

Bridging the Design Gap: Towards an Intuitive Design Tool

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“The stone unhewn and cold becomes a living mould.

The more the marble wastes, the more the statue grows.” (Michelangelo Buonarroti)

Abstract. *A main task of industrial designers is the shaping and transformations of ideas or fuzzy notions into abstract or materialized equivalents. These sketches, models or other representations can be described as the sum of form and shape aspects, aesthetics, intuitive qualities as well as technical and sustainable functionalities. The designer must understand the elements involved in this synthesis of form giving and design. Successful designers compose these characteristics carefully and join them together to form and shape artefacts into a harmonious and balanced whole, while simultaneously manoeuvring within implicit and explicit mechanical and functional aspects.*

With the emergence of 3D computational design, the industrial design process shifted from traditional analogue physical representations of ideas or artefacts to digital virtual realities. This shift is creating pre-dominance of digital design over the idiosyncrasies of analogue craftsmanship of the designer. Loss of control, immediacy, manual dexterity and skills due to constraint in electronic interfaces (keyboard-mouse-monitor) and programmer's directions, gave way to alienation of the physical material world. With every new generation of design students, the widening gap is transforming intuitive design qualities and skills into virtual data processing inertia.

We follow two paths in our attempt to bridge this gap. The first is a set of experiments that aim to measure the effectiveness and other qualities of various shaping techniques. Knowledge about learning curves, quality of the design results and the focus of particular methods enables decisions about ‘the right’ curriculum for Design students.

The second path is the creation of a hybrid design tool where designers are engaged and in which the intuitive and imaginative skills are stimulated, explored and triggered.

This paper explores the distinctions between the analogue and digital representation tools, explain our laboratory experiments, testing results, educational embedding and creative opportunities that emerge from hybrid design tools. For our testing experiments, we used seven (7) haptic representational configurations and set-ups, and involved over 150 test subjects per experiment to map results. In these configurations we measure the performance of form giving and shaping techniques.

Keywords: *analogue, intuitive design, 3D computational design, design representation, design process, design education, hybrid design tools, augmented reality*

1 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 in some form or way. There are many different ways to represent your ideas or thoughts on design issues, these modes and strategies we choose to convey or make visible are closely related to our intuition, tacit knowing, vocation and experiences of how to represent these interim entities. Distributed cognition during the design process enables the designer to manifest ideas to explore and shape product ideas, simultaneously manoeuvring within implicit and explicit mechanical and functional aspects, materials and aesthetic qualities. In this paper we focus on material representation within the ideation and abstract conceptualization phase of the design engineering process. We explore different angles of design representation by means of abstract or material equivalents, address implications and embedding in education. Distinctions between analog and digital interpretations, tacit media, explaining creative opportunities and critical issues that emerge with hybrid combinations and ubiquitous computing (VR/AR) are identified and evaluated. Issues such as once remarked by Herbert Simon: “Computers are sensory deprived!” Designers [Fig.1] are relying on sensory perceptions and sensory feelings, wherein our distortions in visual perception of three-dimensional form can be corrected by tactile observations or tangible interactions.

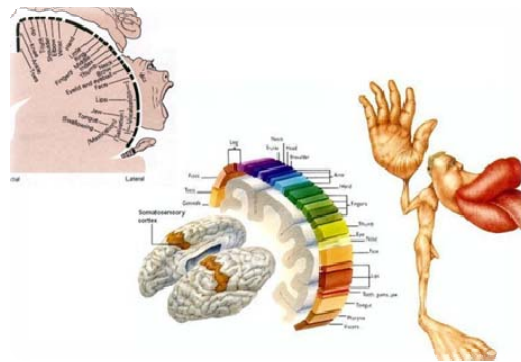


Figure 1: Homunculus Intentio (<http://universe-review.ca>)

2 Current Situation

We scratch, construct and manipulate the earth resources with our tools and artifacts, making buildings, fabricating structures, thereby creating and producing our manifestations of thinking, dreaming and tinkering. We are leaving marks, traces, roaming about and searching for beauty and nature often without real pre-set goals or destinations. In natural course of life walks, we are striving and following somewhat our ambitions and passions, but everything you do or undertake is structured or triggered by our will (automatic system), fuzzy approach (reflective system) and conventions while constantly being influenced by our worldly surroundings.

Why are we doing what we are doing? How come we scar, cut, sculpt, ply, fold, score, crease, pinch, pull, push, blow and scissile our way through the earth resources? Why do we engage in visual and tacit interactions with such great ease and pleasure? How come than that we distant ourselves more and more from our physical sensorial perceptions and immerse ourselves gladly

in virtual digital realities? Why are we so easily lured into visual stimulation, worshipping digital visual junk on high-definition screens? What if we bridge the widening gap between the analogue real and the virtual world? How about hybrid combinations?

2.1 *Inertia and Entropy*

With the emergence of computational design for over two decades, the design industry changed drastically and transformed from a hands-on, practical and analogue profession to a virtual digital one. Designers are being made into data processors, entangled and tethered in virtual digital realities with tools that are developed, directed and designed by system engineers and software programmers. It is apparent that loss of control, manual dexterity and intuitive interactions are surfacing while interacting or being immersed. Inertia and entropy caused by human-computer-interaction is real and apparent. As a user it is virtually impossible to be in sync with a computer, the user is on a leash and placidly follows the digital virtual system boss. Most representational technologies deskill, confuse, simplifying control and removing the unpredictable, the only way to interact is by learning, doing and experiencing programs procedures and categories. 'In such we can conclude that emerging digital design technologies are perceived as replacements for traditional skills, and therefore as potentially threatening to deskill novices, journeyman and professionals'. (ibid. Wooley, 2004)

2.2 *The Best of Both Worlds*

In 2004 we conducted a study on engineering technology and industrial design engineering students to investigate the future of virtual form giving (VFG) in design praxis. The study revealed that virtual form giving is a promising tool, only when:

- Tool creates more insight and understanding
- Tool has low threshold in learning curve
- Tool increases processing speed in solution space
- Tool implies visual and tangible representation
- Tool triggers easy ideation and conceptualizing
- Tool generates and allows simulation
- Tool allows intuitive un-tethered interaction

These findings and results nudged us towards more research and experimentation in the domain of Virtual Reality and Design Tools. Main issue was the implementation of design materialisation and representation assignments in the design engineering program over the last five years. There seems to be a pre-dominance in abstract representation (visual) over material representation (material) in most design educational programs. More emphasis was laid on the use of both sensory perception and sensory feeling within design assignments hence we saw dramatic increase in material representation in conjunction with the abstract. Learning in design is enabled through continually challenging abstract representations against material representations. This comparison between representations reveals gaps that inspire further design activity, experimentation and research.

2.3 Educational Embedding of Tangible Representation

Several methods and strategies were devised and used as experiments within teaching and learning contexts, ranging from very abstract-physical assignments to 5-step design methods. Our latest educational approach is to assign a seemingly more structured method to design an automotive artefact. In this case we hand students an orthogonal projection [Fig. 2] of an automotive design icon (Citroën DS) on A4.

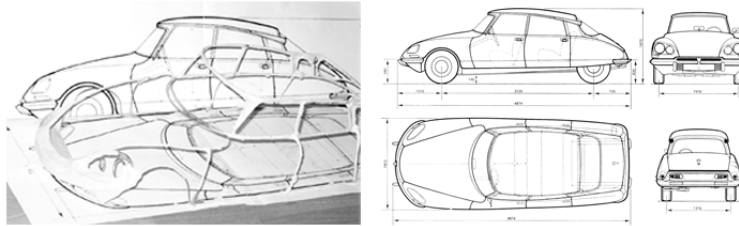


Figure 2: Size Change (left), Orthogonal Drawing DS (right)

The elevations are in proportion, but not to specific scale! The first task is to size-change the elevation drawings to an exact dimension: 488 x 180 x 147 mm. For most students this seems a difficult task and noticeably many variations in size-change become available. Some students will take no direct action, contemplating and thinking about their approach. Next thing they run off to the nearby photocopier to enlarge their drawing. This illustrates how difficult it can be to get grip on proportions and dimensions. The enlarged projections are being used as templates to construct three (3) wire frames [Fig. 3] in aluminium wire, cardboard/paper strips and sheet metal strips. The wire frames have to conform to the enlarged drawings.



Figure 3: Wire Frame DS (left), Paper Strip Frame (middle), Metal Strip Frame (right)

It is a complex assignment because of the translation of two-dimensional elevation drawings into three-dimensional wireframe representation. Many questions and issues arise from this. Key factor is making decisions, being a choice-architect and confrontation by designing-in-action and thinking-in-action. The final step is to add surfaces and surface textures [Fig. 4] to the wireframes to complete the project.¹



Figure 4: Surface Texture examples on DS wireframes

¹ In the appendix we present a sub-project Research on Form Organization in Wire Frames

The object is to improve insight and learning how form and shape are explored and created, how a faulty or sloppy production process can do a good deal of harm and entail major implications to form and shape of an object.

3 Bringing Tangible to Experimentation

We were not surprised, but intrigued, to see the enormous discrepancies and variations in form, shape, design, proportions, and textures of the models and creations of idiosyncratic artefacts.

This made us aware of the huge array of possibilities and untapped potential in learning-by-doing, thinking-on-your-feet, knowing-in-action, the ambiguity in design sketching, abstract conceptualization and tangible representation.

In our observations and in analyzing the results we concluded that if we allow randomness, ambiguity and creative tinkering during the design process students were becoming true synthesizers. The combination of tacit knowing and tangible modelling as parallel congruous interaction gave way to enhanced results, more insight and understanding while at the same evoking awareness, flow, passion, idiosyncrasy, self-esteem and confidence. Other beneficial factors in this approach are visible signs of happiness, fellowship, sharing information, enhanced interaction and concentration. This means key factor is a practical learning context and freedom in creation being crucial to educational endeavour and bestow meaning, fluidity and responsibility.

3.1 On Raw Aesthetics and Raw Philosophy

Designers often design by way of using conventions they are always following the obvious, and are blinded by the familiarity! As designers we all want to create the ultimate shiny glossy design artifact that conquer the world and will make the designer famous, appreciated and wealthy. In general the design industry is about interpreting everyday conventions, we are stepping around in habitual media, make believe virtual worlds and notwithstanding became masters of digital virtuosity. In a world we sleepwalk through, designers are feeding our insatiable appetite for visual stimulation and ever greater optical illusions or simulations.

We propose a hybrid, a mere taxonomy of ‘ugliness’, by implementing Raw Shaping Form Finding (RSFF) early in the conceptualization and ideation design process. This RSFF naturally links to the common interest in ‘beauty and ugly’ in all its manifestations and formal or natural distinctions.

“...What would really be interesting to see for people, is that beautiful things’ grow out of shit. Because nobody ever believes that! Everybody thinks that Beethoven had his string quartets completely in his head that they somehow appeared there and formed in his head. All he had to do is write them down and then they would be kind of manifest to the world. What is so interesting and what really should be a lesson to be learned, is that things come out of nothing, things evolve out of nothing. The tiniest seed in the right situation turns into the most beautiful forest, and then the most promising seed in the wrong situation, turns into nothing. This would be important for people to understand, it gives people confidence in their own lives to know that is how things work. If you walk around with the idea that there are some people who are so gifted, they have these wonderful things in their head, but you are not one of them. You are, sort of a ‘normal’ person, you could never do all that. Then you live a different kind of life, you could have another kind of life where you can say: ‘I know that things come out from nothing very much and start from unpromising beginnings. And I am an unpromising beginning...and I could start something...” (Lanois, 2002)²

² Lyrics by Canadian musician, composer and producer Daniel Lanois: album ‘Here Is What Is’.

4 Two-Handed Interaction in Design Representational Experiments

Tangible sensorial materials sharpen the senses and enable designers to understand their environment through many sensory interactions and experiences. Sensorial materials isolate defining qualities such as color, weight, shape, form, texture, size, smell, sound, etc. The purpose of these materials is to provide a concrete, sensorial impression and understanding for abstract concepts. Designers derive and develop basic skills and tacit knowing in the areas of reading and language development, handwriting, mathematics, geometry, geography, cultural geography and science. All these skills have their beginning in sensorial understanding and exploration. As we know, “The hands are the instrument of the mind”. However, common sense is needed in merging new technologies and develop new intuitive design tools that allow users free, un-tethered interaction while at the same time allowing computational design to be a virtual design assistant (VDA) in the design processing.

4.1 Seven (7) Representational Design Experiments

We introduce seven (7) haptic test benches for various three-dimensional design representation experiments. The participants become a brief set of instructions, design tools, an orthogonal projection of an automotive design icon, a perspective stencil (size constraint) and five (5) minute time constraint.(action in time) We explore and investigate the negotiation between abstract and material representation by use of intuition, experience and tacit interaction. The goal is to proof 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. The following benches were used in our research laboratory:

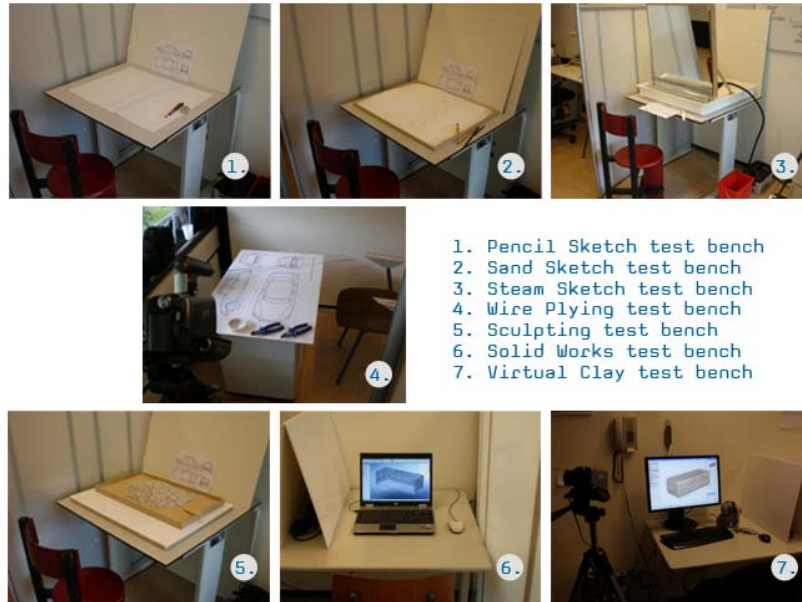


Figure 5: Experimental Set Up in Raw Shaping Form Finding Laboratory

4.2 Analysis Method and Results

We used Video Interaction Analysis (VIA) (Jordan & Henderson, 1995) to investigate the conversation, 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 208 participant tests, students and experts, videotaped 27 hours of interaction during a 3 months period, which resulted in a great amount of 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 [Fig. 6] of 83 participants and concluded provisional results³ from the selected raw data.

	pencil	sand	steam	sculpting	plying	3d solid	virt.clay
number of participants	25	38	40	34	28	22	21
total high speed video test time edited [mm:ss]	26:00	16:00	20:00	25:00	24:00	34:00	46:00
real total video test time [h:mm:ss]	3:28:00	2:08:00	2:40:00	3:20:00	3:12:00	4:32:00	6:08:00
average test time per participant [mm:ss]	08:19	03:22	04:00	05:53	06:51	12:22	17:31

Figure 6: Mapping + Result Chart VIA (selection)

The on-the-fly conceptualization of a design task and representing it either abstract or material showed us that experimentation with haptic interfaces is wise. 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 end-output. Less demanding interfaces steam up the pace and create flow in interaction. Force feedback from material constraints transpires concentration and involvement in processing.

5 Digital Computational Design and Intuitive Material Representation

We propose a new method of design conceptualization and ideation based on intuitive knowing, reflective praxis and tangible augmented representation. The method entails the creation and development of a two-handed material representation workbench [Fig. 9] with real-time or near-real-time vision-based components that generate computational polygon-meshes as possible design solutions. [Fig. 7]



Figure 7: Two-handed interaction (left) Virtual model from tangible interaction (middle) VR model with mesh iteration

³ In the appendix we present test results of the seven (7) haptic experiments.

The Virtual Design Assistant (VDA) [Fig. 8] tracks and shows all the iterative steps of the design representation process and stores them in a solution space library. Real-time interaction or post-interaction with the various iterations is possible with an un-tethered intuitive interface device (UIID) that allows the user (designer) to interact intuitively with the polygon-meshes.

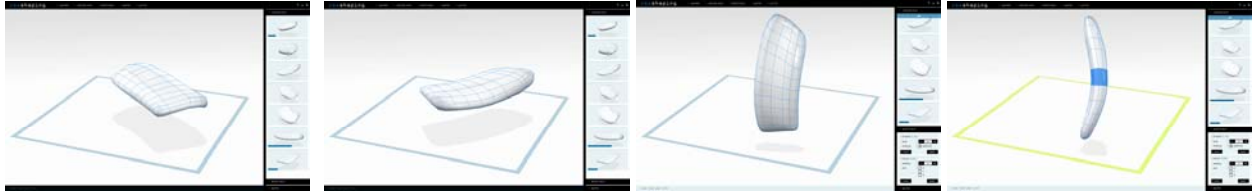


Figure 8: Virtual Shaping Tool in Action – Polygon Mesh Iterations

Synthesizing different mesh iterations is a strong and important feature of the Intuitive Virtual Workbench (IVW), as is the possibility of inserting raw functional elements during the design process. Further possibilities of this full-fledged intuitive system is multi-layered manufacturing to physical explore, test and represent ideas or concepts. The polygon-mesh iterations can also be used in cyberspace by way of Virtual Reality Gaming between designers or design teams. For example, having VDA's on both ends of the playing/gaming field engages designers in multiple iteration conceptualization contests.

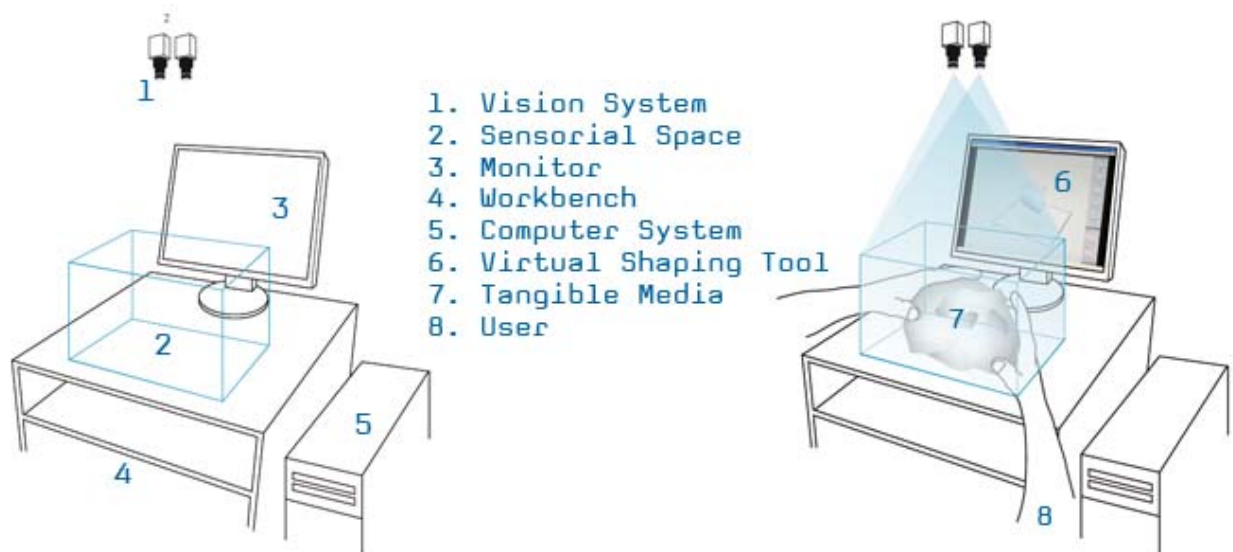


Figure 9: Virtual Design Assistant Workbench

6. Conclusion

We should start from the fact that '*we can know more than we can tell*'. Michael Polanyi termed this pre-logical phase of knowing as 'tacit knowledge'. Tacit knowledge comprises a range of conceptual and sensory information and images that can be brought to bear in an attempt to make sense of something. The designer is filled with a compelling sense of responsibility for the pursuit of a hidden truth, which demands his services for revealing it. His act of knowing exercises a personal judgment in relating evidence to an external reality, an aspect of which he is

seeking to apprehend. (Polanyi, 1966) ‘Abstract conceptualization now becomes something one can analyze and work from’. (Finger and Asún, 2000). In Donald Schön’s, *The Reflective Practitioner* (1983) he directs his attention to technical-rationality as a positivist epistemology of practice. According to Donald Schön it is ‘the dominant paradigm which has failed to resolve the dilemma of rigor versus relevance confronting professionals’. The notions of reflection-in-action, and reflection-on-action were central to his research efforts in this area. The former is sometimes described as ‘thinking on our feet’. It involves looking to our experiences, connecting with our feelings, and attending to our theories in use. It entails building new understandings to inform our actions in the situation that is unfolding. The ‘practitioner-designer’ allows himself to experience surprise, engage in puzzlement, allows for faltering or confusion in a situation which he finds uncertain or unique. He reflects on the phenomenon before him and on the prior understandings which have been implicit in behavior. He carries out an experiment or interaction which serves to generate both a new understanding of the phenomenon and a change in the situation. (Schön, 1983)

We find that our educational experimentations, design method and system could provide a very useful platform for the development of new and more sophisticated design representation tools. Our aim to bridge the gap between the analogue real and the virtual real by making use of tacit skills and traditional tools, an intuitive augmented workbench and common sense provided us with a huge array in data and information on design processing. The findings and results of our fundamental research in the educational field and laboratory tests show that intuitive physical raw shaping and form finding are instrumental in the creation of understanding, insight and change while processing in the design context. To be guided and assisted by a virtual computational device will enhance and improve this representational design process.

We continue working on computer environments that enhance the designer’s seeing-drawing-feeling-sculpting, and provide a system that extends the designer’s repertoire of physical and virtual prototypes, enhances their ability to explore them tangibly or virtually and bring them in transaction with particular design scenarios or concurrent designers. Our goal is to create an environment that helps the designer to discover and reflect upon his own design knowledge.

Our approach to create a Virtual Design Assistant attempts to bridge the widening gap between the intuitive tangible and the virtual haptic illusion. We would like to invite industry, colleagues and the design community to collaborate in improving the current system.

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Synopsis

Through continuing experimentation and investigation within educational and learning contexts, immersing and engaging students or novice designers in challenging tasks and projects we are gathering a lot of data and specific design process information. We apply this to [re]search and experimental laboratory testing to come to an understanding, insight and knowing how designers think, work and process. The merging of the analogue and digital design technologies is a major topic of exploration in our trials and error, endeavours and [re]search to humanize the real and the virtual worlds as an augmented hybrid.

Appendix

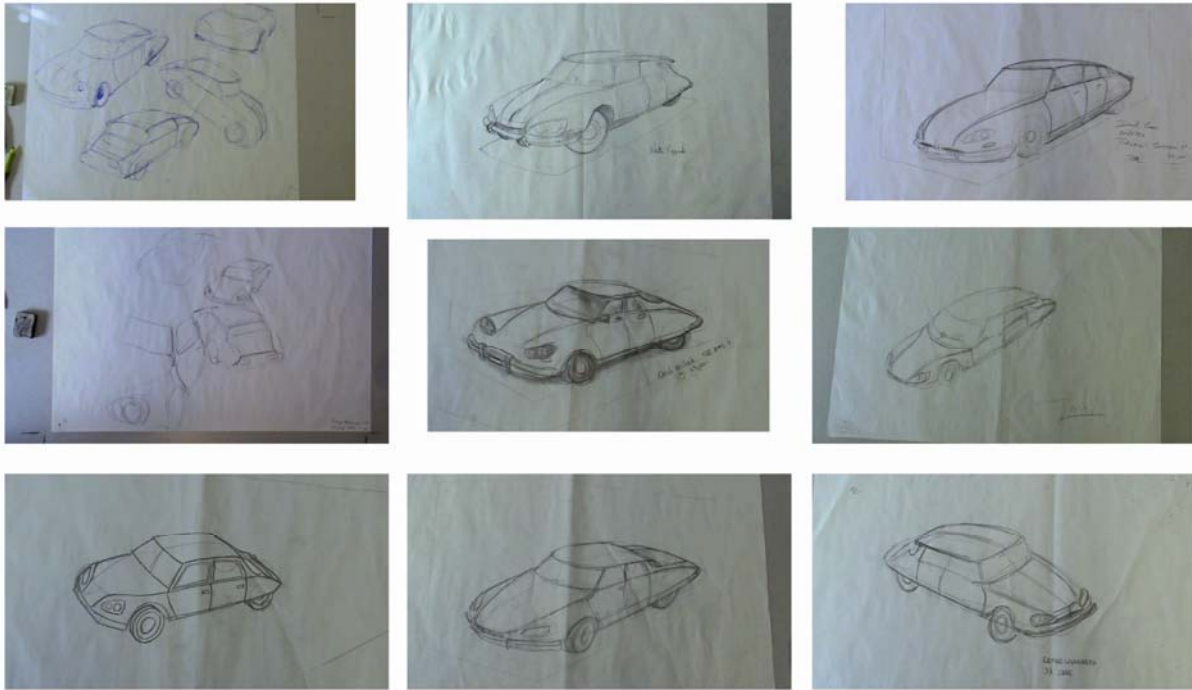


Figure 10: Pencil Sketching Results (selection)



Figure 11: Sand Sketching Results (selection)

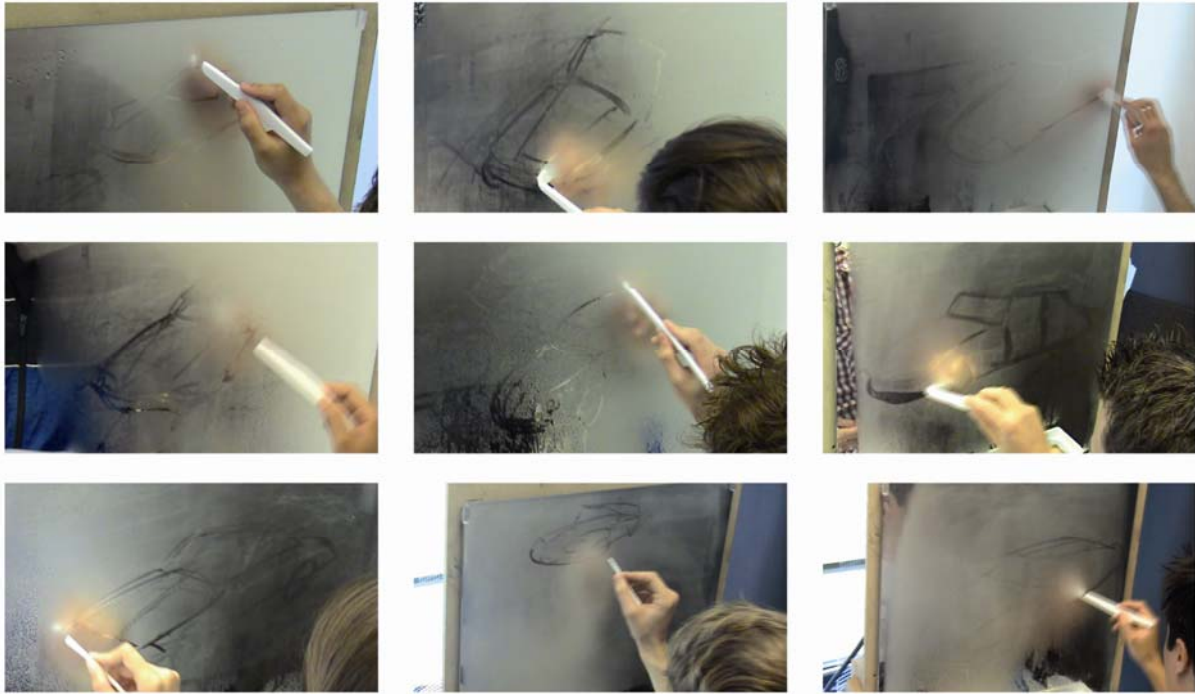


Figure 12: Steam Sketching Results (selection)

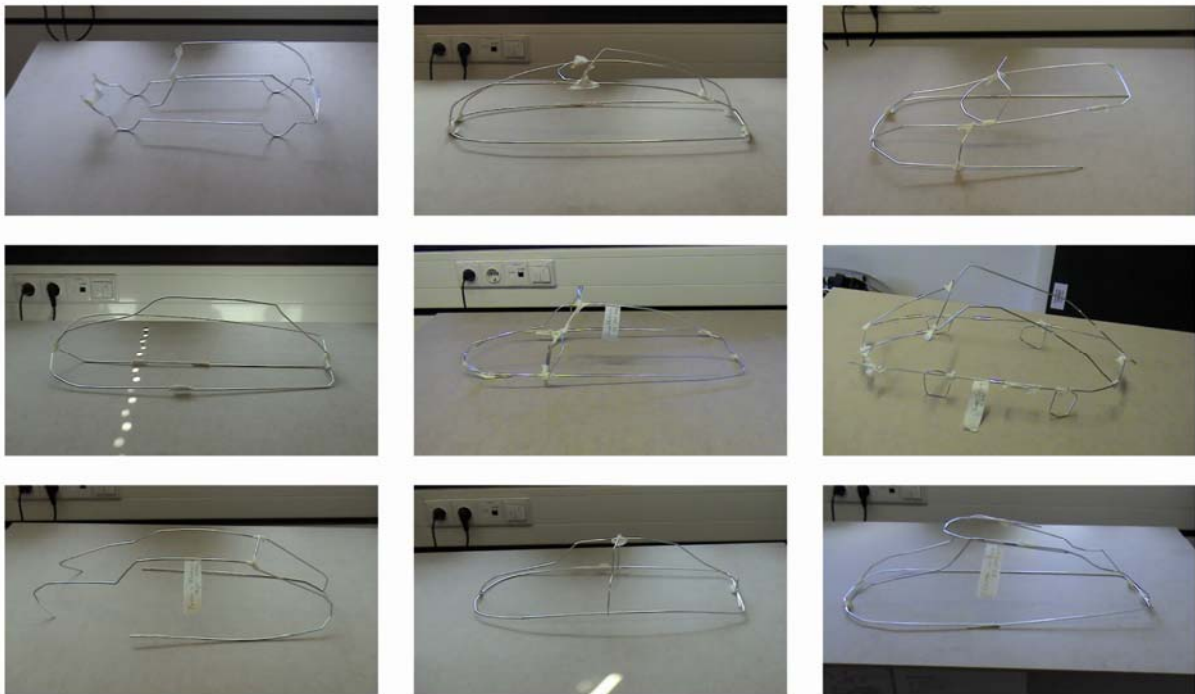


Figure 13: Wire Plying Results (selection)

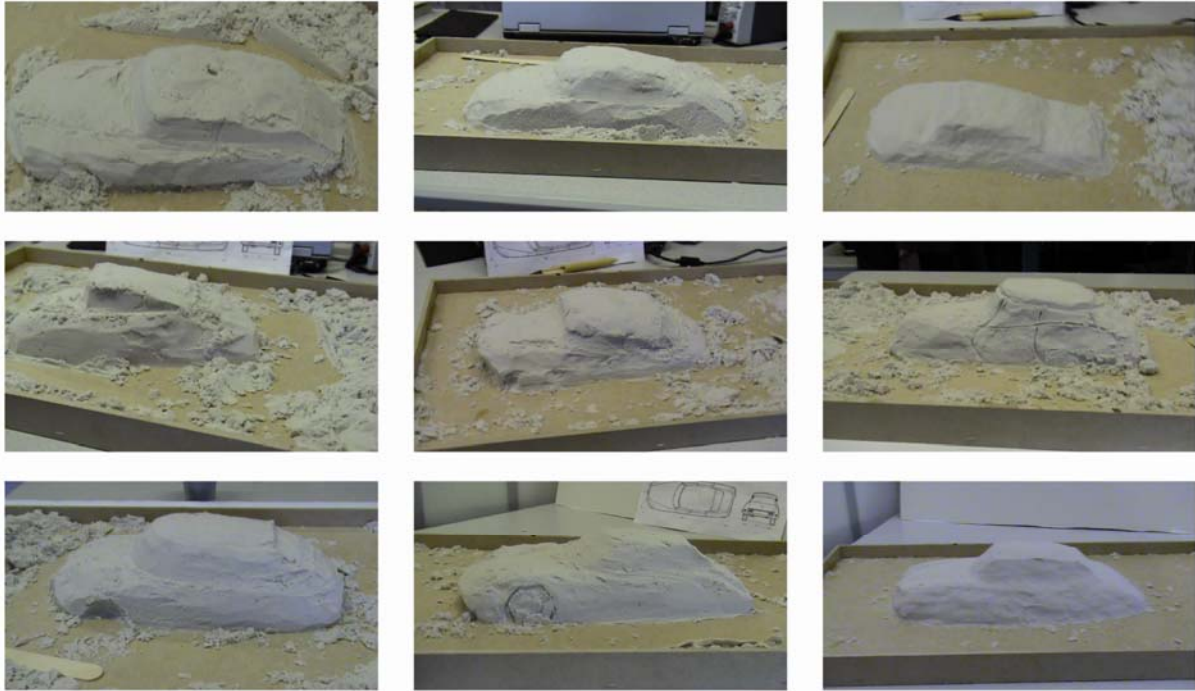


Figure 14: Sculpting Results (selection)



Figure 15: Solid Works Results (selection)

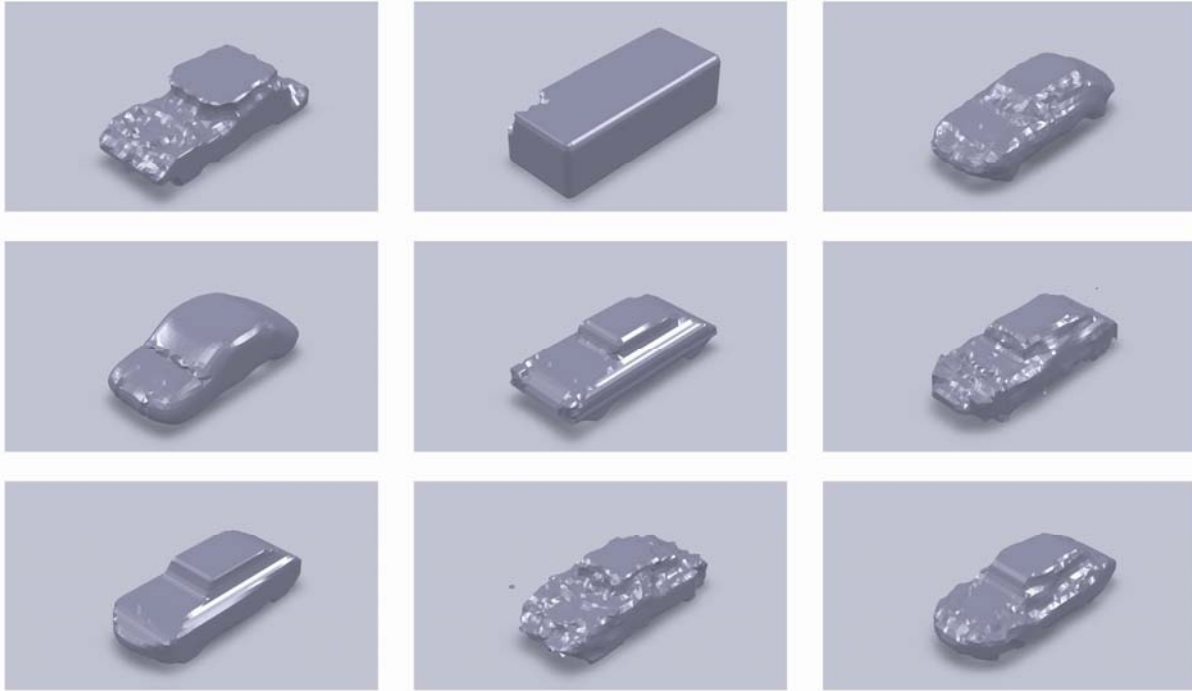


Figure 16: Virtual Clay Results (selection)

DS-Icon Research on Form Organization in Wire Frames

Introduction

This sub-project research document is based on 36 selected models out of 150 Citroen DS iterations made by Bachelor students Industrial Design at the University of Twente, the Netherlands. The assignment was to fabricate, form and shape, in conjunction with a 2d orthogonal drawing of an automotive design icon, a three-dimensional wire-frame model of this artifact. The material used in most cases is aluminum wire, paper/cardboard strips or metal strips. The study and translation is based on and devised as a representational form study, finding and discovering aesthetic criteria, triggering aspects of form-giving, learning about form-organization and expanding the geometric vocabulary of novice designers.

Goal:

- 1) Translating 2D orthogonal projection in 3D tangible form and shape.
- 2) To discover different design approaches and form giving methods in 2D to 3D representation.
- 3) Finding Form and Aesthetic Criteria in tangible objects
- 4) Exploring Form Structure and Form Giving that results from Form Organization
- 5) Enhancing Tacit Knowledge, Understanding and Imagination of Form and Shape

Line-up

All 36 models are placed in a ranking order the best result to the worst result. The best model has been given number 1 and the worst model is number 36. This is useful for the interpretation of the results later on.



1, 2, 3, ...



..., 34, 35, 36

General Aspects

Relations

Modeling a 3D model is about relations and distances between wires, views, surfaces, locations etc. Correct distances between the wires give the model the right proportions.

Question resulting from studying the models:

Which of the images A and B is easier to translate proportional into a 3D model?

Hypothesis

The lines of the doors in Figure A cut the image in 3 pieces that have easier shapes to translate and makes it easier to work within the model. The rear of the car becomes a triangular shape and the middle part looks a bit like a quadrant.

Without these lines (Fig. B) the shape is harder to translate. The shape becomes visually lower and could therefore be translated lower.

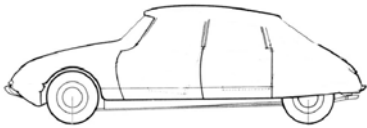


Figure A: Door details



Figure B: No Door details

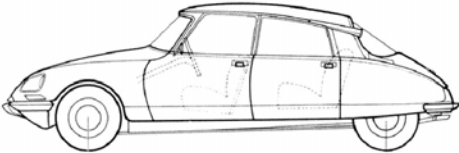


Figure 17: Detailed

Details

The model can have such a low-level of detail that it becomes very hard to keep the proportions right.

Figure D shows (appendix) the numbers of the models in the line-up and their corresponding level of detail. Of each model the lines that are translated are given.

The models with good results (in row 1-6) have a high-level of detail (Fig. C) than the inferior models show (row 31-36).

The models with a low-level of detail correspond to the car in figure B.

ONLY: The low-level detailing in row 23 to 36 could also be caused by lower motivation or engagement of the designer!

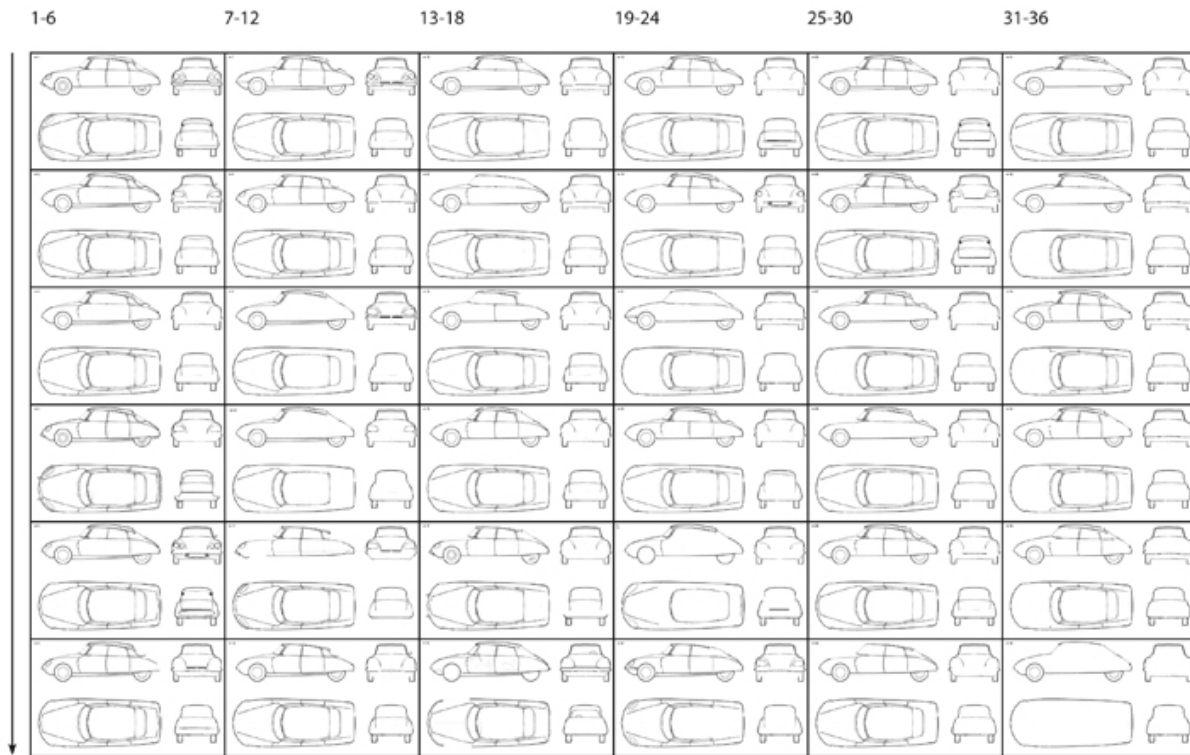
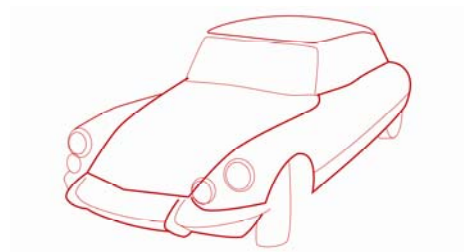


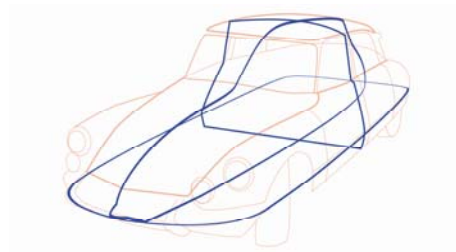
Figure D: Level of Detail of 36 Iterations of DS Wire Frame Models

Two ways of Modeling

For more information and research data on DS-Iconography please visit our website: www.rawshaping.com



Modeling in 3D curved lines



Modeling in Slices