Designing and Engineering Gesture User Interfaces

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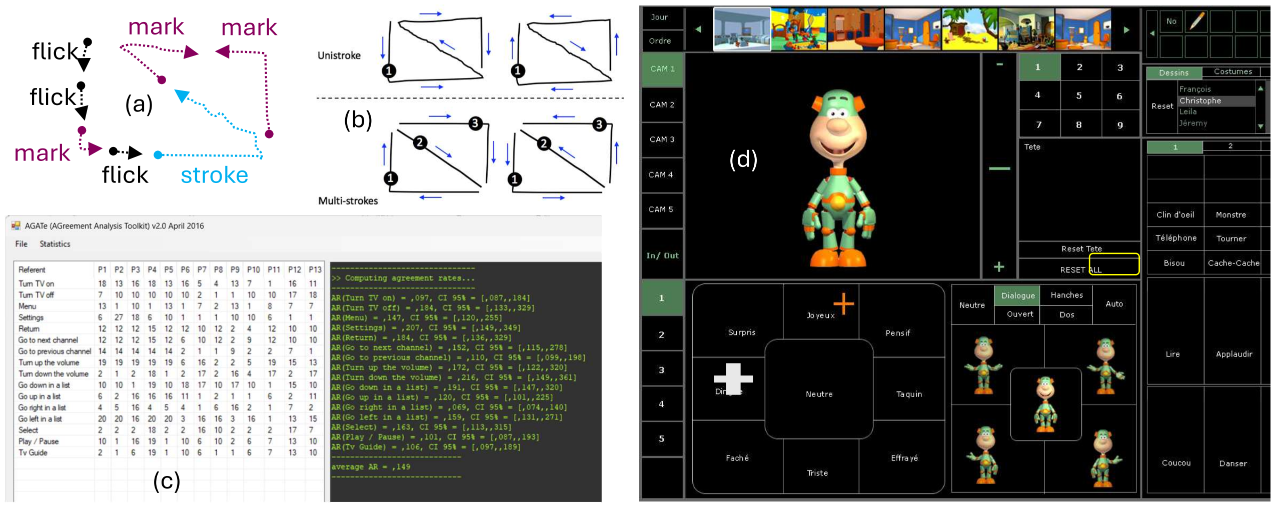

Figure 1: Gesture interaction: basic gestures (a), multi-stroke gestures (b), AGaTe [37] (c), and puppet gestures [31] (d).

Abstract

The goal of this tutorial is to introduce newcomers to the field to the main aspects of designing and engineering gesture user interfaces, while it also targets experienced practitioners, designers, and researchers that wish to increase their knowledge and stay up to date with the most recent developments in gesture recognition, analysis, and design approaches and methodologies. To this end, the tutorial is structured as a suite of 3 complementary modules: Fundamentals of gesture interaction, Designing Interactive Gestures with a Gesture Elicitation Study, and Engineering Gesture User Interfaces.

CCS Concepts

• **Human-centered computing** → **Interaction techniques**; *Gestural input*; *Interaction design theory, concepts and paradigms.*

Keywords

Gesture user interfaces, gesture recognition, gesture analysis, gesture elicitation study, gesture production, user interface design

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1 Tutorial Structure, Outline, and Schedule

This tutorial is presented in the form of three 30-minute modules targeting attendees of various backgrounds and levels of experience in gesture user interfaces:

M1. *Fundamentals of Gesture Interaction* represents the introductory module, designed for any newcomer to the field.
M2. *Designing Interactive Gestures* is an intermediate module, specifically targeted to designers and researchers that have some experience in gesture user interfaces, but want to consolidate their knowledge. This module will demonstrate current methodologies to design effective gesture commands and gesture sets for interactive applications.
M3. *Engineering Gesture User Interfaces* is an advanced module, targeted to designers, developers, and researchers that wish to acquire detailed engineering knowledge on how to implement interactive gesture commands on various platforms, such as aspects related to implementing effective gesture recognition on smartwatches or acquiring gestures in mid-air, to name just two examples of topics planned for this module. It also covers how to select an appropriate gesture recognizer (or classifier) for efficient and robust gesture recognition, depending on the context of use.

2 Fundamentals of Gesture Interaction

We expect a continuous increase in the number and diversity of interactive systems, devices, and services that will afford gesture input [16, 21, 33] that needs to be properly communicated throughout the development team, such as via GestureCards [13]. This statement is easily motivated by how easily humans produce gestures with expressive meanings, interpretations, and goals; the fact that gestures are native, natural, and intuitive; that gestures have started to eliminate middleware devices, like the mouse or keyboard; and, in a multimodal context, gesture input offers a much richer user experience than traditional UIs. In this context, we offer this introductory module to newcomers to the field that wish to learn about the opportunities of gesture input for their own projects. We will start with rigorous definitions of communicative and interactive gestures based on relevant taxonomies ; we will introduce, motivate, and discuss fundamental concepts for gesture interaction [2], such as flicks, marks, strokes (Fig. 1-a), articulation variability [1], properties of invariance (*e.g.,* stroke, direction, position, scale, rotation [22]), properties of gesture sets (*e.g.,* isometricity, isochronicity [30]), gesture recognizers and training sets, including synthetic gesture production [3, 26]. For example, Gestures à Gogo [18] synthesizes stroke gestures based on kinematic theory. Participants will be provided with a concise survey of the most relevant aspects of the literature pertaining to gesture interaction. The main technologies available today to acquire human gestures will be briefly presented: worn and hand-held equipment (*e.g.,* motion sensing controllers, gloves, smart rings [11, 12, 32], smartwatches [17]) as well as non-invasive devices (*e.g.,* radars [6, 28, 29]).

3 Designing Interactive Gestures

Gesture commands can be designer-defined (*i.e.,* decided by designers), user-defined (*i.e.,* proposed by real end users), system-defined (*i.e.,* shipped with a device), or hybrid [41]. user-defined gestures may be more memorable [25] than system-defined gestures, because users have established a strong association between gestures and actions when defining the gestures [42]. This module will introduce attendees to the most recent approaches, methodologies, and tools to design interactive gestures. Discovering gestures using the gesture elicitation methodology [40] (see [38, 39] for recent systematic literature reviews and [14, 20] for recent executions), designing gestures to optimize specific performance criteria, such as production time [2] or difficulty [36], are a few examples of approaches covered by this module. During this module, we will also run a small elicitation study and will engage attendees to participate as experimenters at diverse stages: pre-test (consent form, demographic questionnaire, setup), test (eliciting mid-air gestures [16] for *e.g.,* Internet-of-Things tasks [9]), and post-test (evaluation questionnaires). Attendees can also play the role of a participant. Gestures elicited during the on-site study will be classified, clustered, and agreement rates computed with the AGATe tool [37] (Fig. 1-c). Design criteria for gestures will be explained to participants, such as ease of execution and perceived difficulty [36], accuracy [37], learnability and memorability [25], time efficiency [2], performance [5], benchmarking [24], complexity [15], prediction [19], and gesture fit-to-function. Information will be provided on gesture vocabularies [41], gesture sets [14, 29], and gesture classes [21].

4 Engineering Gesture User Interfaces

Once gestures are adequately addressed and designed, they need to be incorporated in the development life cycle of an interactive application. A first step is to ensure gesture recognition: simple and efficient gesture recognizers, such as those based on templates [21] or grammars [7, 15]. Out of template- or pattern-based recognizers, the $P gesture recognizer [34] was found to be very accurate for a wide range of gesture types [27], yet it is simple to implement on any platform in about 70 lines of code and is easily extendable to multi-touch input (Fig. 1-b). $Q [35] is the fast version of $P optimized for low-end devices. !FTL [30] ensures position, scale, and rotation invariance by definition and controls them on demand. A reference software architecture will be exemplified for several real-world projects [4].

2D stroke gesture recognition is pretty much mastered in terms of accuracy (we expect a recognition rate above 95% or more), efficiency (we expect system response times below 0.5 sec), and robustness (we expect that the gesture recognition is insensitive to contextual variations, such as human articulations). However, 3D gesture recognition is highly dependent on the context of use, not just the end users, but mostly the device or sensor that are used to capture gestures and in which conditions. For example, No interface, No problem [6] demonstrates how mmWave radars can be used to perform hand gesture recognition in an unobstrusive way, while taking into account contextual variations. Consequently, 3D gesture recognition is far from an entirely solved problem. Many works exist for some specific context of use, mainly focusing on devices that largely influence the recognition capabilities.

Software support for implementation will also be demonstrated in some of these contexts of use: toolkits, libraries, and gesture managers. For example, Gelicit [23] supports the design life cycle for a gesture elicitation study with some devices to produce a consensus gesture set. RepliGES and GEStory [10] are two visual tools for systematizing and consolidating knowledge on user-defined gestures with animated transitions [8]: designers can query the on-line catalog of user-defined gestures to determine which ones have been already designed for a certain context of use, defined as a user+device+environment.

5 Instructor

Jean Vanderdonckt, Ph.D., works in Human-Computer Interaction with focus on Engineering Interactive Computing Systems (EICS). He is a Full Professor at the Louvain School of Management of the Université catholique de Louvain, where he leads the Louvain Interaction Lab (LiLab), and teaches HCI, Model-based User Interface Design and Development for undergraduate and graduate MBA and MSc students since 1998. He is an ACM Distinguished Speaker and Scientist (2017), IFIP Pionneer (2025) and Fellow (2021). He is the co-chair of SpaceCHI '26 conference.

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