

博士論文概要

Doctoral Thesis Synopsis

論文題目

Thesis Theme

Non-verbal interaction and amusement feedback capabilities for entertainment robots

エンターテインメントロボットにおける非言語的相互作用と娯楽フィードバック機能に関する研究

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Nowadays, robots are not anymore confined between factory walls but are beginning populating our daily life more and more. In the near future robots are expected to play a major role in the society, assisting humans not only in difficult or dangerous tasks but also in everyday chores. Typical examples range from simple vacuum robots, to assistive and personal robots for the elderly or physically challenged persons. In this framework, robots will need to be able not only to do their task like or better than humans, but also to communicate with fellow humans naturally and smoothly, at the same level of perception.

At the moment, in fact, in order to operate a robot, the user requires training, or at the very least an instruction manual to refer to: the most of the cognitive load for communication is placed on the user, it is the user who has to learn and adapt to the robot language. So far, communication issues are holding robot widespread. To promote mainstream robot adoption in the future, the communication load must be shifted back on the robot, which needs then to learn how to communicate with humans. In fact, smooth communication and natural interfaces are important not only for Robotics, but necessary for ensuring technology acceptance and penetration among all layers of human society.

To implement a natural way of communication between robot and humans, we must start from the observation of natural human-human communication patterns. Communication among humans is achieved through the simultaneous use of both verbal and non-verbal patterns, as well as conscious and subconscious signals. Robots then should learn to use these two types of patterns and interpret these two types of signals. Both types of communication present several cognitive challenges for robots. In verbal communication, humans use a single channel –spoken language– to convey information. However, the actual spoken languages in the world are hundreds, with different phonetic, grammar, and prosody rules, and large vocabularies; and it would require virtually infinite memory and computational abilities. On the other hand, non-verbal communication is achieved through several channels: kinesics, haptics, appearance, proxemics, chronemics, paralanguage, silence, and environment management, some of which are dependent on the particular culture, and some of which are culture independent and virtually universal, characteristic of humans as a species. Non-verbal behavior is as important as verbal communication; it complements and enriches it, and sometimes contradicts and altogether replaces it. In particular, non-verbal communication plays an important role in entertainment performances, in fact skilled entertainers know how to when and how to move to convey effective information, can read the audience emotional reaction and can adapt their performance accordingly. Entertainment robots should then learn how to effectively communicate with the human audience.

In this thesis, the road towards the integration of social communication skills in entertainment robots is presented. The specific goal of this work is to develop a communication interface for a musical entertainment robot, enabling the robot to detect and process human non-verbal social signals, both conscious and unconscious. More specifically, the proposed system aims at solving this problem: how can human body language, both conscious, direct and unconscious, emotional, be automatically detected and processed. The advantage of such a system is that an entertainment robot will be able to perceive commands and emotional feedback from the interacting human partner, and be able to adapt its performance accordingly. More interestingly, this system can

also be used in several different applications, in the fields of Robotics and Healthcare.

In this work the aims are achieved by:

- 1) analyzing human motion carrying communication and emotional information
- 2) combining human tracking system and surface electromyography in a body communication interface system
- 3) verifying that the proposed method is effective in recognizing the human social information

At the end, this research demonstrates a general approach to human non-verbal communication signals perception. The system is reconfigurable and can be further expanded to detect different types of non-verbal communication signals, both conscious and unconscious, and adapted to different scenarios.

The validity of the proposed system is verified with specific experiments in the field of musical and humorous entertainment. The results are extremely promising, and show that this is an effective approach to enhance human-robot interaction and take entertainment robots to the next step. In addition, this methodology can be used in a more general context as a general methodology to achieve natural human-robot interaction in a variety of application fields in which natural human-robot interaction would be beneficial, like in the educational, medical, personal service fields.

The research has been carried out in Japan, United States, United Kingdom and France.

This thesis consists of 6 chapters in which I present the background of the issue I address, the theoretical and empirical notions on which the proposed methodology is based, the specific robot platform used and the experiments to test and validate such methodology, and a discussion on limits and possible extensions of this work. The thesis is laid out as follows:

Chapter 1 introduces the background with a detailed analysis on the motivations at the basis of this work. I explain the theory on entertainment, why entertainment is important, and in particular what are the current problems in entertainment robotics.

Chapter 2 explains in deep the theory of human social communication, exploring in particular paralanguage and kinesics, conscious and subconscious communication. It contains the basics of emotions and physiological changes related to them, and it explains the methodology proposed for detection and analysis of both cognitive and emotional kinesics.

Chapter 3 is dedicated to the specific entertainment robot platforms used in the development of this work, the Waseda Flutist robot WF-RVII, the Waseda Saxophonist robot WAS-3, and the Waseda humanoid emotional robot, KOBIAN. It describes their characteristics and purpose, and the limitation that the present work is meant to overcome. In particular, it gives an overview of the state of the art of the robots and their specific interaction needs and purposes.

Chapter 4 is the continuation of the work in Chapter 2. It addresses the problem of direct, intentional kinesics, and it presents the practical implementation of the proposed general human-robot interaction method on the Waseda Flutist robot WF-RVII, according to its specific needs. In particular, basic theory of music and musical interaction is presented, together with a novel non-verbal, direct interaction framework. At the end of the

Chapter the proposed approach limitations and extensions are discussed.

Chapter 5 is the continuation of the work in Chapter 2 and Chapter 4. It addresses the problem of indirect, subconscious kinesics, and it presents the practical implementation of the proposed general human-robot interaction method on the Waseda Saxophonist robot WAS-3 and the Waseda humanoid emotional robot KOBAN, according to their specific needs. In particular, theory of humorous interaction is presented, together with a novel non-verbal, emotional interaction framework. At the end of the Chapter the proposed approach limitations and extensions are discussed.

Chapter 6 concludes the thesis. Results are restated and evaluated from a general perspective.

Broader considerations and future works are discussed, showing the overall contribution of this thesis, and also different future research directions.

In conclusion, the following results were achieved. A framework for conscious and subconscious kinesics interaction was developed, allowing robots to understand and interpret human direct and indirect social signals. Specifically, the developed interaction system and interface allowed the Waseda Flutist robot WF-RVII to follow the directions of an orchestra conductor and adapt its performance accordingly. An expanded version of the system would allow the Waseda humanoid emotional robot KOBAN and the Waseda Saxophonist robot WAS-3 to detect amusement cues, in the form of spontaneous laughter, from its audience, tuning its humorous performance accordingly.

Through the human conscious and subconscious kinesics perception method proposed in this thesis, it will be possible for robots to perceive human natural social communication signals, thus increasing the decisional power of the robots during interaction-related tasks, and making the robot more effective, increasing its field of action. As a result, not only the robots used in this work, but the whole field of robotics can take advantage of the concepts in this thesis. According to the interaction mechanisms described in *The Media Equation* by Reeves, in fact, “Individuals’ interactions with computers, television, and new media are fundamentally social and natural, just like interactions in real life;” or better say, the effects on people interacting with media, and especially autonomous agents like machines and robots, are often profound, leading them to behave and to respond to these media in unexpected ways, most of which they are completely unaware. For this reason, not only humanoids, but any kind of service robot should be able to understand both conscious and subconscious human communication, as people tend to respond to them as they would to another person.

早稲田大学 博士（工学） 学位申請 研究業績書
(List of research achievements for application of doctorate (Dr. of Engineering), Waseda University)

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種別	題名	発表 発行掲載誌名	発表 発行年月	連名者 (申請者含む)
1. 論文				
(new)	Objective Evaluation of Oral Presentation Skills Using Inertial Measurement Units	Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE	2015年08月 (accepted)	S Sessa, W Kong, D Zhang, S Cosentino , U Manawadu, M Kawasaki, G T Thomas, T Suzuki, R Tsumura, A Takanishi
(new)	Angular Sway Propagation in One Leg Stance and Quiet Stance with Inertial Measurement Units for Older Adults	Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE	2015年08月 (accepted)	W Kong, S Sessa, D Magistro, D Zhang, S Cosentino , M Zecca, H Ishii, H Takeuchi, R Kawashima, A Takanishi
○ (new)	Automatic discrimination of laughter using distributed sEMG	6 th AAAC International Conference on Affective Computing and Intelligent Interaction ACII 2015	2015年09月 (accepted)	S Cosentino , S Sessa, W Kong, D Zhang, N Bianchi-Berthouze, A Takanishi
	Balance analysis of one leg stance for older adults with Inertial Measurement Units	IEEE Healthcare Innovation Conference (HIC), 2014, pp. 307-310	2014年10月 (published)	W Kong, S Sessa, D Magistro, D Zhang, U Imtiaz, S Cosentino , M Zecca, H Ishii, H Takeuchi, R Kawashima, A Takanishi
	Development of a comic mark based expressive robotic head adapted to Japanese cultural background	Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on, pp. 2608-2613	2014年09月 (published)	T Kishi, H Futaki, G Trovato, N Endo, M Destephe, S Cosentino , K Hashimoto, A Takanishi
	Development of new muscle contraction sensor to replace sEMG for using in muscles analysis fields	Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE, pp. 6945-6948	2014年08月 (published)	D Zhang, Y Matsuoka, W Kong, U Imtiaz, L Bartolomeo, S Cosentino , M Zecca, S Sessa, H Ishii, A Takanishi
	A multisensory non-invasive system for laughter analysis	2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)	2014年08月 (published)	S Cosentino , S Burger, L Martin, F Metzke, T Kishi, K Hashimoto, S Sessa, M Zecca, A Takanishi
○	Natural human-robot musical interaction: understanding the music conductor gestures by using the WB-4 IM system	Advanced Robotics, Volume 28, Issue 11, p. 781-792, Taylor & Francis	2014年06月 (published)	S Cosentino , K Petersen, Z Lin, L Bartolomeo, S Sessa, M Zecca, A Takanishi

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種 類 別 By Type	題名、 発表・発行掲載誌名、 発表・発行年月、 連名者（申請者含む）(theme, journal name, date & year of publication, name of authors inc. yourself)			
論文続き				
	Bipedal humanoid robot that makes humans laugh with use of the method of comedy and affects their psychological state actively	Robotics and Automation (ICRA), 2014 IEEE International Conference on, pp. 1965-1970	2014年05月 (published)	T Kishi, N Endo, T Nozawa, T Otani, S Cosentino , M Zecca, K Hashimoto, A Takanishi
	A Robotic Head that Displays Japanese “Manga” Marks	Advances on Theory and Practice of Robots and Manipulators (book), pp. 245-253	2014年01月 (published)	T Kishi, H Futaki, G Trovato, N Endo, M Destephe, S Cosentino , K Hashimoto, A Takanishi
○	Human-humanoid robot social interaction: Laughter	Robotics and Biomimetics (ROBIO), 2013 IEEE International Conference on, pp. 1396-1401	2013年12月 (published)	S Cosentino , T Kishi, M Zecca, S Sessa, L Bartolomeo, K Hashimoto, T Nozawa, A Takanishi
	Development of a real-time IMU-based motion capture system for gait rehabilitation	Robotics and Biomimetics (ROBIO), 2013 IEEE International Conference on, pp. 2100-2105	2013年12月 (published)	W Kong, S Sessa, S Cosentino , M Zecca, K Saito, C Wang, U Imtiaz, Z Lin, L Bartolomeo, H Ishii, T Ikai, A Takanishi
	Use of an ultra-miniaturized IMU-based motion capture system for objective evaluation and assessment of walking skills	2013, 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)	2013年07月 (published)	M. Zecca, K. Saito, S. Sessa, L. Bartolomeo, Z. Lin, S. Cosentino , H. Ishii, T. Ikai, A. Takanishi,
	Walking assessment in the phase space by using Ultra-miniaturized Inertial Measurement Units	Mechatronics and Automation (ICMA), 2013 IEEE International Conference on, pp. 902-907	2013年08月 (published)	S Sessa, K Saito, M Zecca, L Bartolomeo, Z Lin, S Cosentino , H Ishii, T Ikai, A Takanishi
	Biomechanical Evaluation of the Phases during Simulated Endotracheal Intubation (ETI): Pilot Study on the Effect of Different Laryngoscopes	Proceedings of 2013 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC, pp. 4887-4890	2013年07月 (published)	L Bartolomeo, Y Noh, Y Kasuya, M Nagai, M Zecca, S Sessa, S Cosentino , K Saito, Z Lin, H Ishii, A Takanishi
	Impression survey of the emotion expression humanoid robot with mental model based dynamic emotions	Robotics and Automation (ICRA), 2013 IEEE International Conference on, pp. 1663-1668	2013年05月 (published)	Kishi, Kojima, Endo, Destephe, Otani, Jamone, Kryczka, Trovato, Hashimoto, S Cosentino , A Takanishi
○	Music conductor gesture recognition by using inertial measurement system for human-robot musical interaction	Robotics and Biomimetics (ROBIO), 2012 IEEE International Conference on, pp. 30-35	2012年12月 (published)	S Cosentino , Y Sugita, M Zecca, S Sessa, Z Lin, K Petersen, H Ishii, A Takanishi
	Assessment of walking quality by using Inertial Measurement Units	Innovative Engineering Systems (ICIES), 2012 First International Conference on, pp. 13-18	2012年12月 (published)	K Saito, MZecca, SSessa, Z Lin, L Bartolomeo, S Cosentino , K Petersen, H Ishii, T Ikai, A Takanishi

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論文続き				
○	Musical robots: towards a natural joint performance	Innovative Engineering Systems (ICIES), 2012 First International Conference on, pp. 19-24	2012年12月 (published)	S Cosentino , Y Sugita, M Zecca, S Sessa, Z Lin, K Petersen, L Bartolomeo, H Ishii, K Saito, A Takanishi
2. 講演				
	Human-robot laughter interaction	2014 Italy-Japan Workshop Robot coworker Waseda University, Japan	2014年12月	S Cosentino , S Sessa, A Takanishi
	Human-robot emotional interaction: Laughter	RSJ 2013 - the 31th annual conference of the robotics society of Japan	2013年09月 (published)	S Cosentino , T Kishi, M Zecca, S Sessa, L Bartolomeo, K Hashimoto, T Nozawa, A Takanishi
	Motion recognition system for conductor and flutist robot interaction	RSJ 2012 - the 30th annual conference of the robotics society of Japan	2012年09月 (published)	S Cosentino , Y Sugita, M Zecca, S Sessa, Z Lin, K Petersen, H Ishii, A Takanishi
3. 賞				
	Student competition finalist award	2014 Italy-Japan Workshop Robot coworker Waseda University, Japan	2014年12月	S Cosentino , S Sessa, A Takanishi
	Best Student paper award	Robotics and Biomimetics (ROBIO), 2012 IEEE International Conference on, pp. 30-35	2012年12月	S Cosentino , Yoshihisa Sugita, M Zecca, S Sessa, Zhuohua Lin, Klaus Petersen, Hiroyuki Ishii, A Takanishi