論文の内容の要旨

Actuated Tangible User Interface: An Extensible Method for Tabletop Interaction

(駆動型タンジブルユーサザインタフェース:
テーブルトップインタラクション拡張のための一手法)

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Along with the development of natural user interface, there is a need for new user interfaces that can give direct physical feedback simultaneously with manipulations. This thesis proposes a conceptual framework of actuated tangible user interface for tabletop interactions with direct physical feedback. The framework demonstrated in this thesis consists of a self-contained interactive table and extensible actuated tangible user interfaces that give feedback in the physical form, of which users manipulate them, in order to meet the concept of "input equals output". This extensible method can create a mixed-reality space within a tabletop environment, in which interaction with virtual objects and real world objects can be integrated seamlessly, bridging the gap between physical world and information world. The proposed method can be applied for, and is capable to bring new interaction experiences to, many different applications from a wide application range.

The approach is supported through the design and implementation of a self-contained table system and a number of extensible actuated tangible user interfaces, which are in the form of robots or shape-shifting devices. The table in the framework supports simultaneous multi-touch and tangible inputs, and provides a robust control of multiple remote devices. The first actuated tangible user interface was designed and developed in the form of a mobile robot, which shapes a tangible user interface with kinetic feedback. An extension to the robot that enables feedback in the form of height variation was developed in order to provide an additional dimension of shape-shifting feedback. Technical analysis shows the approach to be robust and verified the possibility of the concept "input equals output" for bringing new interaction styles in a tabletop environment.

A series of user evaluation experiments were conducted based on three scenarios in different applications domains. These scenarios involve applications for entertainment, education and professional use. Qualitative and Quantitative user evaluations of the framework within a real-world setting illustrate its usability for game play, learning and simulations. Our observations revealed possibility of new interaction styles with simultaneous physical interaction and physical feedback mapping to the information space for tabletop applications with different purpose.

The thesis suggests that by providing physical feedback to tangible user interfaces we give application designers more freedom to invent a broad range of interactive applications in various social environments, such as classroom, museum, and office. Contributions of the thesis include: conceptual framework of actuated tangible user interface, development of mobile and shape-shifting tangible user interfaces for tabletop interaction, prototype designs and user evaluations for mixed-reality game, programming learning and urban planning applications.