Exploring Tacit and Tangible Interaction Design: Towards an Intuitive Design Tool

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Abstract—Our [re]search is aiming at the identification of essential voids in the support of design processes offered by commonly available methods and tools. Some remarkable results were obtained during design sessions with novices and experts by engaging them in tangible experiments that were designed to stimulate and enhance their skills, tacit knowing and creativity that enable them to represent their ideas and concepts in an intuitive way. We explored and captured the differences in designer's behavior during use of "analogue" and digital representation tools. We will explain our laboratory experiments, test results, educational embedding and creative opportunities that emerge from hybrid design tools. Furthermore we propose an exciting hybrid design tool to bring the tacit and tangible elements of design back into CAD systems. We follow two different routes in our attempt to identify and fill the voids. In the first procedure is a set of observations to measure the effectiveness, various shaping and representation techniques. Knowledge about learning curves, time constraints, idiosyncrasy, quality of design results and focus of particular design methods gives insight in peoples abilities to improve and support decisions about the structure and content of the "best" curriculum for industrial design engineering students. The second procedure is the creation of a prototype of a hybrid design tool to stimulate intuitive and imaginative skills. For the experiments, we used nine (9) haptic representational configurations and set-ups, and involved over 95 participants per experiment. In these configurations the participant's performance of form giving and shaping techniques were captured, observed and rated.

Keywords—intuitive product design; design work bench; hybrid design tools; virtual design assistant

I. INTRODUCTION

There can be no design activity or process without the use of design representation, i.e. visual or physical. Ideas or fuzzy-notions must be shared with others or oneself and therefore be represented and manifested in some form or way. There are many different ways to represent your ideas or creative thoughts on design issues, these modes and strategies we choose to convey or make visible are closely related to our intuition, tacit knowing, vocation, social-cultural context and experiences of how to represent these interim entities. Distributed cognition during the design process enables designer’s to make manifest imagination to explore and shape product ideas, simultaneously working within e.g. implicit and explicit functional and mechanical aspects, material constraints and aesthetic qualities.

II. CURRENT SITUATION

A. Framework

We created a framework and identified the specific [re]search field for our explorations and experimentation. This allowed us to conduct and fundament our divergent [re]search approach and investigate the large variety in ‘analogue’ and digital representation tools.
B. Two-Handed Interaction

As we know, ‘The hands are the instrument of the mind’ or to paraphrase McCullough, ‘Hands are underrated because they are poorly understood’. To work with tangible materials allows the designer to investigate and explore ideas physically, feel the constraints of materials, tinker intuitively and create insight and interact with artifacts that are manifested through manipulation and tacit knowing. We focus our research on the intuitive design of products and tangible representation through two-handed interaction assisted by ubiquitous computing. “Fig. 02” We support designing-in-action and thinking-in-action in combination with a Virtual Design Assistant (VDA) leading to virtual models created by tangible interaction being transformed into virtual mesh iterations. “Fig. 03 + 04”

III. TANGIBLE EXPERIMENTS EMBEDDED IN EDUCATION

Scaling and 2D to 3D transformation from orthogonal projections of artifacts were implemented as design assignment in industrial design engineering education.”Fig. The scaled projections are being used as templates to ply and construct three (3) wire frames “Fig. 6” in aluminum wire, cardboard/paper strips and sheet metal strips. The wire frames have to conform to the enlarged drawings. The assignment is complex translating and transforming two-dimensional views and elevations into tangible three-dimensional wireframe representations. Secondly making decisions about the right approach, being a choice-architect and exploring form structure and form organization. The final step in this assignment is to add surfaces or surface textures “Fig. 7” to the wire frame, meaning to build shapes of seemingly great complexity.

A. Methods of Modelling

We extracted two main methods of modelling the 3D objects from our selected line-up of 36 object iterations. Models were either made by use of the slicing method or through modelling with 3D curved lines. With the slicing method the respective views from the orthogonal drawings are literally translated in the model. The top view becomes the base and is often the starting point of the model. All other elevations are translated and mounted onto the base. The side elevation is being used as a mid section slice in most models. When modelling in 3D curved lines the scaled 2D drawings (view and elevations) are being used to create 3D models. The chosen lines for executing the curved line model are not exact outlines or
translated sectional views but flowing and fluent lines in 3D space that cover more than one view or section.

B. Objective and Approach

The object is to improve insight and learning how form and shape are emerging and created, how a faulty or sloppy production process could do a good deal of harm and entail major implications to form and shape of an object. However, the contrary could be an acceptable approach by allowing randomness in design processing the geometry will be jagged, but with logic of its own and one that is easy to understand and identifies the idiosyncratic value of the object. In design ideation and conceptualization we support and look for unintentional change in processing, serendipity, unpredictability in shaping and forming, being oblivious to blind-spots, create variable contexts resonate intentions of design interactions and allow adversaries creating stories. Inadvertently we all inherent the same shortcomings, perceptive and sensorial problems and issues that come to the design workbench or computational design work station in multitudes of multiples where the need for Design Thinking about design blind spots are necessary and imminent to implement in design and design engineering curriculum.

IV. LABORATORY TESTING ON NOVICE AND EXPERT DESIGNERS WITH TANGIBLE EXPERIMENTS

We introduce nine (9) haptic representational configurations and set-ups. “Fig. 8” The participants get a brief set of instructions, design tools, an orthogonal projection of an artifact, a perspective stencil (size constraint) and five (5) minute time constraint. We measure the effectiveness and other qualities between abstract and material representation by use of intuition, experience and tacit interaction. The aim is to acquire knowledge and make apparent the emerging inertia and entropy deriving from un-tethered and tethered tool use, stall, high learning curve threshold, tacit knowledge, routines, context constraints, signs of flow, gestures and skill development.

A. Haptic Test Benches for Three-Dimensional Design Interaction:
1. Pencil Sketch test bench
2. Sand Sketch test bench
3. Sculpting test bench
4. Wire Plying test bench
5. Steam Sketch test bench
6. Solid Works test bench
7. Virtual Clay test bench with Haptic FF-Mouse
8. Blindfold Tacit test bench
9. Blindfold Tangible test bench

B. Analysis Method and Results

We used Video Interaction Analysis (VIA) (Jordan & Henderson, 1995) to investigate the gestures, expressions, actions, immediacy (context), iterations and interactions with hardware and software. Video recording enables us to make qualitative analysis and evaluations of the various tests and test-results. Data was extracted from the video footage in the following order of test benches. We assessed 95 participants per test, novices and experts, videotaped 41 hours of interaction during a 4 months period, which resulted in a large set of video data. All the participants were made aware of the video recording no further reference was made to the video camera during the assessments. The duration of the assignment was 5 minutes (effective), in some cases (test bench nr. 6+7) we allowed some additional time (±10 min.) because of program inertia or high learning curve. Since we engage in ongoing experimental research, we decided for this paper to use a quantitative selection Table I on average 30 participants and concluded provisional results from the selected raw data. Only in the last two tests (nr. 8 + 9) we used the data of 79 participants. The on-the-fly ideation of a design task and representing it either abstract or tangible showed us that experimentation with haptic interfaces is useful. Results show us that tangible interaction has merit, speeds up interaction, lowers threshold in learning curve and stimulates flow and engagement. Un-tethered two-handed interaction is adding more quality, more detail and convey higher output in less time. Intuitive interfaces steam up the pace and create flow in interaction. Force feedback from material constraints transpires concentration and involvement in processing. The use of digital devices (i.e. mouse, keyboard) and the use a digital force-feedback device in ideation and conceptualization did not prove to be very effective, in some cases the participants gave up
after being frustrated with the result on the screen from their input.

V. HYBRID TOOL

We propose a new method of design conceptualization and ideation based on intuitive skills, tacit knowing, reflective praxis and tangible augmented representation. The method entails the creation and development of a two-handed material representation Workbench with real-time or near-real-time vision-based components that generate polygon-mesh iterations as possible design solutions. The Virtual Design Assistant tool (VDA) “Fig. 9” stores and shows all the iterative steps as raw polygon meshes during the design representation process and places them in a solution space library.

The creation of a prototype of this hybrid tool “Fig. 10 - 13” and Workbench for physical interaction “Fig. 14 + 15” to stimulate intuitive and imaginative skills allowing the designer more control, flexibility, flow in interaction, choice architecture, analogue tinkering, manual dexterity and allowing randomness. These elements are essential in

**TABLE I. RESULTS NINE (9) HAPTIC TEST BENCHES**

<table>
<thead>
<tr>
<th>number of participants</th>
<th>pencil</th>
<th>sand</th>
<th>steam</th>
<th>sculpting</th>
<th>plying</th>
<th>3d solid</th>
<th>virt. clay</th>
<th>b. tact</th>
<th>b. tang</th>
</tr>
</thead>
<tbody>
<tr>
<td>pencil test time [mm:ss]</td>
<td>26:00</td>
<td>16:00</td>
<td>20:00</td>
<td>25:00</td>
<td>24:00</td>
<td>34:00</td>
<td>46:00</td>
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<td>n.a.</td>
</tr>
<tr>
<td>sand test time [mm:ss]</td>
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<td>2:20:00</td>
<td>3:20:00</td>
<td>3:12:00</td>
<td>4:37:00</td>
<td>6:08:00</td>
<td>7:13:00</td>
<td>7:04:00</td>
<td>5:29:00</td>
</tr>
<tr>
<td>average test time per participant [mm:ss]</td>
<td>08:19</td>
<td>03:22</td>
<td>04:00</td>
<td>05:53</td>
<td>06:51</td>
<td>12:22</td>
<td>17:31</td>
<td>05:29</td>
<td>05:22</td>
</tr>
</tbody>
</table>

Real-time interaction or post-interaction with the various mesh iterations is possible with an un-tethered interface (multi-touch screen) that allows the user (designer) to interact intuitively with the polygon-meshes, blend them or synthesize the solutions. The possibilities of inserting raw functional elements in design iterations leading to multi-layered manufacturing are strong and important features of this tool.
notions. Commonly available tools and methods demand learning and practice before becoming valuable and/or reliable design systems. Some of these tools and methods have such high learning curves or constraints in mediation that users are getting de-motivated by the experience and start looking for other possibilities and tools to use. We recognize the importance of computational design and the increasing possibilities of emerging technologies, but we need to reconsider the human interaction approach and embed the significance of analogue tinkering and intuitive modelling in design processing. By starting in the creative or ideation phase we respect the awareness, consciousness and idiosyncrasies of the designer instead of being confronted right from the start by 3D digital modelling constraints and perceived affordance. (ibid. HCI, D. Norman, 1988)

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