Face-to-face exchanges are an extremely rich form of interpersonal communication. As humans process what people are saying, we also adeptly read subtle variations in their posture, facial expressions, gestures, and vocal prosody. This exchange includes pragmatic information, emotional clues, and potentially displays of dominance or markers of rapport. People often become highly skilled at reading others, and they engage deeply in these interactions, both socially and pragmatically. Communication is highly social, and thus this richness provides both opportunities and challenges for natural virtual characters.

Virtual characters can be a powerful tool for a range of applications, from storytelling and games to tutoring, training, and general interfaces. Yet, human users have keen observation skills, which means they will be aware of any errors in the virtual character’s performance and may easily read unintended messages into the communication if an agent’s performance is flawed. This special issue takes up these challenges in order to move our field closer to being able to reap the benefits of virtual characters.

Character animation, like human communication, is multimodal. In computer animation, different modes employ very different technical representations. For example, facial animation and muscle bulges are often achieved by directly deforming a polygonal mesh that represents a character’s skin. Gestures and locomotion are generally represented with a skeleton, a series of connected bones where the free parameters controlled by the animation system are the angles of the joints. These bones are in turn used to drive the gross movement of a character’s skin. Effects like breathing may involve both skeleton and mesh deformations. Crowd animation involves planning algorithms that employ a relatively coarse abstraction of the individual character.

To produce intended messages through animation, we must carefully coordinate a character’s facial expressions with posture changes, gestures with speech, breathing with gaze, and so on. Orchestrating this coordination presents a significant challenge because people are so likely to notice errors, which they may view as character attributes rather than technological errors. For instance, incorrect gaze modeling can lead to a character being viewed as disinterested. Poor coordination between speech and gesture might lead to a character being viewed as nervous or ineloquent. This need for coordination extends from the modes of a single character to interaction between pairs of characters to the large-scale behavior that emerges with crowds.

To complicate matters further, character behavior is performed and interpreted by the user within specific contexts. Thus, if two characters are in a conversation, they must engage appropriately with each other, adjusting their behavior to their interlocutor. Such coordination extends to crowds, where characters must both take actions to avoid each other and generate appropriate social interaction. In many applications, virtual characters must be designed to interact with real people, so their behavior must adjust based on the human participants’ actions as well.

A key challenge in all this is understanding which behaviors virtual characters should perform to achieve a desired impression. Here, virtual char-
acters offer a unique platform for studying human communication. Because we can precisely control behavior, stimuli can be easily generated for experiments that examine how a particular movements impact the perception of the character.

**In This Issue**
Each of the articles in this special issue touches on one or more of these challenges.

Our faces convey attitude, emotion, prosody, and much more. Because they are such important means of communication, facial behaviors and expression give much life to virtual characters. In "Data-Driven Approach to Synthesizing Facial Animation Using Motion Capture," Kerstin Ruhlend, Mukta Prasad, and Rachel McDonnell propose a way to modify the traditional cartoon animation pipeline. Traditionally, cartoon animators copy their own movement to drive a 3D character's animation. Using the proposed approach, animators record their movements in front of a real-time, video-based motion-tracking and retargeting system. The authors then compute a synthesized version and match the recorded motion-capture patterns to a database of hand-animated motion curves. The goal is to produce facial animation that closely resembles the quality of the refining stage, with easily editable curves that an animator can polish in a final production stage.

One of the more challenging aspects of character animation is generating expressive variation, altering motions to reflect mood, personality, age, injuries, physical capabilities, and so forth. These attributes are often described as the "style" of the motions to distinguish them from the actions performed, or "content." In most cases, style changes elude easy mathematical representation and are difficult to encode computationally. In "Fast Neural Style Transfer for Motion Data," Daniel Holden, Ikhsanul Habibie, Ikuo Kusajima, and Taku Komura adopt a style-transfer approach whereby the style embedded in one action can be transferred to different actions. They use a deep neural network that can transfer style from a single input clip without the need to align clips. Previous neural style transfer approaches have been slow, but the authors present a fast feed-forward neural network and accompanying training scheme that performs style transfer thousands of times faster.

Virtual characters can be used as surrogates in social role-playing applications, interacting with people for training or other purposes. A key research goal in this context is understanding how to customize a virtual agent's motion to communicate a particular social message. "Perception of Virtual Audiences" by Mathieu Chollet and Stefan Scherer describes an application in which an audience of virtual characters is used to help real people improve their public-speaking skills. It presents an innovative method that uses crowdsourcing to suggest appropriate agent behavior in order to convey attributes such as boredom or engagement. The authors generated simulated audiences to display these behaviors, and then as part of a user study, humans rated their perception of the agent behavior. Using virtual characters allowed the authors to precisely control the stimuli, including which behaviors were displayed and how many audience members displayed particular behaviors. The study offers a detailed analysis of which aspects of movement communicate specific messages. For example, gaze behavior appears to be the largest contribution to arousal. Head movements, nods, and shakes contribute strongly to valence, as do gaze and posture changes. Interestingly, facial expressions were relatively poor communicators in an audience setting.

**Character animation, like human communication, is multimodal. In computer animation, different modes employ very different technical representations.**

During an interaction, humans adapt to each others' behaviors. They may imitate one another's smiles, react to emotional expressions, align their vocabularies, and even synchronize their behaviors. Such behavioral coordination is a mark of engagement, which is a complex phenomenon that involves being involved in and interested in an interaction. Elisabetta Bevacqua, Romain Richard, and Pierre De Loor's article "Believability and Co-presence in Human-Virtual Character Interaction" looks at how body coupling between interactants affects the users' experiences and their perception of virtual characters. The authors developed a platform to adapt the agent's body behavior to the user's behavior to facilitate such coupling. They evaluated their model in terms of the user's feeling of co-presence and the believability of the agent using a custom fitness exergame.

Although virtual characters are animated individually in the other articles in this special issue, this is not possible when animating a crowd of numerous characters. One application of crowd animation is to simulate building evacuation plans. In the article "Evaluating and Optimizing Evacuation Plans
for Crowd Egress,” the authors Vinícius J. Cassol, Estêvão Smania Testa, Cláudio Rosito Jung, Muhammad Usman, Petros Faloutsos, Glen Berseth, Mubbaseir Kapadia, Norman I. Badler, and Soraia Raupp Musse proposed several metrics to identify optimal evacuation plans. Evacuation simulation determines the number of agents that follow a certain path and chose a particular exit. The optimal solution relies on decision points that control these parameters. To evaluate the evacuation solution, the authors’ metrics capture many of the important aspects of an evacuation: total evacuation time, average evacuation time, agent speed, and local agent density. The proposed approach was validated using a night club model that incorporates real data from an actual evacuation.

**Future Directions**

The articles gathered in this special issue propose different techniques, relying on motion-capture data, procedural animation, or even manual animation. Their applications range from simulation to animation creation tools and even games, and they focus on creating high-quality animation, paying attention to subtle facial motion or motion style, or developing interactive agents able to adapt their behaviors to that of the user.

Building systems capable of supporting human–virtual-character interactions involves both the automatic specification and the generation of appropriate character motion, as well as coordination across communication modes and between multiple characters. Although significant advances have been made, important challenges still remain. In addition to producing believable animations, future work must focus on developing autonomous agents that can express a range of socio-emotional signals while maintaining consistent character personalities and clearly communicating intended messages.

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