A Method for an Agile, User Centered Development of Natural User Interfaces

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***Abstract*—In this work we introduce a novel iterative and user centered method to facilitate the development of intuitive and natural user interfaces. To showcase our agile procedure we conducted an explorative user study, which focusses on intuitive and seamless gestures for controlling appliances in smart environments. We found a variety of individual user preferences, which indicates the need of a highly personalized interaction control. Furthermore, we implemented one of the resulting gesture sets using our multimodal integration platform for human computer interaction studies. This platform enables a rapid implementation cycle as well as a lightweight adaptation to technological advantages. A reliable comparison of different gestures, sensors and algorithms is provided by the combination of the explorative study design and a straightforward implementation. Moreover, the presented method allows an easy adaptation to users' needs, due to the included interview and quick implementation cycle.**

I. Introduction

A recent trend is the growing popularity of smart solutions and controls in assisted living, health care organizations, smart homes and collaborative robots. Many technologies for sensing human input and automated actors are available on the market, but the wide spread adoption of natural user interfaces driven by gestures has not happen yet. We identified challenges that might hamper adaptation. 1. Users maintain diverse manual and cognitive skills and have their individual usage preferences. For instance it is difficult to find a universal and average optimal mapping philosophy due to conflicting goal objectives: convenience vs. performance. 2. Buildings represent a long term investment and to make them smart should not be a fashion which is obsolete after the next technology wave. Therefor a strategy to carry forward adaptations and insights to the next interface technologies generation is imperative. 3. A diverse user base, including the aging population, increases the need for differentiated accessibility requirements [1]. Research has shown that a universal and intuitive interface cannot be provided. 4. Differences in culture and personality commonly result in a misinterpretation of gestures due to a great variety in the use of gesticulation in daily routines [2]. Inherently the degree of freedom while interacting through natural user input is higher than during the usage of the classic WIMP interfaces, though it lacks tactile feedback. This makes the interpretation more difficult [3], on the other hand it gives more room for the individual freedom of expression as found in language and music [4].

The surge of input technologies in various application domains provides many specific solutions as research results and products. However the transfer of these solutions is often limited to its specific application or technology context. Much could be gained from a systematic use of existing research approaches by integration, extension and cross-evaluation. In an environment of divers systems and applications an overall functional comparison is seldom performed. Many current approaches focus on new implementations and technologies rather than on overarching insights and integration. Evolving input technologies is a trend sustained over the last decade and transfers research in consumer products: iPhone, Kinect, Amazon Echo, Hololens, Leap Motion, etc.

Besides the initial fascination with new technologies we found that consumers value when products meet their individualized needs. In addition, they look for longer lasting solutions that sustain technology shifts and prefer the adaptation of their personal style of interaction.

In this work we provide a development method to find, optimize, combine and evolve gestures originating from user preferences. We introduce an iterative approach to enhance the individualized mappings of gestures to meet users' needs. To showcase the advantages of our method we conducted an explorative user study in our smart home laboratory to facilitate the discovery of the users envisioned interactions. Furthermore we implemented a prototype using our multimodal integration platform for human computer interaction experiments.

II. Related Work

The field of human computer interaction has generated a wealth of solutions for gestural interaction, multimodal interaction and the user-centered design. Starting in the 80's Bolt showed the advantages of a multimodal approach combining

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speech and gesture [5]. Nowadays this topic is still relevant as research in natural user interfaces, companion systems, 3D UI and predictive user models shows.

Our contribution take a fresh perspective on topics concerning the user centered approach, gestural interaction with and without devices, the application and evaluation of different sensors and algorithms.

Recent research at the Bremen Ambient Assisted Living Lab (BAALL) includes the development of a multimodal and interactive device control system allowing a seamless combination of speech and gestural control introduced in [6]. Their contribution also provides a user evaluation conducted in a Wizard-of-Oz manner. Their study included German and Chinese participants and analyzes the cross-lingual commands as well as the cultural differences. Performing evaluations which include users is a common procedure in the field of human machine interaction. Kühnel et al. work with users to evaluate and define a set of gestures for smart-home control using a smartphone device [7]. The conducted three user studies to deife the gesture vocabulary, examine the distinctness of the gesture vocabulary and finally to examine the memorability. Every study required form the participants to examine over 20 different effects or referents, including controlling the blinds, lamps, TV, etc.

Controlling kitchen appliances using the Wii-Mote controller for the Nintendo Wii console is the method introduced in [8]. The authors conducted an elaborated user study which had seven different functional tasks and took ca. 90 minutes for each user. The detail level of the user evaluation enabled the authors to investigate two different approaches, one using a single gesture to operate a single device and one using a single gesture to trigger a shortcut phrase which operates on multiple devices at once.

Our work also includes a user evaluation to determine a suitable gesture set to control selected home appliances. We prefer the execution of smaller tasks and shorter tests focusing on a preselected scope and hence creating a less stressful environment. This way users do not feel like being a part of an examination with the need to perform in a particular way. We strive to avoid a social-evaluative treat, since they are perceived as stressful according to [9]. Also by implementing an iterative approach, an increasingly accurate approximation to the users' needs can be reached. Our approach also does not include any devices while interacting with home appliances, hence they can be easily misplaced, as noted by Dezfuli et al. in their research on imaginary interfaces [10].

To provide a natural user interaction, different techniques and technologies can be used. Previously named research includes external devices which for example make it possible to avoid the start-stop-problem of continuous gesture recognition. The use of RGB or CCD cameras and color vision algorithms is a frequently used approach. The contributions of [11], [12] and [13] introduce an approach for gesture recognition using CCD camera. A combination of a depth and color-based approaches was introduced in [14], whereas [15] and [16] present their solutions based only on depth camera technology to track the body skeleton. Our prototype implementation also uses a Kinect 2 depth camera, although the provided platform also allows the integration of different sensors. Therefore, a lightweight interchange of technology can be easily provided.

Based on the chosen technology, a suitable method and algorithm for data handling and gesture recognition needs to be applied. This area of research also provides a wide spread of possible approaches. Machine learning is often used. The contributions [13] and [17] use Hidden Markov Model-based (HMM) motion recognizer. A support vector machines based approach is presented in [18]. Furthermore a heuristic approach is introduced in [15].

Our prototype implementation is based on a heuristic approach which can easily be adopted and extended. New gestures can be implemented very quickly by providing new rules for a new gesture definition. Furthermore, the integration platform is designed to easily incorporate further agents providing different kinds of recognition methods, e.g. based on machine learning. This is an advantage over the previous contributions and provides an easy way to extend the examination scope as well as evaluate and compare different technologies, sensors and algorithms with each other.

III. Methodology

In this work we present a novel iterative user centered development method to facilitate seamless and intuitive natural user interfaces, in particular for gestures. Figure 1 illustrates the essential steps.

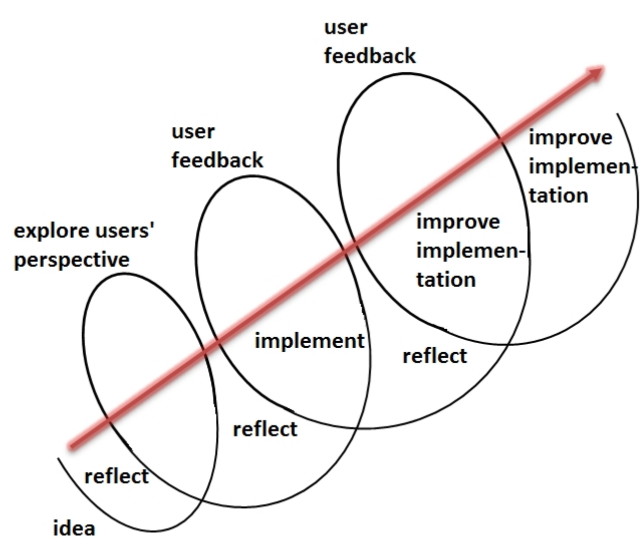


Figure 1. Agile, user centered development method

First, an initial idea undergoes a user evaluation to explore the users' perspective. This step can be conducted in form of an explorative user study, where participants are encouraged to share their view. Next, the results gathered in the study must be reflected. The users' input contributes significantly to the prototype implementation. The prototype must then again be verified by the users in a practical manner to gather feedback. Reflecting upon that feedback contributes to the improvement of the next implementation. A short and frequent feedback loop is crucial to consider users' preferences. A quick implementation enables an increasingly accurate approximation to the users' needs.

Variety of modern user input technologies is the basis for smart homes to develop and investigate new seamless controls. The smart laboratory Living Place Hamburg [19] is the environment where we conducted an explorative user study. Our study focuses on intuitive and seamless gestures to meet the individual user needs.

Furthermore, we illustrate our presented method by an exemplary implementation of a gesture set. The multimodal integration platform for human computer interaction studies enables a rapid and lightweight implementation. Furthermore, the presented platform is scalable regarding sensors, gestures and algorithms. By supporting an easy adaptation to technological advances, our approach overcomes the often missing interface comparability. Our iterative user centered design method allows the easy and reliable comparison of different gestures, sensors and algorithms, due to both the explorative study design and quick implementations.

The presented approach allows a lightweight adaptation to user preferences, by including interviews and a brief iterative implementation cycle. In summary, our agile development method facilitates rapid gesture prototyping, incorporating the user perspective.

IV. Explorative User Study

To explore the users disposition to engage with their surroundings in an interactive way, a user study was conducted which will be presented below. The goal is user interaction with a smart home environment without the use of any additional devices but their own body, using body gestures. Should the participants be willing and able to do so, the study will show such an interaction can be performed in a natural and intuitive manner. Furthermore the study will show which gestures the users prefer to control selected home appliances. Additionally the results include suggestions from the participants of our study regarding different types of interaction in the context of smart environment.

The participants were asked to perform a practical task and to answer a few questions afterwards. A questionnaire providing a rating scale and some open questions was introduced to the attendees. All of the participants agreed to the acquisition of audio and video data during the study.

A. Participants Profile

Fifteen participants were invited to engage in our explorative study. Four of the attendees used a different modality to complete the given task so that the presented results are based on the data collected from the remaining 11 trials. The participants were asked e.g. questions regarding their age, sex, student status and previous experience in dealing with 3D gestures as well as their estimation of their own expertise in this field. Furthermore, the participants were asked if they would like to use 3D gestures in the daily life situations while interacting with a home environment and if so, with which appliances they would like to be able to interact. Finally, they were asked if they would like to contribute their own gestures to interact with the environment or if they prefer that a set of gestures would be provided to them.

The age range of the participants varied from under 18 to over 70 with the majority (73%) being 25-35 years old. Six men and five women took part in the study. Six of the participants were university students at the time the study took place. The majority of the participants (73%) stated they have had some previous experience with 3D gestures while 45% of all participants rank their confidence in dealing with 3D gestures high or very high. All of the participants declared the desire to use body gestures to interact with a wide range of home appliances and almost all of them (90%) wanted to define their own gestures. Some users stated they would be interested in pre-defined gestures if they were able to alter them as needed.

B. Experiment Set-up

The explorative study was designed to learn about the users' perspective and needs while designing and implementing a natural user interface for a seamless interaction with a smart environment. The laboratory where the experiment took place was the Living Place Hamburg [19]. It is a fully functioning smart loft flat equipped with the technology to conduct different kinds of usability experiments. Figure 2 shows the floor plan of the flat which includes a living area, a bedroom area, a kitchen, a bathroom, a control room and a few office spaces.

The smart environment was chosen to perform the study to give the users the most natural scope to accomplish the task. The users could imagine being in a regular flat or hotel room which is more natural than a common usability lab. The laboratory is equipped with cameras and microphones which were used to collect audio and video material during the experiment, so that the data could be evaluated at a later time.

Figure 2. Living Place Hamburg floor plan

The study consisted of two tasks. The first task was practical and interactive. The second task consisted of filling out a questionnaire. In the practical part of the experiment each user received the same introduction explaining the task. The users did not know what they were supposed to do until shortly before the experiment began. This was to provoke a spontaneous and intuitive reaction. Each user was asked to imagine coming into a smart hotel room. This means that a variety of the home appliances can be controled in an automated and wireless way. The attendees were asked to concentrate on the lights and the roller blinds in the room. In the beginning the lights in the room are switched on and the roller blinds are open. The following scenarios should then be performed: first the case was going to sleep, in which case the blinds should be closed down and the lights switched off. Then the second scenario should be performed which was waking up. Here the blinds should be opened and the lights switched on. The tasks should be conducted with no use of an external switcher or additional devices, using only the body motions. Each user was asked to use the body movement she or he sees fit to accomplish the task. Additionally, the users were asked to comment on all their intentions and undertakings along the way and to speak their minds aloud. This approach is particularly well suited to experimental qualitative analysis where one is interested in the users' estimation.

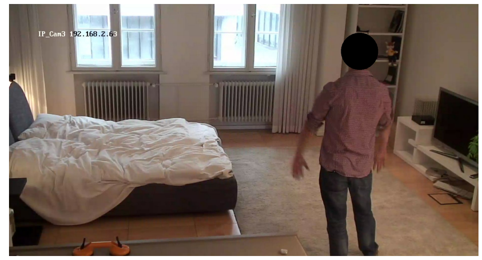
The simplified setup including only two home aplliances is intended. The user should not be overwhelmed with the task. It should not feel like an exam so the results reflect a spontaneous and natural approach. Also the selection of the two home appliances is intentional. Each of it requires a different level of abstraction in translating the action into a gesture metaphor. The mechanical movement of a roller blind suggests a continuous movement. The switching on of the light, on the other hand, appears to be a more abstract event with no mechanical movement to observe.

The study was conducted in a wizard-of-Oz manner which means all the user actions had an immediate effect on the environment and led to controlling the designated devices. The users had the impression their actions were responsible for the changes in the flat whereat actually another person hidden from the view of the participant controlled the actual device using a remote control application.

C. Experimental Procedure

Each attendee had the opportunity to perform the task alone in the laboratory. There was no defined time range so each user could take all the time they needed to finish the given task. In average it took three to five minutes for a user to complete the practical tasks and five to ten minutes for the interview and the questionnaire. At all times users were able to ask questions to the researcher who was at scene and were encouraged to do so if they felt like it. All users commented aloud on their performance and their intentions while doing so. Every action conducted by a user was evaluated as a valid input. Figure 3 shows a user performing a gesture to shut the roller blinds down while figure 4 shows another user performing a gesture to stitch the lights on.

(a)



(b)

Figure 3. Close down the roller blinds

(a)

(b)

Figure 4. Switch the lights on

Users noticed that their action had a direct effect on the environment which often resulted in a spontaneous and enthusiastic reaction. The overall experience as well as our approach received a positive feedback and the attendees were happy to be part of the experiment.

D. Results

Our explorative study results include gestures user proposed to control lights and roller blinds. While our results to control roller blinds were consistent throughout our participants, the preferences for controlling the lights were highly individual and diverse. The comments on an approach as well as suggestions from the interview and questionnaires will be presented in more detail in the following.

Some of the 15 participants voiced their preference to use a different modality, e.g. speech, to control the home appliances. This indicates the need of further iteration steps to provide a more personalized adaptation.

Table I shows the preferred gestures by users to control the roller blinds. Over 90% of the users chose a similar gesture to interact with this appliance. This part of the task was easily performed by all of the attendees and was often commented on with "*I would just put my arms up and then perform the movement down (...)*" or "*I would consider the movement of the roller blind namely it should go down so that I would put my arms up and then pull them down (...)*", "*I think this is quite a distinct gesture. Anything else would probably confuse me (...)*". The users performed the suggested gesture quickly and without the need of a longer consideration. The previous experience in dealing with 3D gestures had no impact on their performance in this task.

Tabelle I
RESULTS FOR THE PREFERRED GESTURES TO CONTROL THE ROLLER BLINDS

Close down the roller blinds		Open up the roller blinds	
Gesture	Number of attendees	Gesture	Number of attendees
Slide with one or both arms stretched out before you from above your chest to beneath it. Armes are oriented towards the roller blinds	10	Slide with one or both arms stretched out before you from below your chest to above. Armes are oriented towards the roller blinds	10
Grab in imaginery roller blind cord and pull it down repeatedly	1	Grab in imaginery roller blind cord and pull it down repeatedly	1
Total	11	Total	11

The preferred gesture results to control the lights are presented in Table II. In this task few users had difficulties finding a suitable gesture to perform the lights control. We can find a variety of proposals. Some users even choose more than one gesture as they were undecided. One of the proposed solutions was clapping with both hands. Some users associated it with a familiar sci-fi movie from the past and commented e.g. "*I would assume that this would work because you know it from the movies (...)*". Some users named more than one gesture to control ceiling and bedside lights.

Tabelle II
RESULTS FOR THE PREFERRED GESTURES TO CONTROL THE LIGHTS

Switch the light off		Switch the light on	
Gesture	Number of attendees	Gesture	Number of attendees
Clap with both hands	5	Clap with both hands	6
Flip/Snap with fingers	1	Flip/Snap with fingers	2
Touch with one hand on the bedside lamp	2	Touch with one hand on the bedside lamp	2
Point with an arm to the ceiling lamp and move the arm to the side	2	Point with an arm to the ceiling lamp and move the arm to the side	1
Put the palm of your hand horizontally in front of your face and move it down your face	1	Put the palm of your hand horizontally in front of your face and move it up your face	1
Point with your hand to the ceiling lamp and rotate your hand (similar as a light bulb)	1	Point with your hand to the ceiling lamp and rotate your hand (similar as a light bulb)	2
		Point with one arm at the bedside lamp	1
Total	12	Total	15

Users usually took longer to perform this task. They would often emphasize the challenge associated with the task by stating: "*I find it harder to control the lights* (...)", "*The lights... what should I do with the lights. Maybe clapping?*". This task was difficult to solve for experienced users as well as for those who came across 3D gestures before.

During the interview users voice their interest in interacting with other home appliances using gestures. They identified various electric devices, including TV or HiFi, light intensity, the bed backrest and bathroom appliances.

The overall results of our explorative study show the need of a highly personalized interaction control for appliances without a simple mental gesture representation. Also possibility of multi gesture control without conflicts is required.

V. MULTIMODAL INTEGRATION PLATFORM

The rapid and straightforward implementation of a software system for human computer interaction allows a fast feedback loop for a better realization of user requirements. To enable such a procedure and embrace the advantages of an agile approach an integration platform for HCI experiments will be introduced. The application scope examined in this paper includes experiments conducted in a smart home environment although other scenarios are also applicable. Therefor the platform encapsulates the variety of existing technology solutions around the smart home environment which are often inhomogeneous. The design includes a middleware solution for distributed agent-based systems introduced by Eichler in [20] and [21]. The provided middleware operates in publish-subscribe manner as a blackboard. Agents can publish information about the environment, e.g. the state of a particular sensor or appliance. Other agents can subscribe to get updates on that information and can process them further in a certain way and republish the data for others to use.

The integration platform provides a variety of additional agents enabling the integration of multiple sensors, actors and algorithms into the platform. The architecture design is inspired by the contribution for companion technology in multimodal interaction introduced by [22]. The adapted architecture diagram is presented in Figure 5. The input device component gathers the data from a device e.g. a camera sensor or microphone. Multiple input devices can be supported. The data is then handled by the multimodal fusion component which aggregates and prepares the data for further handling by the interaction management component. This crucial component is responsible for the correct data evaluation. It has the access to the knowledge base and the context information about the system. Based on the input data and the context information it decides which action should take place next. This information will be passed to the multimodal fission component which chooses the correct modality to execute the command. Finally the determined action is taken by the selected output device.

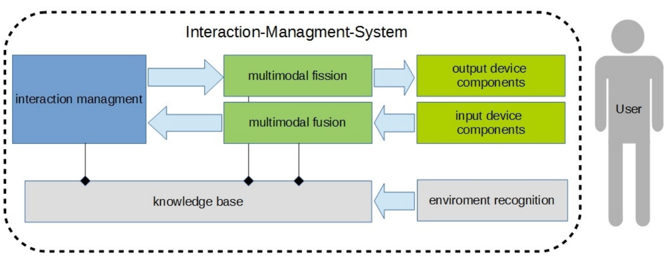


Figure 5. Integration platform system architecture based on [22]

The integration platform provides multiple agents which can handle diverse sensor data, algorithms and control actors. One of the use cases of application was presented in [21]. The challenge here was to provide a body tracking system using multiple cameras which input data needed to be fusioned. The fusioned body data was then used to recognize the motion of the user walking based on a heuristic approach for gesture recognition. To solve this task multiple agents for data fusion, visualization of the tracking data, walking detection and logging were provided.

A. Prototype Implementation of the Roller Blinds Agent

A prototype of gestural control interface for roller blinds based on the multimodal integration platform was implemented. We chose to implement the control of the blinds since it provides the most homogeneous results in the experimental study. The proposed gestures were presented in Table I.

The realization includes the implementation of a Gesture Recognition Agent for opening and closing the blinds. Figure 6 shows the components diagram of the prototype.

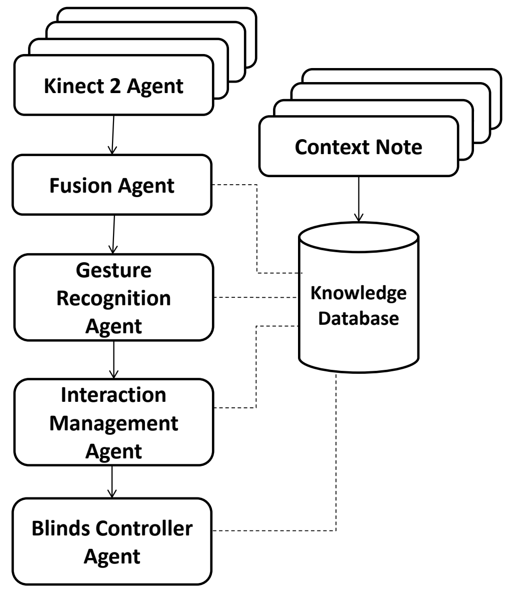


Figure 6. Components diagram of the prototype implementation

To track the users' body joints, four Kinect 2 for Windows cameras were used. Four Kinect 2 Agents are provided by the platform for handling the input data. Following, the data is passed by to the Fusion Agent component. Here, the data is aggregated into a single body skeleton. The Gesture Recognition Agent subscribes to receive the prepared skeleton data. This component is responsible for the recognition of the gestures for opening and closing the blinds. A heuristic approach is used to define the gestures.

During the experimental study, some participant used one arm, while others chose to use both arms to perform the gesture. Our prototype supports both ways of interaction to meet the users' needs.

The skeleton API provided by the integration platform encapsulates the native Kinect SDK API. The Gesture Recognition Agent is implemented in Java. The following heuristic rules apply to recognize the gestures for opening and closing the roller blinds:

- user is directed towards the blinds
- one or both arms are located below the chest
- one or both arms are located at the chest height
- one or both arms are located above the chest
- one or both arms are held above the chest for a preset interval

Only in case of a successful recognition of this sequence the roller blinds, that the user is directed towards, will be opened. The gesture only takes affect in a certain context, namely if the blinds are already closed down. After a gesture was successfully recognized, the agent waits for a defined time interval after which he is once again ready for recognition. To close down the roller blinds a reverse sequence of rules applies. The context information is used to check if the provided gesture applies, e.g. the roller blinds are currently opened up.

VI. Results and Conclusion

The presented novel iterative and user centered approach has shown to facilitate the design and development of a natural user interface to meet users needs. With the explorative study we have shown the variety of individual user preferences, therefore the need of a highly personalized interaction control. Our implementation of a representative gesture set shows the first prototype to meet the identified needs. The multimodal integration platform for user interaction studies supports a lightweight adaptation to technological advances. The combination of the study and the implementation supports an easy and reliable comparison of different gestures, sensors and algorithms. Furthermore our method for an agile and user centered development of natural user interfaces allows a lightweight adaptation to user preferences, due to the included interviews and the brief iterative implementation cycle. Moreover, it shows the benefits of a rapid interface prototyping considering the user perspective enabled by the integration platform.

References

[1] C. Röcker, "Intelligent environments as a promising solution for addressing current demographic changes," *International journal of innovation, management and technology : IJIMT*, pp. 76–79, 2015.

[2] S. Kita, "Cross-cultural variation of speech-accompanying gesture: A review," *Language and Cognitive Processes*, vol. 24, no. 2, pp. 145–167, 2009. [Online]. Available: http://dx.doi.org/10.1080/01690960802586188

[3] D. A. Norman, "Natural user interfaces are not natural," *interactions*, vol. 17, no. 3, pp. 6–10, May 2010. [Online]. Available: http://doi.acm.org/10.1145/1744161.1744163

[4] T. Blaine and S. Fels, "Contexts of collaborative musical experiences," in *Proceedings of the 2003 Conference on New Interfaces for Musical Expression*, ser. NIME '03. Singapore, Singapore: National University of Singapore, 2003, pp. 129–134. [Online]. Available: http://dl.acm.org/citation.cfm?id=1085714.1085745

[5] R. A. Bolt, ""put-that-there": Voice and gesture at the graphics interface," *SIGGRAPH Comput. Graph.*, vol. 14, no. 3, pp. 262–270, Jul. 1980. [Online]. Available: http://doi.acm.org/10.1145/965105.807503

[6] D. Anastasiou, C. Jian, and C. Stahl, "A german-chinese speech-gesture behavioural corpus of device control in a smart home," in *Proceedings of the 6th International Conference on PErvasive Technologies Related to Assistive Environments*, ser. PETRA '13. New York, NY, USA: ACM, 2013, pp. 62:1–62:6. [Online]. Available: http://doi.acm.org/10.1145/2504335.2504402

[7] C. Kühnel, T. Westermann, F. Hemmert, S. Kratz, A. Müller, and S. Möller, "I'm home: Defining and evaluating a gesture set for smart-home control," *International Journal of Human-Computer Studies*, vol. 69, no. 11, pp. 693 – 704, 2011. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1071581911000668

[8] R. NeSSelrath, C. Lu, C. Schulz, J. Frey, and J. Alexandersson, "A gesture based system for context - sensitive interaction with smart homes," in *Ambient Assisted Living*, R. Wichert and B. Eberhardt, Eds. Springer Berlin Heidelberg, 2011, pp. 209–219. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-18167-2_15

[9] S. S. Dickerson and M. E. Kemeny, "Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research." *Psychological bulletin*, vol. 130, no. 3, p. 355, 2004.

[10] N. Dezfuli, M. Khalilbeigi, J. Huber, F. Müller, and M. Mühlhäuser, "Palmrc: Imaginary palm-based remote control for eyes-free television interaction," in *Proceedings of the 10th European Conference on Interactive Tv and Video*, ser. EuroiTV '12. New York, NY, USA: ACM, 2012, pp. 27–34. [Online]. Available: http://doi.acm.org/10.1145/2325616.2325623

[11] Z. Z. Bien, J.-H. Do, J.-B. Kim, D. Stefanov, and K.-H. Park, "User-friendly interaction/interface control of intelligent home for movement-disabled people," 2003.

[12] S.-e. Yang, J.-h. Do, H. Jang, J.-w. Jung, and Z. Bien, "Advanced soft remote control system in human-friendliness," 2006.

[13] J.-H. Do, H. Jang, S. H. Jung, J. Jung, and Z. Bien, "Soft remote control system in the intelligent sweet home," in *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Aug 2005, pp. 3984–3989.

[14] S. Y. Chou, S. C. Wang, and Y. C. Fan, "Depth and color-based three dimensional natural user interface," in *2016 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)*, May 2016, pp. 1–2. [Online]. Available: http://ieeexplore.ieee.org/document/7521054/

[15] B. Williamson, C. Wingrave, J. LaViola, T. Roberts, and P. Garrity, "Natural full body interaction for navigation in dismounted soldier training," in *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2011*, 12 2011, pp. 2103–2110, https://www.youtube.com/watch?v=846146PuoIM. [Online]. Available: http://www.eecs.ucf.edu/isuelab/publications/pubs/itsec2011.pdf

[16] M. Dontschewa, S. Rosmann, and M. Marinov, "Using motion capturing sensor systems for natural user interface," in *2016 XXV International Scientific Conference Electronics (ET)*, Sept 2016, pp. 1–4. [Online]. Available: http://ieeexplore.ieee.org/document/7753474/

[17] D. Kim and D. Kim, "An intelligent smart home control using body gestures," in *2006 International Conference on Hybrid Information Technology*, vol. 2, Nov 2006, pp. 439–446. [Online]. Available: http://ieeexplore.ieee.org/document/4021249/

[18] C.-T. Hsieh, C.-H. Yeh, K.-M. Hung, L.-M. Chen, and C.-Y. Ke, "A real time hand gesture recognition system based on dft and svm," in *2012 8th International Conference on Information Science and Digital Content Technology (ICIDT2012)*, vol. 3, June 2012, pp. 490–494.

[19] HAW Hamburg, "Living place hamburg," 2017, abgerufen 03.2017. [Online]. Available: http://livingplace.informatik.haw-hamburg.de

[20] T. Eichler, "Agentenbasierte middleware zur entwicklerunterstützung in einem smart-home-labor," Master's thesis, Hochschule für Angewandte Wissenschaften Hamburg, 2014. [Online]. Available: http://users.informatik.haw-hamburg.de/~ubicomp/arbeiten/master/eichler.pdf

[21] E. Langbehn, T. Eichler, S. Ghose, K. von Luck, G. Bruder, and F. Steinicke, "Evaluation of an omnidirectional walking-in-place user interface with virtual locomotion speed scaled by forward leaning angle," in *Proceedings of the GI Workshop on Virtual and Augmented Reality (GI VR/AR)*, 2015, pp. 149–160. [Online]. Available: http://basilic.informatik.uni-hamburg.de/Publications/2015/LEGVBS15

[22] F. Honold, F. Schüssel, F. Nothdurft, and P. Kurzok, "Companion technology for multimodal interaction," in *Proceedings of the 14th ACM International Conference on Multimodal Interaction*, ser. ICMI '12. New York, NY, USA: ACM, 2012, pp. 67–68. [Online]. Available: http://doi.acm.org/10.1145/2388676.2388696