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Design and Semantics of Form and Movement

DeSForM 2019
Beyond Intelligence

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Beyond Intelligence

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October 9, 2019

Venue: Samberg Center, 6th Floor, E52 MIT Campus. 50 Memorial Drive, Cambridge MA 02139.

15.00   Conference Registration

15.30   Welcome & Introduction
         • Yihyun Lim, Sara Colombo - *Conference Chairs, MIT Design Lab*

15.45   Panel Presentations: "Beyond Digital: Designing with Living Things"
         • Orkan Telhan, *Cofounder, Chief Design & Technology Officer Biorealize Inc.*
         • Jiwon Woo, *Biodesigner, Hypha Design*
         • Jorge Duro-Royo, *Co-Director, DumoLab*

16.30   Break

16.45   Panel Discussion / Q&A
         • Moderated by Scott Penman, *MIT Design Lab*

18.00   Conference Reception

October 10, 2019

Venue: Samberg Center, 6th Floor, E52 MIT Campus. 50 Memorial Drive, Cambridge MA 02139.

8.15   Conference Registration & Breakfast

9.00   Welcome
         • Federico Casalegno, *MIT Design Lab*

9.10   Conference Opening Words
         • Sara Colombo, Yihyun Lim - *Conference Chairs, MIT Design Lab*

9.30   Keynote Presentation "AI as Tool, Partner, and Inspiration"
         • Martin Wattenberg, *Google PAIR*

10.30   Coffee Break

10.45   Paper session 1 - Design Manifestos: What's Next | *Chairs: Sara Colombo and Yihyun Lim*
         • Future Forecasting Wicked Problems: A New Framework for Design
         Fillippo Sanzeni, Ashley Hall, Paul Anderson *(Royal College of Art, London)*
         • Eventual Design for an Emergent World
         Nathan Felde *(Northeastern University, Boston)*
         • The Decentralization Turns in Design: An Exploration Through the Maker Movement
         Massimo Menichinelli *(RMIT University, Barcelona; Aalto University, Helsinki)*,
         Priscilla Ferronato *(University of Illinois, Urbana-Champaign)*

11.45   Coffee break

12.00   <u>Paper session 2 - Interacting with Domestic Intelligences</u> | *Chair: Edgar Rodriguez Ramirez*

• The Domestic Shape of AI: A Reflection on Virtual Assistants

Davide Spallazzo, Martina Scianname, Mauro Ceconello *(Politecnico di Milano)*

• Conversational Smart Products: a Research Opportunity, First Investigation and Definition

Ilaria Vitali, Venanzio Arquilla *(Politecnico di Milano)*

12.40   Lunch + <u>Short Paper / Demo Session</u>

• Prosumeristic Publications: alt+yd

Harshali Paralikar, Ajitesh Lokhande *(National Institute of Design, Paldi, Ahmedabad, Gujarat, India)*,

• Swimming Coach: An Immersive Swimming Learning System

Shuo Li, Cheng Yao, Mingxuan He, Qingcong Wang, Ying Wang, Yuyu Lin, Juanli Liu *(Zhejiang University, Hangzhou)*, Fan Xia *(Mercyhurst Preparatory School, Erie)*, Leijing Zhou *(Zhejiang University, Hangzhou)*

• Designing Transparent Collaborations - Weave

Gissoo Doroudian *(College for Creative Studies, Detroit)*

• Huxley: Intelligent Book as Essentialist Artefact

David Ramsay, Joe Paradiso *(Massachusetts Institute of Technology, Cambridge)*

• OlfacEnhancer: A Vision-Based Scented Necklace for Cross-Modal Perception and Olfaction Augmentation.

Yuyu Lin, Kai Zheng, Lijuan Liu, Yang Chen, Jiahao Guo, Shuo Li, Cheng Yao *(Zhejiang University, Hangzhou)*, Fangtian Ying *(Hubei University of Technology, Wuhan)*

• APOSEMA: Exploring Communication in an Apathetic Future

Adi Meyer, Sirou Peng, Silvia Rueda *(University College London)*

• HuValue: A Toolkit to Facilitate Considering Various Human Values in a Design Process

Shadi Kheirandish, Mathias Funk, Stephan Wensveen *(Eindhoven University of Technology)*, Maarten Verkerk *(Maastricht University)*, Matthias Rauterberg *(Eindhoven University of Technology)*

• Playing with Systems: Tactile Games as System Prototypes

Tom Maiorana *(University of California, Davis)*

• Attributes of Aliveness: A Case Study of Two Interactive Public Art Installations

Humbi Song, Oliver Luo, Allen Sayegh *(Harvard University, Cambridge)*

• Understanding User Customization Needs: Requirements for an Augmented Reality Lamp Customization Tool

Ana Carina Palumbo, Hella Kriening, Barbara Wajda *(Eindhoven University of Technology)*, Monica Perusquía-Hernández *(Eindhoven University of Technology; NTT Communication Science Laboratories)*

• Speculating on the Future of Graphic Design in the Age of Intelligent Machines

Sekyeong Kwon, Robyn Cook *(Falmouth University)*

• AI-Stylist: An AI-based Framework for Clothing Aesthetic Understanding

Xingxing Zou, Waikeung Wong *(The Hong Kong Polytechnic University)*

14.30   Introduction of AIM Institute Research Initiatives: Artificial Intelligence in Value Creation

Margherita Pagani, *Research Center on Artificial intelligence in Value Creation - AIM Institute - Emlyon Business School*

14.40   <u>Paper Session 3A - Interacting with Urban Intelligences (I)</u> | *Chairs: Yihyun Lim and Sara Colombo*

• AI-to-Microbe Architecture: Simulation, Intelligence, Consciousness

Dennis Dollens *(Universitat Internacional de Catalunya, Barcelona)*

• Envisioning and Questioning Near Future Urban Robotics

Maria Luce Lupetti *(Delft University of Technology)*, Nazli Cila *(Amsterdam University of Applied Sciences)*

• Robot Citizenship: a Design Perspective

Maria Luce Lupetti, Roy Bendor *(Delft University of Technology)*, Elisa Giaccardi *(Umea Institute of Design)*

15.30   Coffee break

15.45   <u>Paper Session 3B - Interacting with Urban Intelligences (II)</u> | *Chair: Scott Penman*
               • Towards Transparency Between the Autonomous Vehicle and the Pedestrian
               Selin Zileli, Stephen Boyd Davis, Jiayu Wu *(Royal College of Art; Intelligent Mobility Design Centre, London)*
               • The Coerced User and the Era of Smart City Dissonance
               Guy Cherni, Roee Bigger *(Bezalel Academy of Arts and Design, Jerusalem)*

16.30   Keynote Presentation "How to Design for the Unconscious"
               • Matthias Rauterberg, *Full professor for "Interactive Systems Design", Department of Industrial Design ,
               Eindhoven University of Technology*

18.00   Conference Dinner - *Charles River Sunset Cruise Dinner*

               October 11, 2019
               Venue: Bartos Theater, Building E15 Lower Level, 20 Ames Street, Cambridge MA 02139.

8.15   Conference Registration & Breakfast

9.00   Keynote Presentation: "Adaptive Dynamics: Creating Intelligent Sportswear Experiences "
               • Charles Johnson, *Global Director Innovation, PUMA*

10.00   <u>Paper Session 4 - New Interfaces for Complex Ecosystems</u> | *Chair: Davide Spallazzo*
               • Drawing Interfaces. When Interaction Becomes Situated and Variable
               Ilaria Mariani *(Politecnico di Milano)*, Tommaso Livio *(Thingk)*, Umberto Tolino *(Politecnico di Milano, Thingk)*
               • Individual Mid-Air Gesture Sets Informed by Conceptual Metaphors: A Case Study on How Users
               Generate Mid-Air Gesture Sets to Control Video Streaming
               Gulben Sanli Eren *(Istanbul Technical University)*
               • A Pedagogy for Noticing – Soma Literacy and the Designer
               Stephen Neely *(Carnegie Mellon University, Pittsburgh)*

11.00   Coffee break

11:20   Introduction of Northeastern University Center for Design
               Paolo Ciuccarelli, *College of Art, Media and Design - Northeastern University*

11.30   <u>Paper Session 5 - Smart and Multi-Sensory Systems for Behavior Change</u> | *Chair: Lucia Rampino*
               • Designing Phygital Activities in a Smart Multisensorial Room: A Collaborative Cognitive Environment
               for Children with and without Disabilities
               Micol Spitale, Agnese Piselli, Franca Garzotto, Barbara Del Curto *(Politecnico di Milano)*
               • Recommendations when Designing to Address Procrastination: A Psychological Perspective
               Helen Andreae *(Northumbria University, Newcastle upon Tyne; Victoria University of Wellington)*,
               Abigail Durrant, Steven Kyffin *(Northumbria University, Newcastle upon Tyne)*
               • R2S: Designing a Public Augmented Printed Media System to Promote Care Home
               Residents' Social Interaction
               Kai Kang, Jun Hu, Bart Hengeveld, Caroline Hummels *(Eindhoven University of Technology)*

12.30   Lunch

13.15   <u>Participatory Workshop: "The Soma Literacy of AI"</u>
           • Stephen Neely *(Carnegie Mellon University, Pittsburgh)*

14.15   <u>Paper Session 6 - Design and Semantics for Health and Inclusion</u> | *Chair: Sotirios Kotsopoulos*
           • Nova Creatio: A Clinical Perspective on Rehabilitative Everyday Objects for People with Chronic Stroke
           Mailin Lemke, Edgar Rodríguez Ramírez, Brian Robinson *(Victoria University of Wellington)*
           • The Semantics of Conspicuity: Design Strategies to Address Conspicuity in Type 1 Diabetes Medical Devices for Adolescents
           Madeleine J. Hazelton, Gillian M. McCarthy, Edgar R. Rodríguez Ramírez *(Victoria University of Wellington)*
           • Sitting Still: Seat Design for a New Head-Only MRI Scanner
           Christy Wells, Edgar Rodríguez Ramírez, Mailin Lemke, Benjamin Parkinson *(Victoria University of Wellington)*
           • Designing Research Prototype for the Elderly: A Case Study
           Cun Li, Jun Hu, Bart Hengeveld, Caroline Hummels *(Eindhoven University of Technology)*

15.35   Coffee break

15.50   <u>Paper Session 7 - Designing with Humans, Machine Intelligence, and Data</u> | *Chair: Scott Penman*
           • Plug-ins Jungle: Algorithmic Design as Inbuilt Dynamism Between Human and Artificial Creativity
           Giuseppe Bono *(University College London)*, Pilar Maria Guerrieri *(Politecnico di Milano)*
           • Defining a Data Impact Tool for Design Courses
           Laura Varisco, Margherita Pillan *(Politecnico di Milano)*, Patrizia Marti *(Università' degli Studi di Siena)*

16.50   Conference Closing Ceremony

October 12, 2019
Boston Brewing & Beyond - Craft Beer Brewery Tour of Boston

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Drawing Interfaces: When Interaction Becomes Situated and Variable

Abstract

The widespread and pervasive presence of devices equipped with small-size, small-cost sensors and increasing computational capacity affected our interactions, making them growingly ubiquitous and dynamic; an interaction that shifted from being indirect to becoming more physical and direct, as using gestural or vocal commands to control smart systems. In this context, we developed interfaces that draw themselves accordingly to the user need. Drawing User Interfaces receive information from the physical world (users and environment) via sensors, and react modifying their aesthetics and function.

Keywords

User Experience, User Interface, Physical Interaction, Embedded Technology, Smart Objects

1. Interfaces, Embodiment and Materiality

We are in a historical moment of change, where our way of interacting with objects is culturally evolving, due to the unceasing advances of technology. The progressive technological pervasiveness made a growing number of devices more intelligent, interactive and capable of dialoguing among themselves, with the surrounding context and with us. The result is innovative and advanced interactions that produce models and patterns of use that reinterpret the relationship between humans and technology [1–3]. In a context where people and computers are no more considered as separate but as a whole [4], our interest concerns integrated ecosystems where the physical and digital worlds dialogue because of embedded sensors, microcontrollers, and actuators that make machines "sensitive" to external stimuli [5, 6]. Benefitting of a progressive increase in computational capacity (ubiquitous computing), such ecosystems can adapt automatically to circumstances and decrease users' *cognitive load* [7], namely the information they must process to perform a task. Overcoming Graphical User Interfaces (GUI), it expanded the range of possible interactions: from typing and visualizing (as PCs) to manipulation (as *Beosound Edge* that activates a touch-sensitive control interface when the user approaches), dialogue (as *Amazon Alexa* and *Google Home* that can be controlled starting a conversation through voice interaction), and gestures (as *Xbox Kinect* that responds to motion sensing inputs, making the user's body become the controller). This brought to a dual technological advance: the research on Natural User Interfaces (NUIs) [8, 9] and on Tangible User Interfaces (TUIs) [10]. In the former case, the logic revolves around the absence of a visible interface

[11], namely user interfaces that are invisible to its users, or become so through subsequent interactions. The latter case regards embedding the interface into the object using manipulation logics typical of the analogical dimension [5, 12]. Although we recognize that NUIs' immediate and non-mediated interactions are interesting and promising, TUIs pop up as even more fascinating since they imply analog-like manipulations on objects that hide a digital dimension and echo the concept of *memory of use* [13]. However, dealing with physical and computational elements that empower materials, making them reactive and able to inform [14], opens up inevitable reasoning on *materiality* [15], *embodiment* [16, 17] and *affordances* [1, 18]. TUIs make the object on which are mounted both a representation of information and a controller [10]. Achieving such a total unity between interface and interaction has implications as the graspability of the interactions and actions supported [19]. Moreover, as stated by Ishii himself when criticizing tangible bits in favour of his more contemporary concept of *radical atoms* [14], TUIs have limitations in representing change.

Then, recalling that objects are nowadays more than ever *shapers of behavior* [20], we cannot neglect that blending the physical and digital dimensions reconfigures the users' behaviour towards the product, impacting on the kind of learning such objects demand to be properly used [21]. The interfaces we propose advance from this very argument.

1.1 Interfaces that Draw Themselves

We consider that especially the material perspective brings interesting opportunities for the interaction design and HCI fields. Looking for potentially meaningful aesthetic interactions, our specific interest goes on the role that materials, environments and the user's physical body as a combination assume in interactions involving embodied technologies [16, 22]. From this notion, we developed what we define *Drawing User Interfaces* (DUIs henceforth), namely interfaces that draw themselves. Such interfaces receive information from the physical world (users, the environment, and potentially other objects) through sensors, and act accordingly, modifying their aesthetics and function. DUIs concern interactions with objects where the digital information is translated into a manifestation that allows direct manipulation.

However, it differs from Ishii's radical atoms [14] where digital information assumes a physical form. Indeed, whereas the physical interaction is maintained, it goes through a visual interface that rises from the surface. DUIs appear on objects rather than being the object itself or part of it, as in the case of TUIs [10]. As GUIs, they display the information on screens, but not the traditional ones. The interface is integrated into the same material that composes the devices, and the feedback is given by the very *skin* of the object that changes depending on the information they receive or to explain the result of an operation. The interface is embedded in the material, and what changes is either its chemical or physical properties. Designing interfaces that draw themselves implies to alter and modify users' perception of objects. In so doing, these interfaces advance a reasoning that grounds on *hacking* objects' meanings [23].

2. Process and Methods

The research is conducted by Thingk, a spin-off of the Politecnico di Milano that experiments with interactive technologies, designing products that disguise themselves. It digs into apparently simple and minimal artifacts (form) that are technologically enriched (function), following the slogan: "objects of daily use with superpowers" (thingk.design). Thingk takes advantage of the principles of digital transformation [24] while pursuing technological hybridization, blending analogue properties and digital immateriality. This approach results into objects with invisible technology and essential aesthetics, that are augmented with unexpected properties. By redesigning their appearance and functions, hence affordances and interactions, the meaning of the artefacts gets affected. Our study capitalizes on how different skins activate different functions, changing how they are interpreted and approached by user [25, 26].

Experimenting on how to use and innovate with DUIs, we apply an iterative design process (fig. 1) where multiple approaches and methodologies are combined to answer different needs [21]. The overall process consists of two main macro-phases. The first follows a design-driven innovation concept [27] that is applied to the research and design phases, when prosumers are involved in co-design sessions with early prototypes
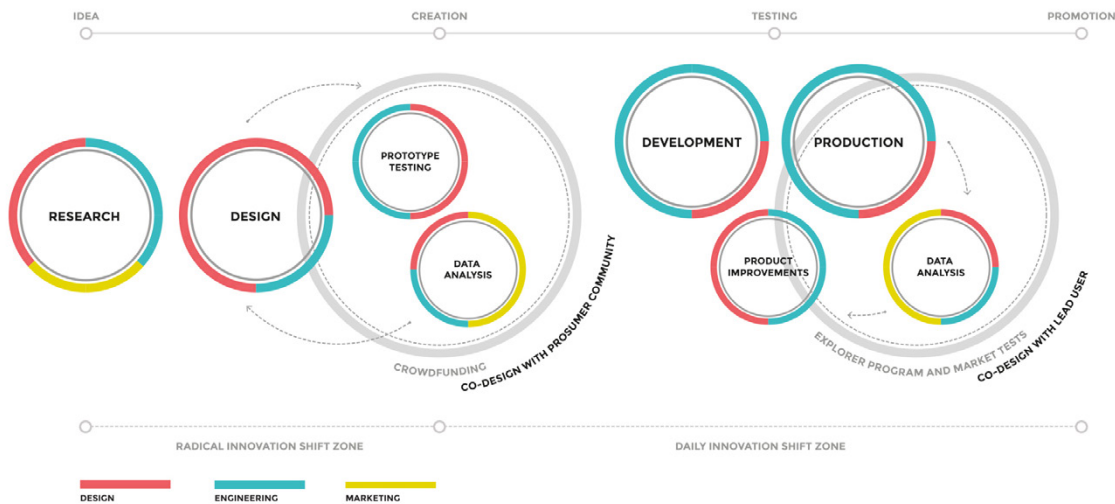
Fig. 1. Thingk's iterative design process, highlighting the steps and perspectives involved

to provide insights. The latter revolves around user testing and data analysis and regards development and production.

The *Research phase* focused on deepening our knowledge about contexts where several elements are intertwined, interacting among them and with the surrounding environment. We analysed lifestyle and technological trends (state of the art) to point out potentialities and constraints of the context of reference, especially breakthroughs in the contiguous areas of interaction design, electronics, and material research. Acknowledging the existence of interfaces that emerge from the surface as Mui's *Calm Design*, and our own *Slab!*, we are also aware of their limits, as their being static and localized. This suggested the concept of a multilayered interface in which layers are activated according to the function required. We tapped into extending from multiple functions to multiple language and meanings that coexist under the skin of the same object.

We are currently running the *Design* phase, with prototypes of use expected by the end of this year. Informed by the research conducted, we decided to completely hide the interface until the object detects motion, an interaction, or a connection with other objects. At this point, the interface appears. This phase involves lead users to verify their response towards the product/interfaces designed, gathering data from survey and qualitative enquiry (from rapid ethnography

and participant observation to interviews), but also focus groups and workshops where sketches, renders and use cases are leveraged to stimulate discussion and validate our design choices. The *Development* and *Production* phases are expected to respectively start in one and two years. From an engineering and design perspective, the challenge is developing objects that reconfigure their own function according to the surface that they show, in a logic of quick adaptability to the context of use. We are currently conducting studies on possible technologies (electrochromic displays) and application (from smart product to smart buildings), as part of *DecoChrom*, a Horizon 2020 Project that will end in 2021. During the project we will verify DUIs flexibility through three different applications on everyday objects. Working prototypes will be tested with the *DecoChrom* partners and a with community of prosumers, conducting user analysis to identify possible improvements.

3. Results

In conceptualizing the meaning of *design*, Krippendorff [25] described it as the attribution of meaning to things. Artifacts should, in fact, communicate their function through their aesthetic, which should introduce users to their correct functioning [28]. As theorized by Tidwell [29] the interface has an operational function that triggers the dialogue with the user. Therefore, redesigning the meaning of objects is a practice of a certain importance, which becomes paramount if we consider that Thingk reframes the

form-function relationship of products, pursuing an innovation inspired by design, while recognizing users' needs [26], and the current growing technological opportunities [27]. When objects change their meaning, their language becomes anything but obvious [30]. Examples are those interactive artefacts that rely on integrated technological component (IoT) to become extended systems that dialogue with applications and other objects. Starting from such assumptions, we conceptualized a model of variable and situated interfaces that reacts not just to the interactions triggered by users, but also to the surrounding environment (context of use). Recognising the limitations and constraints of both TUIs [14] and NUIs [8], and being aware of the *invisibility dilemma* [31] that comes along, we conceived a typology of dynamic interface that expresses itself and communicates to the user what its form hides (affordance). In an attempt to integrate smart functionality into everyday objects without falling into the aforementioned dilemma of choosing between minimizing disturbance from the main task and adding value including explicit interaction, there is a tendency to hide object's intelligence.

However, the consequence of keeping/making invisible to the user such an increase of functionality results into a dichotomy between aesthetics and functions. Making functionalities recognisable allows users to identify such augmented artifacts as smart and hence use them appropriately. In parallel, the *control dilemma* [32] exposes a crucial point when dealing with smart object automation. The attention lies in designing objects that act and react autonomously to certain inputs, hiding the ongoing complexity to the user without lessening his/her perception of applying control. On this regard, significant is the study on the use of the remote control *Nest Learning Thermostat*, where the users' interviewed stated they were not able to fully understand the object learning process of their habits, hence they were not able to utterly rely on how the smart home automation device was self-setting certain functionality. The control dilemma requires to pay attention to the user, who wants to know what is going on; this insight is on the ground of DUIs concept.

3.1 Ecosystemic (Situated) User Experiences

Focusing on functionality, we often face the problem

of how much information an interface should return in order to perform each task. The advantage lies on using a different set of variable commands that allows to isolate and "situate", or contextualize, a device's main functions according to its actual use case. Employing DUIs allows indeed to define situated user experiences that are variable in time and space since they are closely related to the context in which they are immersed. Moreover, these interfaces can be modified and updated over time, potentially changing the product functionality: the object doesn't change, it updates its functions. In this perspective, an object or device can change the interface depending on, for example, its own positioning, and inclination, or according to the location of the user.

So far, we identified three possible use cases:
• Movement: Response to being relocated within an environment
• Reaction: Response to environmental changes (presence of people, physical variations, and other modification in or of the context)
• Dialogue: Functional variation based on the relationship with other connected objects present in the surrounding space

Below we present existing case studies as pretexts to explain possible use cases of DUIs. Describing their functioning we explain how DUIs could be applied to perform similar functions, making the interaction more direct, complete and immediate. In the first use case, *Movement*, the interface responds to the change of position and orientation, revealing itself and displaying different functions. Microsoft' *Surface Dial* is a controller that interacts with different programs and digital elements, serving specific functions according to how it is activated and manipulated. However, the function of the interface is delegated to an external screen, where the information is displayed, while the product itself does not provide any visual feedback on its surface. In this case study, the potential use of DUIs lies in overlapping object and interface, so that functions are communicated directly on the product. In the second use case, *Reaction*, the interface reacts to proximity or interaction with external elements, which can be as much the user as the environment with its variables. Lapka's *Environment* consists of a series of four environmental sensors embedded into as much small
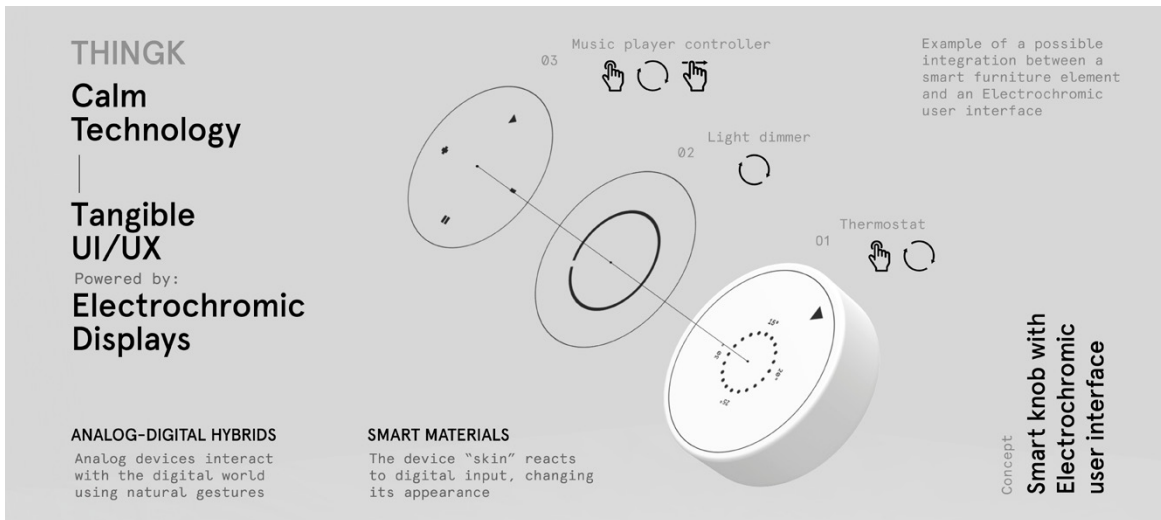
devices, translating complex data into user-friendly visualizations displayed on the smartphone. Once again, the function of showing data is entrusted to an external element: the smartphone display. Mounting DUIs could allow to provide immediate feedback on the product itself. In the last use case, *Dialogue*, the interface relates to the surrounding smart objects. Ikea's *Trådfri* remote control connects to different lamps working by proximity, managing on and off, dim, and color temperature. The remote control recognizes and regulate bulbs within a range of 10m, but does not provide information or feedback. In this case, applying DUIs would allow to show the object to which the remote control is connected, clarifying the functions available. In addition, in the hypothesis of multiple smart objects in the surrounding environment that could be managed by a single controller, DUIs could change the controller interface depending on the object ruled and the function that can be performed. Changing its *communicative skin*, the object performs tailored functions depending on the interpretation of the surrounding variables. The research phase brought to think to functional layers that overlap, populating a single object with multiple capabilities. The main result of our study is designing the transition among various commands and as many functions that coexist in the same object. The output of our investigation is a surface capable of smoothly changing and reacting during the user experience.

To provide a sharp idea of how they work, fig. 2 presents a use case of DUIs applied on a smart object

acting as a controller. The object can be exemplified as a cylinder embedding smart sensors that can perform the regulation of values as temperature, volume, and so on, and that is provided with a silent interface. Such object contains multiple layers, each with its own function that gets activated according to the previously described use cases. The object becomes a repository of information that is going be communicated once used. For example, one layer could show how to regulate the temperature through rotation and selection; another one could display a linear scale to operate on the intensity of light, using rotation to dimmer; then, the third layer could allow to play/manage music or movies through interactions as selection, rotation and swipe. This design scenario is an example of possible use cases, as employing DUIs to increase the variables at play, introducing an *auto-nomatic dimension* [33] that enhances the qualities of the elements involved. Attributing a performing ability to the interface, its visual elements gain the ability to instantly act and react to manipulation [34]. These feature and dynamicity require to design considering the relation between the object and the environment both in the form of positional/static identities and as variable elements that are fluid and responsive in their composition.

4. Discussion. A Discourse on Possibilities and Constraints

The use cases described can be developed harnessing various technology. The ongoing tendency to dematerialise objects' physical interfaces frequently

led to delegate the operational functions of an object to digital screens. Indeed, most of the contemporary smart products uses embedded displays or transfer data to other devices with screens (mobile and tablet). Such displays, acting as communication gateway, are in charge of returning information. That said, the current technological state of the art witnesses the appearance of smart materials able to reconfigure their shape, becoming potential drivers of information. However, we are still far from the concrete possibility of a material so ductile to display a continuous and updated flow of digital data, through a modification of its intrinsic physical properties. At this state of technology, DUIs are affected by this restriction, and they present a further limitation: since they allow an object to embed multiple functionalities, they do not make any function manifest by default. The absence of the interface, when none of the layers is active, as well as the presence of a variable interface concealed until the moment of use, affects the way in which the object communicates and is interpreted by the user.

In addition, their being entirely based on visual elements makes them unsuitable for being used by people with visual disabilities. By contrast, the information behind these visual components could be translated or implemented by combining them with additional sensory stimuli. For example, dealing with TUIs, Ishii recommends the use of more "malleable" forms of feedback, such as audio and video, that complement, support and complete interfaces. Our reasoning on DUIs possible implementations goes in a direction similar to what Ishii [10] identified as *Double Interaction Loop*, namely a cycle that starts with a first and immediate level of interaction and haptic feedback provided in consequence of touching, grasping and manipulating a physical object, followed by intangible feedback (as audio) and possible physical modification of the object, reflecting a change of the digital data. A possible field of application of DUIs is between analog (aesthetics and materials) and digital (functions and transitions). Several technologies can be used to build such interfaces. Particularly, we investigate those materials that change the state of their chemical (electrochromic) or physical (e-ink) properties. Both technologies can be integrated into surfaces made of natural materials—as wood, marble, metal—without

contaminating their appearance and tactile properties. On the one hand, aiming at the e-ink, as in the case of the *Yotaphone*, ensures excellent graphic resolution but has a color range limited to black and white. On the other hand, electrochromic screens have the advantage of being the result of a monochrome screen printing technique on transparent surfaces, allowing them to be positioned above the material of the object itself. However, since electrochromic is the technology subject of the research of the European project *DecoChrom*, it is currently the basis on which we are conducting the experimentation. An advantage of choosing this not-new technology is that the electrochromic absorbs energy only when transitioning from a state of transparency to that of opacity; once a state is reached, there is no consumption related to its maintenance.

Designing interfaces we follow a model of experimentation closely connected to the field of IoT where the relationship between objects, technology and context is at the heart of the project. We privilege a design-driven innovation method that takes into account the needs of the user. Hence, the innovation is oriented to the relationship between function and aesthetics, and it relates to the context of use. One of the results achieved is to preserve the aesthetics of products that historically did not mount interfaces, inserting an interactive layer capable of manifesting itself and disappearing when needed. The implications of integrating physical elements with computational processes expand the design possibilities in terms of choosing materials that *become* reactive, dynamic and able to shape, transform and inform [13]. We consider this reasoning significant to various disciplines, from design to HCI, as it explores how interfaces can exploit smart technologies to modify themselves while mixing digital and physical.

As said, DUIs are currently in the prototyping phase, as user research will take place in 2020. The main issue that will be the subject of our upcoming enquire concerns how users will react in front of interfaces that design themselves when necessary, namely changing according to their being placed in space, the dialogue with other smart objects of the digital ecosystem, or the interaction with the user. In doing so, it is central to

understand the role of aesthetics in dynamic digital-physical ecosystems. Addressing the design of interfaces for distributed, hyperconnected, and complex smart ecosystem requires to tap into the implications of having multiple meanings coexisting into the same object; meanings that are not persistently displayed, but emerge from the surface when needed. In consequence, it is crucial to enquire the way in which the users will interpret and interact with objects that contain interfaces that are simultaneously:
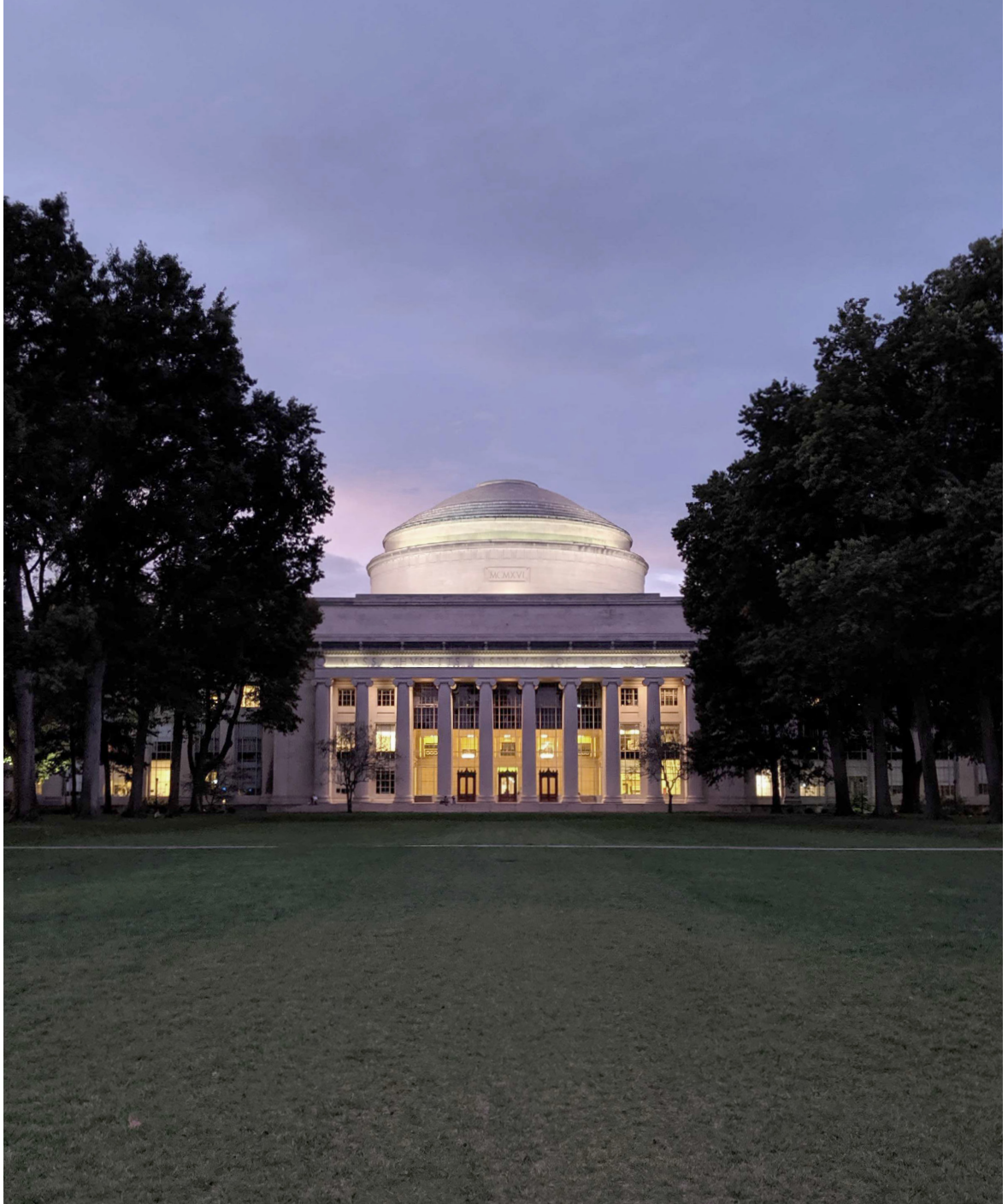
• Hidden, since they are not always displayed
• Variable, since they reconfigure themselves according to the environment
• Updatable, since they are designed to last more time than the lifespan of the object itself.

To conclude, DUIs take advantage of how micro-processors and sensors can provide an ecosystem of smart objects with awareness of their surrounding, exploiting their ability to dialogue with users, other objects and the environment. These interfaces can disappear, hence they can be used on objects and products that maintain their overall aesthetics while being augmented. The interface is no more influencing or contaminating the look-and-feel of a product. That said, future developments concern the enquiry on users to understand how such interfaces have implications in terms of experience; in parallel, possible advances of electrochromic technology, as well as the application of other technologies, could positively impact on the project.

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