluctuated representation

Brereton [2004] describes four dimensions along which representations can be classified (Figure 2 left) Embodied imagination (physical experiences and its structures), intentionality, and metacognition could simultaneously 'link' this imagination (individually or collaborative) congruous with the digital realm based on our natural physical and intuitive interactions and explorations (Figure 2 right). Human attention fluctuates between meaning, timbre, texture, rhythm, syntax, pitch, colour, shape, form, creating a complex weave in which the total package matters less than the aggregation of the individual characteristics of perceived objects and /or artefacts. Lastra [2000] stated: There is never a fullness to perception that is somehow 'lost' by focusing on a portion of the event, by using the event for certain purposes, or simply by perceiving with some particular goal, say understanding or insight, in mind. When a thought process is categorized into intuitive and rational processes, the intuitive system (System 1) is characterized by the keywords: fast, immediate/automatic, slow learning, effortless and associative. The rational, conscious system (System 2) is characterized by the keywords: slow, controlled, flexible, effortful, and rule governed [Kahneman 2011]. Flow separates and combines both forms of thinking: concentration on the task and deliberate control of attention [Wendrich 2013]. The deep meaning of embodied cognition is that it enables disembodied thought [Tversky 2005]. Blending realities was already present during the initial wake of the computer-revolution; the idea of 'disembodied cognition' became very popular, e.g. [Mahon and Caramazza 2008], [Tversky and Hard 2009]. The trouble here is that being 'disembodied' created great challenges, frustrations and problems to solve in human interaction with machines.

3. Enhanced hybrid design tool environment

How can current technology fluidly afford cognitive, emotive, affective, and gesture-based shape and form externalisation in an enhanced Hybrid Design Tool Environment (HDT-E)? Some of the most important aspects and intrinsic to the design and engineering of such ecosystems are:

1. Cognitive: related to knowledge and mental abilities | Aggregating the current knowledge during the process as a result of experiential learning | Supporting decision-making and choice-architecture in later stages by providing overview and understanding of the design process.
2. Emotive: related to subjective, personal experiences | Affective computing; becoming responsive, aware and adaptive to the emotions of the user | Emotional expressivity in the

design; the perceived emotions directly influence the externalised representation through, e.g., colour, form details and context.

3. Gesture-based: related to human computer interaction | Human Computer Interaction (HCI) in multiple modalities (multimodal), simply put: finding ways of interacting with the computer that are more intuitive than keyboard and mouse in a 3-D modelling environment | Gestures to control the virtual interaction; e.g. selecting, adding, transforming, morphing, translating and rotating models.
4. Shape and form externalization: related to different types of representation used during the design and/or ideation of a products | Shapes are representations in two dimensions, whereas forms are three-dimensional.
5. Hybrid Design Tool Environment: A design tool that integrates physical and virtual interaction in a contextual environment that supports a designer during the early phases of a design or product creation process.

Guidelines for the HDT in conjunction 3-D sensorial interaction has the following characteristics [Wendrich 2004], [Kruiper 2015]:

- Tool creates more insight and understanding | 3-D surface data is acquired with the depth camera
- Tool has low threshold in learning curve | Gesture based HCI is one of Kinect's key-features
- Tool increases processing speed in solution space | Optical 3-D scanning, so (near) to real-time interaction is possible
- Tool implies visual and tangible representation | No controller to generate 3-D content, but surface information from interaction with tangibles
- Tool triggers easy ideation and conceptualizing | Quick low-fidelity data acquisition, the accuracy does not exceed the limit of several millimetres
- Tool allows intuitive un-tethered interaction | Most, if not all, non-opaque and non-reflective materials can be used | Besides raw surface measurements, speech and gesture based interaction can be integrated into the HCI of the HDT
- Tool is applicable in a comfortable, contextual surrounding
- Sensing area of the sensor system suits a workbench approach with a sensorial workspace
- Tool and content are portable | The size of the sensor system allows for portability of the HDT
- Cost: COTS products, components, and availability of open source libraries for software development

4. Interaction design (IxD) and user experience (UX) for HDT(E)

Building on the analysis of our previous research and tool creation, this study integrates knowledge from several fields of research into a broad, contextual direction for the design of HDT's. Generic guidelines for the creation of a HDT(E) are drawn from analysis of experimentation and tool creation. The goal of creating a HDT(E) is to overcome limitations and deficiencies of CAD tools regarding ideation and creative processing in the product creation process (PCP) [Wendrich 2009, 2010, 2011, 2012], [Verduijn 2012]. In doing so, the interaction design (IxD) is an important aspect that has not been addressed yet [Kruiper 2015]. According to Hartson [2010] usability stems "from the effectiveness of cognitive affordances for understanding how to use physical affordances, the physical ease of using the physical affordances, and from the sensing of these via sensory affordances". The usefulness of a system stems from the utility of functional outcomes of user actions. Designing for usability and interaction with interactive technologies is about exploring design spaces, and realizing new systems and devices through co-evolution of activity and artefacts – the task-artefact cycle [Carrol 2014]. The cycle implies that HCI is an ever-changing exploration of new applications and application domains through the co-evolution of activity and (supportive) technological artefacts. This requires the consideration of many alternatives at every point in the progression, if the focus lies too strongly on the affordances of currently embodied technology we are too easily and uncritically accepting constraints that will limit contemporary HCI as well as future trajectories". Hartson [2010] proposed a similar but more detailed IxD model as interaction-cycle mostly based on Norman's [1990] stages-of-action model. Both models consist solely of user-actions, whereas interactive products interpret, process and present information as well. Abowd and Beale [1991] extended the stages-of-action model by adding the system. Figure 3 displays the various models including a proposed integration of an interaction-reflection model; leading to a generic interaction model for the HDT(E) and the cognitive processes that occur.

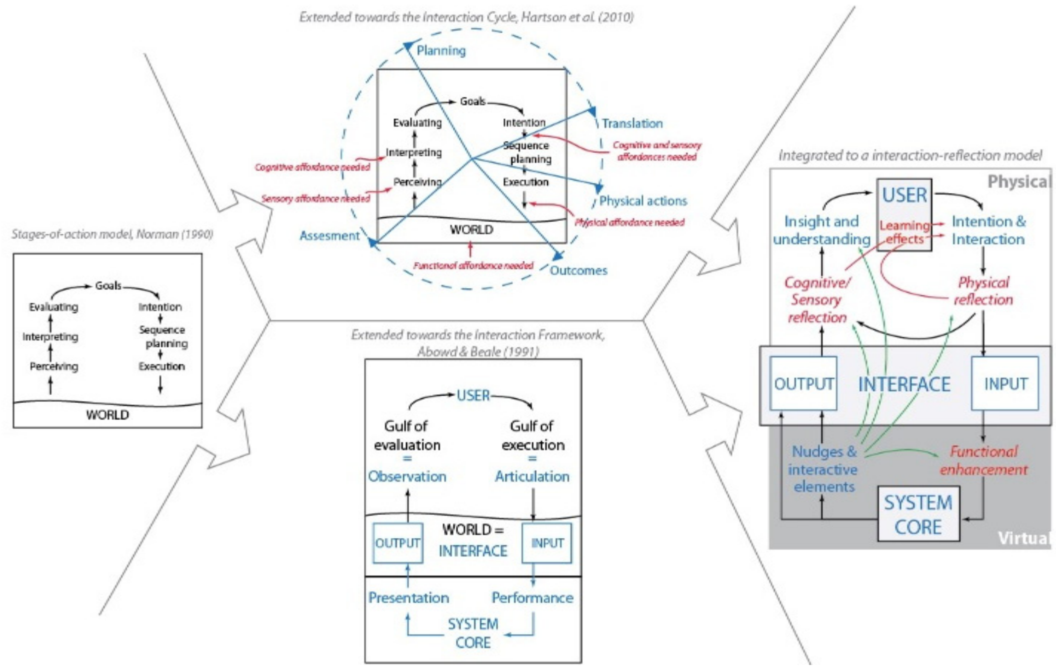

Figure 3. HDT(E) generic interaction model, based on integration of existing and proposed interaction models. Green arrows represent how the system might nudge the user to perform certain actions, red arrows represent how a user learns from reflection-in/on-action.

IxD is concerned with "designing interactive products to support the way people communicate and interact in their everyday and working lives" [Rogers et al. 2011]. Interactivity is "an expression of the extent that in a given series of communication exchanges, any third (or later) transmission (or message) is related to the degree to which previous exchanges referred to even earlier transmissions" [Rafaeli 1988]. In this definition interactivity is regarded as a user-oriented, uni-dimensional and process-based attribute of a product or system. The goal of IxD can be regarded as the optimisation of user experience (UX), user engagement (UE) and usability in specific, progressing user-context situations through a product's behaviour. This is different from Human-Computer Interaction (HCI), which concerns the design and use of computer technology and focuses particularly on the interface between users and computers [Kruiper 2015]. Interaction with current CAD tools is usually based on interfaces with Windows, Icons, Menu's and Pointers (WIMP). Mouse and keyboard are used to perform actions within the virtual 3-D environment. Jetter et al. [2013] state that research on post-WIMP interfaces is focussed on achieving natural and unobtrusive computational support during a variety of activities. The interaction with post-WIMP technologies is usually user-centred and aims to achieve ubiquitous computing environments with 'invisible' technology. However, "HCI researchers still do not understand why some post-WIMP designs are perceived as 'natural' or 'intuitive', while others are not". Jetter et al. [2013] continues that the latter is due to lack of theory, model or framework about the cognitive processes that let us perceive UIs this way or the other. Correlating the use of tangible, physical tools and IxD helps understanding the underlying framework of tangibility, physicality, dexterity and embodiment. Spool [2005] states that a design is intuitive if the user does not require new knowledge to operate the system. According to Hurtienne et al. [2007] interaction with a technical system is intuitive "if the users' unconscious application of prior knowledge leads to effective use". From this we infer that interaction is considered intuitive when the user is able to operate a system by applying existing knowledge in carrying out intention.

4.1 HDT(E) integration with LFDS and NXt-LFDS

We design, develop and build various machines and systems based on our HDT(E) framework [Wendrich 2009, 2010, 2014, 2015] with various embodiments, configurations, multiple modalities, and an expansive variety and array in hardware and software structures (Figure 4).

Figure 4. HDT(E) various embodiments of LFDS (1 - 2 - 3) and NXt-LFDS (4 - 5)

The Loosely Fitted Design Synthesizer (LFDS) and NXt-LFDS incorporate multi-modality systems that consist of a fuzzy-mode (FM) and a logic-mode (LM) to afford different interaction styles that fit the user-requirements [Wendrich 2013]. Table 1 shows the differences between the FM and LM based on a summarized description and extended to suit various tools and interface extensions (Figure 5); i.e. wearable EEG interface (5-1), 3-D voxel scanner (5-2), puff&sip interface (5-3) and a HDT equipped with Kinect (5-4).

Table 1. The difference between FM and LM

Fuzzy-mode (FM)	Logic-mode (LM)
Focus on physical modality	Focus on virtual modality
Unobtrusive technology	Prominent technology
Input devices used for content creation	Input devices used to control content
Benefits from reduced complexity	Overview of created content
Low amount of functions	Alter separate iterations
Obvious interaction styles	Recombine separate iterations
Untethered interaction	Interactive GUI elements
Core functionality in plain sight	More specific functionality
Capture-button	Menu's with familiar icons and descriptions
New canvas	
Optionally undo function	

4.2 HDT(E) equipped with wearable EEG

This wearable user interaction (UI) device (Figure 5-1) affords to stimulate and facilitate ideation using Brain-Computer-Interfaces (BCI) as an intelligent sensor during the early-phase of a design process in an intuitive HDT(E). With further development of BCI technology it is possible to gain insight in and understanding of user-aspects yet to be integrated in human-computer-interactions (HCI), such as affective and cognitive states. This plug-and-play interface defines body-signals to provide the user intuitive modalities to execute system actions using facial expressions. The presence of ambiguous elements in using facial expressions, as executer of system tasks, lead to awareness of these expressions, as well as creating experience of the system nudging when these expressions occur unintentionally.

4.3 HDT(E) equipped with puff&sip interface

This device and system allows glassblowing like interaction with a computer, humans have a lot of fidelity with the pressure and airflow they can exert, so this makes it an interesting input modality for a design process (Figure 5-2). We developed a Tangible User Interface (TUI) with common off the shelf components that can accurately measure airflow and pressure of a human blowing, and make this data available on a computer for virtual representation and simulation. A graphic user interface (GUI), and visualizer (representation) are facilitated. The wireless handheld device is capable of measuring both human blow pressure and flow rates, simultaneously sends the data values to a receiver that is connected to a PC. It has a 6DOF orientation sensor, so interaction with how the device is held can be created. The combined wireless sensor platform enables users to have new interaction with a PC. Complementary to the hardware we created a software data visualizer that enable data representations to create, e.g. 3-D meshes that can be opened and further iterated in 3-D software suites (e.g. Blender).

Figure 5. HDT(E) Tool and interface extensions (1 - 2 - 3 -4)[1]

4.4 HDT(E) equipped with 3-D visual hull scanner

A low-cost, low-resolution 3-D visual hull scanner (Figure 5-3) is developed to facilitate near real-time scanning of objects and/or artefacts for integration with a HDT(E). The digitization of 3-D raw objects and low-resolution physical/tangible models during early-phases of design processing to stimulate and generate virtual prototypes or models is crucial during ideation and conceptualization. The application is partly based on the shape-from-silhouette scanner (SFS) [Forbes 2006] whereby five silhouette images (photos) are used to capture and construct a 3-D virtual model from real-world objects. The device use two off-the-shelf planar mirrors that are positioned to show five views of an object, a LED-backlight surface is used to automate and support the silhouette selection and snapshots are captured from different viewpoints with a HD-video camera. A video camera is chosen to make it possible to generate and make use of live-view feedback during interaction. Silhouette outlines are represented by polygons, and pixels are assumed to be square. The parameters are adjusted automatically to minimise the sum-of-of square distances between epipolar tangencies and corresponding projected tangents using the Levenberg-Marquardt method [Moré 1978]. Each of the five cameras' silhouette views of the real object can be used to compute the five-view visual hull of the object [Forbes 2006]. The average time to generate a 3-D virtual model is about six to thirty seconds depending on the required image resolution levels.

4.5 HDT(E) equipped with a Kinect

The emotions a user experiences (UX) during HCI with a HDT(E) can be applied in different ways. Three main applications of emotional awareness (AE) and user engagement (UE) have been based on the different processes in HCI: interaction, feedback, or processing. A design process can be augmented through the use of nudge creation, extrapolate emotional awareness, and support emotional feedback [Kruiper 2015]. Besides HCI that adapts to the emotion of a user, monitoring emotional states in a naturalistic setting provides information on the influence of emotional states on the design process and outcome. This could be used to gain insight in the effects of positive affect and flow, the latter being "a state of concentration so focussed that it amounts to absolute absorption in activity" [Csikszentmihalyi

[1] https://vimeo.com/139182156, 132374254, 131660292, 131555878

1990]. Flow is a reoccurring phenomenon during several RST experiments [Wendrich 2014]. Optical 3-D scanning (e.g. Kinect) based on structured light and triangulation, allows for fluid cognitive and gesture-based shape and form externalisation in a HDT(E). Although enhanced interaction might be possible, further research is in progress to determine whether this technology can allow for affective computing. There is no functional prototype as of yet, however incremental use-case studies in conjunction with Kinect setup (Figure 5-4) have been executed and tested [Wendrich 2010, 2014] [Kruiper 2015]. This conceptual approach is taken with regards to the Interaction Design (IxD) of a prospective HDT(E) using a Kinect (Figure 6). The IxD of a HDT(E) is crucial to overcome the deficiencies and limitations of current CAD tools as described by Kosmadoudi et al. [2012]. Part of the solution revolves around the application of gamification and integration of tools that afford a large range of interaction styles in physical, virtual and mixed realities. Moded design, as used in the LFDS, and gamification can improve immersiveness while shifting between these realities. Post-WIMP interaction styles, e.g. gesture-based interaction, and sensorial virtualisation (e.g. the puff & sip UI), provide more insight and understanding in the virtual design space than conventional input devices like mouse and keyboard [Kruiper 2015].

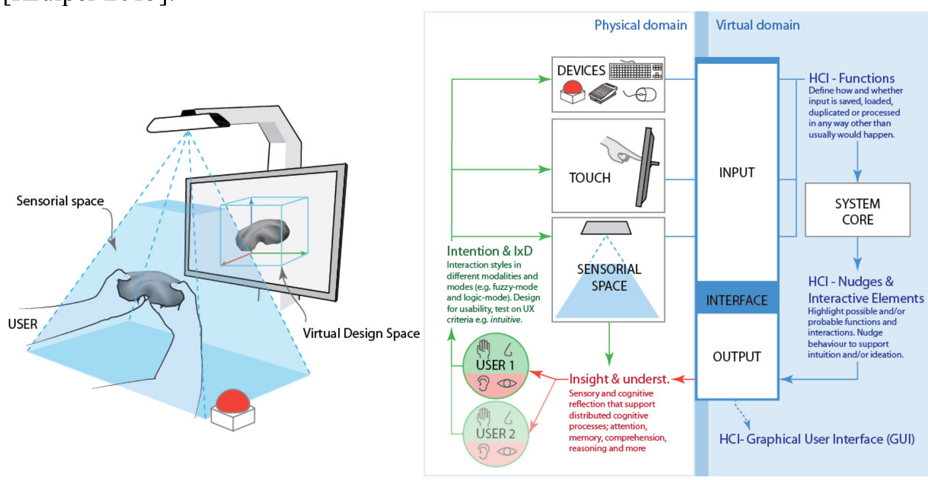

Figure 6. HDT(E) with integrated interaction model equipped with e.g. a Kinect. The system allows for three types of input: analogue, touch and sensorial virtualisation

5. Conclusion

The apparent communication gaps between the human and the machine, is like a gulf of mutual incomprehension. As long as channels for 'communication' remain open and alive the distance between and the differences of the two worlds, are essential to reconceptualise these fertile but ill-defined contested spaces and realms. According to Truex et al. [1999], ill-structured systems need to be developed using a totally different set of goals that would support emergence, growth and change. Alexander [1964] stated that the main problem often lies in separating activities surrounding analysis and synthesis, rather than recognizing their duality. According to our previous research, the use of tangibles in the early design phase is key to design processing and the development of a HDT(E). In order to use tangibles for physical interaction, the manipulations of these tangibles are to be translated into real-time representations of a virtual model. Reflection, incubation and learning are encouraged when technology is supportive and calm, it allows user-control, engagement and fosters learning skills while harnessing talent [Wendrich 2014]. The HDT(E) is a full-loop system, which is used to generate both physical and virtual models. The type of deformations and manipulations on both models depend amongst others on the technology used to acquire data. Further research towards 3-D interaction with a HDT(E) is necessary, as well as research into enhanced interaction through automatic emotion recognition (AER) and other methods to detect creative slowdown. According to Dyck et al. [2003] CAD systems do not have a strategy to communicate between the system and the engineer to enhance the UX and UE. Games on the other hand "…communicate information to users in ways that do not demand the user's attention and do not interrupt the flow of work" McCullough [1996] states, "The possibility of craft lies not so much in the technology as in the outlook you bring to it" (p272). Using a variety of HDT(E)'s based on different COTS technologies allows for a variety of interaction styles and serendipitous outcomes. The integration of different tools within one virtual environment can provide a designer with a hybrid workbench that is dedicated to support ideation, creativity and intuition.

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