PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Researches advanced in human-computer collaboration and human-machine cooperation: from variances to common prospect

Jinwei Zhang

Jinwei Zhang, "Researches advanced in human-computer collaboration and human-machine cooperation: from variances to common prospect," Proc. SPIE 12348, 2nd International Conference on Artificial Intelligence, Automation, and High-Performance Computing (AIAHPC 2022), 123482N (10 November 2022); doi: 10.1117/12.2641865

Event: 2nd International Conference on Artificial Intelligence, Automation, and High-Performance Computing (AIAHPC 2022), 2022, Zhuhai, China

Researches Advanced in Human-Computer Collaboration and Human-Machine Cooperation: From Variances to Common Prospect

Jinwei Zhang*
University of Glasgow, UK
*2429518z@student.gla.ac.uk

ABSTRACT

The booming technology of artificial intelligence (AI) and robotics enable people not only prospect its huge potential, but also limitation of capability when solving inplicit problems comparing with human. As a result, fields like Human-Computer Collaboration (HCC) and Human-Machine Cooperation (HMC) are developed and explored, with relevant concepts such as Human-in-The-Loop (HiTL) being aroused. Whereas, such types of research areas are lack of uniform standards and procedures, even measurements, attributing to the way too specific works to scenarios. Thus in this paper, a review of Human-Computer Collaboration (HCC) and Human-Machine Cooperation (HMC) is conducted from the aspects of vaiances to their common prospects. From data gathering to decision making and support, finally to interaction interface, the processing and operation of HCC/HMC systems are discussed, with key issues like trust level to agents proposed and future works suggested.

KEYWORDS-Human-Computer Collaboration, Human-Machine Cooperation, Human-in-The-Loop, Adaptive Robots, Trustworthy AI, Human-Computer Interaction

1 INTRODUCTION

The rapid development of Artificial Intelligence (AI) and Robotics in recent years has arisen a large trend of the industrial revolution, where intelligent applications on business, data analysis, manufacturing industry and medicine not only enhanced the working efficiency but also provided various novel services to human. Whereas, as the partnership of human and intelligent agents become increasingly close, limitation of such technologies gradually emerged that while an independent AI could have great performance, in scenarios of human-intelligent agents collaboration, humans are always lacking trust in AI, while the working patterns of AI are unfriendly to cooperate with human operators. In order to realize the final target that AI provides perfect services for human being's life, researchers proposed variant measurements from distinctive aspects like Strong AI, Human-in-The-Loop (HiTL). Part of scientists believe that the higher intelligence AI has, the better service it could provide to human, thus researches on enhancing performances of deep neural network and developing neuromorphic computing were carried out [1, 2]. Other scientists took the status quo of AI development, insisting that human-centered application and human-computer collaboration middleware of AI programs is the most urgent, as well as the perpetual need of this intelligent age.

In 1967, Brodey et al. proposed the need of a new climate of man-machine interaction, in which humans and intelligent machines promote each other and optimize together [3]. They believed that with the large-scale application of machine intelligence in the future, evolutionary artifacts of human enhancement on control and perception are supposed to be developed to face the deeper human-computer interaction. As yet, the prescient perspective has come true and has had a profound impact on this era of artificial intelligence explosion. From AI or robot side, technologies like collaborative AI and adaptive robots are conceptualized [4-9]. A Collaborative AI system (CAIS) is defined as a kind of intelligent system cooperating with humans in a shared space aiming at achieving common goals, and similar to which, adaptive roots are autonomous robots that are able to learn from the environment and adapt to behaviors of human users accordingly. From the perspective of human operators and customers, researchers also proposed notions like Human-Centered System and Human-in-The-Loop (HiTL) [10]. Human-centered design is an approach to interactive systems development by focusing on the users' needs and requirements, which aims to make systems usable and useful by applying human factors/ergonomics, usability knowledge and techniques [11], while human-in-The-Loop is a workflow where the human can commit actions in the close loop of operation, a middle ground between full automation and pure manual processing. All those considerations of the relationship between humans and intelligent agents have profound significance, and to

2nd International Conference on Artificial Intelligence, Automation, and High-Performance Computing
(AIAHPC 2022), edited by Ligu Zhu, Proc. of SPIE Vol. 12348, 123482N
© 2022 SPIE · 0277-786X · doi: 10.1117/12.2641865

conceptualize it under a more general sight and taking the final target as collaboration, some scientists start to utilize Human-Machine [37-39]/Computer [40-42] Collaboration (HMC/HCC) to describe it.

	Peripheral Devices	Expected Outcomes	Evaluation Standards
HRC	Human sensing devices	Higher working efficiency	Safety, flexibility, efficiency
HAIC	Computer interaction interface	Enhanced intelligence	intelligence

Figure 1: Difference between Human-Robots Collaboration (HRC) and Human-AI Collaboration (HAIC)

Regarding the predicament that the developed artificial intelligence/robots cannot replace human workers in function, Human-Machine/Computer Collaboration is believed as a new solution to enhance the performance of the human-agent comprehensive system and improve the comfort level of human operators or users of intelligent applications. Whereas, papers relevant to this field are mostly too specific, which are only suitable to specific scenarios and particular processing stages. Besides, since tailored to distinctive applications, these methodologies are too versatile to be concluded as a general framework. Thus a systematic review and classification of such technology is significant, for the sake of constructing overall perception of it and finally building a standard HCC/HMC framework.

In this paper, the recent research progress of Human-Computer Collaboration and Human-Machine Cooperation is reviewed and discussed, from the distinction of various collaboration systems to the common prospect they all own. In section II, the collaborative systems are divided according to the cooperating objects, of which the main disparity is discussed. Section III illustrates the methodology of designing and operating Human-Computer/Machine Collaboration systems in the order of general process. Finally, In section IV, we finally conclude the limitation of existing Human-Computer/Machine Collaboration frameworks and look forward to its future development.

2 OBJECTS OF COLLABORATION

Classified by the objects that humans cooperate with, the main collaboration systems under the conception of Human-Machine or Computer Collaboration can be differentiated into two major parts, Human-Robots Collaboration (HRC) and Human-AI Collaboration (HAIC). Evidently, the HRC system is more concerned about the mechanical interaction between humans and robots, and the co-working space of such systems utilized in industrial environments is designed particularly from aspects of enhancing safety [12] as well as collaborating efficiency. While in terms of the Human-AI Collaborative system, the research is more focused on enhancing hybrid intelligence of collaborative systems on decision making or design of a specific entity. Neglecting the similarities between HRC and HAIC such as human intention recognition, the discrepancies on interaction devices, expected outcomes as well as key evaluation standards are illustrated in Fig. 1.

2.1 Human-Robots Collaboration

For interaction devices, the Human-Robots Collaboration system usually incorporates various periphery devices for interaction depending on the task requirement based on the mechanical architecture of the robots. For instance, wearable devices may be attached to recognize the end of human operations for the sake of protecting human workers [13], and robotic skin can be utilized to provide direct feedback of human co-workers' information [14]. Distinctive from Human-AI Collaboration, Human-Robots Collaboration systems focus more on the physical position or posture of the human collaborators, which is why their peripheral devices are so diversiform. Generally utilized in an industrial environment and social interaction, the expected outcomes of the HRC system are achieving higher working efficiency. And considering the substantiality of collaborating objects, the safety of operating such a system is very essential, especially in the hybrid assembled environments in industries. In [12], strategies to prevent collisions or minimize their consequences when they occur were reviewed. Through applied them, the final target of implementing HRC is increment the flexibility and working efficiency of the whole system as much as possible, while human operators' security is guaranteed.

2.2 Human-AI Collaboration

In terms of Human-AI Collaboration (HAIC) however, situations change for the reason that the collaborative objects, artificial intelligence, have no substance and even no form. Thus taking such AI as brains of intelligent agents, works on HAIC mostly concentrate on enhancing the hybrid intelligence of the system, instead of just completing cooperative jobs with human beings. Also because that those collaborative AI are usually independent of the outer physical world, except as otherwise required, the peripheral devices of the HAIC system for interaction and data input generally are human-computer interaction interfaces. However, while the types of interaction devices of HAIC are less than that of HRC from the aspects of interacting form, the high intelligence, which is the cooperative aim, requires the interactive facilities to have more capacity to recognize complex human intention. Affective computing is a promising approach to face the challenge that collaborative learning situations being less structured, though the construction of shared meaning is of the highest priority [15], thus some new studies tend to utilize Brain-Computer Interface (BCI) seeking for deeper abstract of human-side data.

3 PROCESSING AND OPERATION OF HUMAN-COMPUTER/MACHINE COLLABORATION

Though there are certain differences, Human-Computer Collaboration (HCC) and Human-Machine Collaboration (HMC) still have a common processing flow and operational measurements. Beginning from data gathering, decision support and operation loop, to adaptive reinforcement learning measurements and interaction interface, the generality of human cooperation with intelligent agents of HCC and HMC possibly can result in some universal collaboration frameworks, which are illustrated and discussed as followings.

3.1 Data Gathering

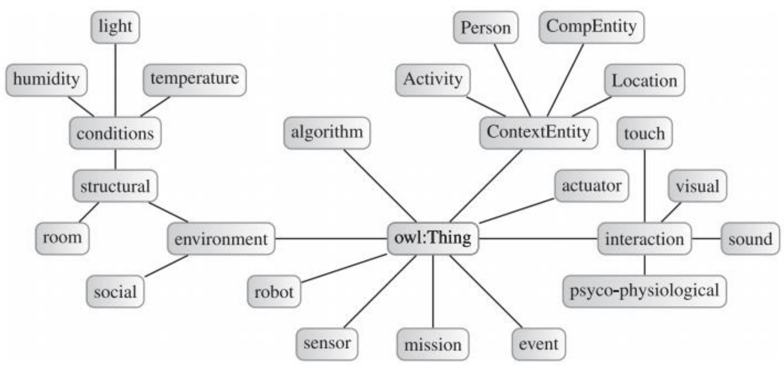

Fig. 2. Taxonomy for the entities in the human–system interaction information model of [18]

To begin with, data gathering related to collaboration and environment, context-based processing is an expectable option with prominent advantages, which supports a combination of environment information, as well as the context of interaction intention from humans [16, 17]. Through detecting contextual information about interacting intention, the author believed that those intention recognition mechanisms like gaze tracking and gesture analysis can provide important information for achieving the construction of a robot that can infer about user intention [17]. And in order to adapt to those collected contextual data including human's intention and interaction information, for the sake of supplying decision support in Human-Machine/Computer Collaboration system, an information model like [18] can also be constructed, which is context-aware and available for automatic discovery of features (i.e., algorithms). In the field of Human-in-the-Loop, where measurements of processing gathered data are similar to that of Human-Machine/Computer Collaboration, ways of extracting insights from data, building knowledge bases/graphs and fostering data/software communities also have great referential values [19].

3.2 Decision Making and Support

The decision models of the Human-machine/Computer Collaboration system can be classified into three types: human-primed decision making, machine/computer-primed decision-making and hybrid decision making. Human-primed decision making collaborative systems are those ones assisted by intelligent machines/computers but mainly manipulated by humans. For instance, intelligent assist devices (IAD) described by [20] are computer-controlled tools that enable production workers to lift, move and position payloads quickly, accurately, and safely. A system like [21, 14] which can assist operators in moving and lifting large payloads through utilizing cable angle sensors can be recognized as human-primed decision making collaborative, since where humans make all the decisions like where and when to move payloads, and the machine only plays an assistant role. And machine/computer-primed decision-making systems are usually human-assisted intelligent systems. Through adding participation of humans to the operation or decision making process of pure machine intelligent systems, [22] could realize the failure avoidance in robot manipulations, and in [23], the relationship of human-assisted decision making and machines' correlated observations were researched, thus we can understand when the human's decision can augment the machine's observation to yield improved decisions. Whereas, hybrid decision making in a pattern that is more adaptive to the cooperative action between human and their high-intelligent equal collaborator agents. A classic instance of hybrid decision-making is the cooperative system of human and self-driven cars. Wang etc. [24, 43] introduced an automated driving system in highway scenarios where the drivers can freely inject their prediction into the "intelligent Traffic Flow Assistant" (iTFA) system at any moment through interacting with a graphical user interface (GUI). As shown in Fig 3, the system first predicts the lane-changing behavior predict the behavior of each relevant traffic participant with probability ("Prediction Level"). After observing and predicting the surrounding traffic, the driver has the intention to intervene in the prediction of the iTFA system (can be recognized as the "machine/computer" in the HCC/HMC framework). In this scenario, the driver thinks that the truck wants to change to the left lane, and interact with the GUI through gazing on the vehicle (shown in red in Fig 3B). The iTFA then raises the probability of the truck changing lane to 1.0 ("Prediction Level"), and recalculates the optimized trajectories and their costs for each possible future composition as well as selects the trajectory that has the best combination of composition probability and cost ("Plan Level"). Finally, the iTFA adapts the vehicle control accordingly (e.g. slowing down), which indicates that a hybrid decision of lane-changing behavior in this model is made, through combining the original decision of the iTFA system and the human driver.

But how to provide support for decision-making procedures in Human-Machine/Computer Collaboration systems, to decide hybridization strategies and manage conflicts of joint actions of Human and intelligent agents, especially for those high-intelligent hybrid systems? In terms of decision support of the Human-Computer/Machine Collaboration system, one prime challenge is to understand human collaborators' intention and decision, which can be implicit, intuitive and complex thus augmenting difficulty to collect, conclude and process comparing with information from machine/computer side. Thus supported information about psychology such as emotional structure [25], and interaction

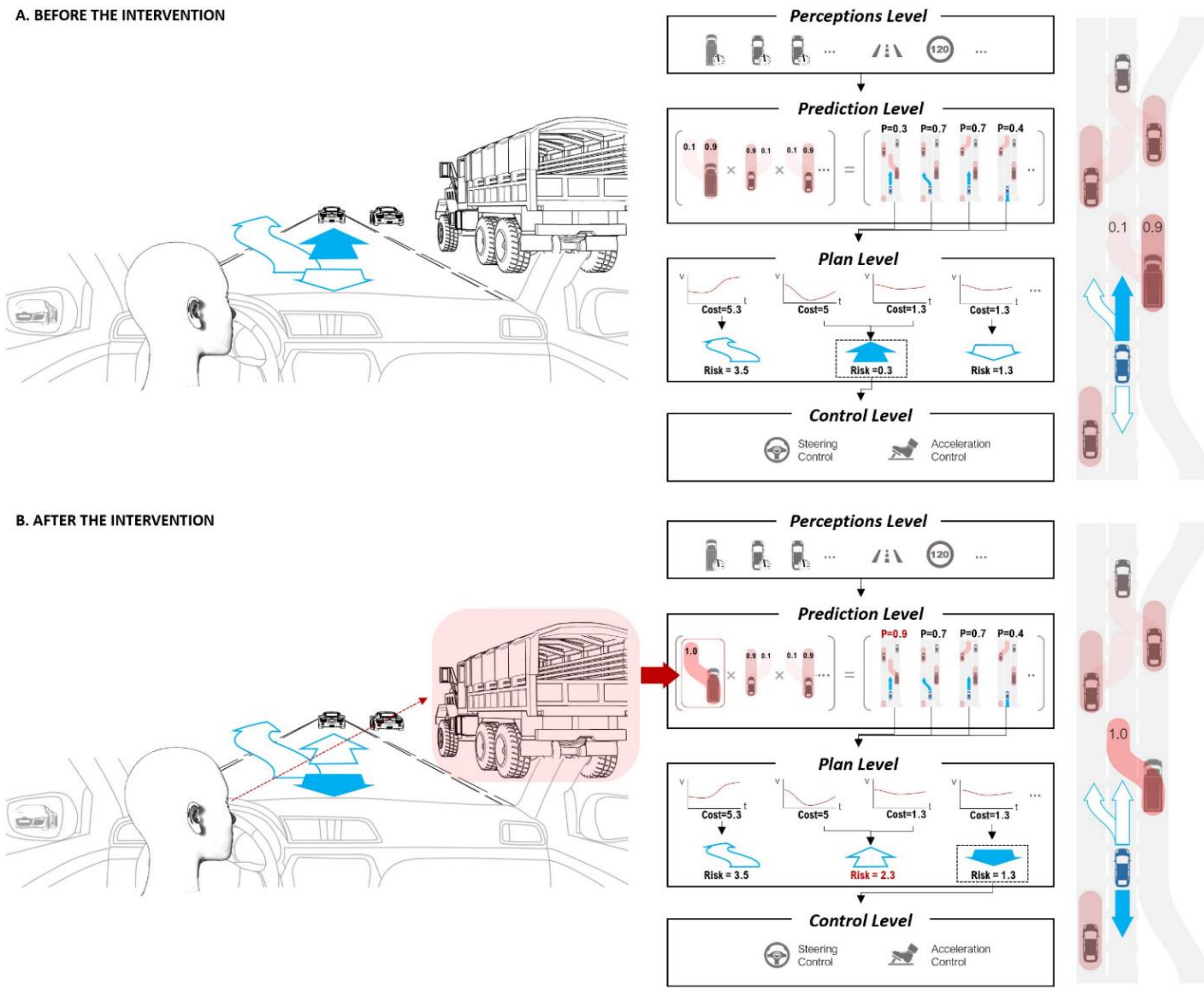

Fig. 3. Example of hybrid decision making: processing flow of iTFA (A) and its adaption with human driver (B). [24, 43]

pattern language [26] are applied in collaborative systems. And through describing the fussy intention of interaction, the hybrid decision of human and intelligent agents can be combined and compromised, finally obtaining the optimized decision of the whole cooperating processes. Research relative to information fusion systems based on human-machine collaboration has also been carried out like [27], which introduces an automatic information processing system in HCC/HMC.

Another challenge of the decision-making support of HCC/HMC system is determining the final hybridization strategy of the system decision. Many relative workers applied pre-decided and simple strategies to obtain final decisions, which attributes to the very specific scenario that their systems applied to. For instance, due to human's lack of trust in their cooperative intelligent agents, many collaborative decision-making systems directly adopt human decisions as the final decision, which is actually a fake hybrid decision. In order to obtain human-agent joint decisions, measurements can be utilized like constructing concept maps within decision models [28]. Concept maps graphically represent knowledge in the form of concept labels linked by a propositional relationship [29]. As the progress of concept maps in the field of HCC/HMC, effective dialog (e.g. connect, subscribe, alert, request) between human and intelligent agents is believed to be realized and optimized [28].

3.3 Hierarchical Model and Collaborative Loop

After obtaining decision support of the hybrid intelligent system of human-machine/computer collaboration, the operation loop or the collaborative framework should be designed. Meanwhile, the processes and the interactions between human and intelligent agents should be evaluated. In [30], under the background of Intelligent Manufacturing System (IMS), a collaboration between the human operator and the intelligent manufacturing control system is realized through an information exchanging model containing strategic, tactical, or operational levels. To be specific, the operational specification is in short term and directly connected to commands, while the tactical specification is at a higher hierarchical level in order to achieve intermediate objectives. And the strategic level is the highest decisional level, utilized to implement intermediate objectives planning. Among those levels of the same side (i.e. from human operators or the system side), decisions and requests are exchanged between every two levels, and the three specification levels from different sides also exchange information with each other. At the same time, there also exists a data flow to the behavioral model of each side from the three specification levels of that side and integration of mutual observation (through the cooperation process), for the purpose of investigating the limited reliability of both sides. Through designing such kind of operation loop and collaboration model, HCC/HMC systems can be constructed and analyzed.

3.4 Reinforcement Learning Measurement

In the operation of the Human-Machine/Computer Collaboration system, reinforcement learning measurements are applied for the sake of achieving better hybrid decisions in decision-making procedures or to accelerate adaptive training of intelligent agents to humans. To begin with hybrid decision-making optimization, based on an information model backing the Human-Machine/Computer Collaboration system, several reinforcement learning measurements can be taken [31]. POMDP (Partially Observable Markov Decision Process), which is an ideal model for sequential decision making in a dynamic uncertain environment, enables optimization of making decisions in HCC/HMC system when combined with context and environment information. For instance, in [32], a trust-POMDP is designed to infer human collaborators' trust and reason about the effect of its actions on human trust, and finally choose actions that maximize system performance over the long term. Another approach to optimize collaborative results is to optimize the collaborating processes, such as [33] applied on Human-Robot Collaboration artificial agents supporting mutual adaptation and learning, being able to accelerate collaborative learning of the system while minimizing the total training time. In addition, considering that the Human-Machine/Computer Collaboration is multi-agent collaboration in nature, strategies in traditional multi-agent reinforcement learning such as value-centered and policy-centered approaches can also be considered as the inspiration of HCC/HMC system development.

3.5 Interaction Interface (HCI/HMI)

In addition, Human-Computer/Machine Interaction and Interface (HCI/HMI) [35] is also an inevitable part of Human-Computer/Machine Cooperation, as the interaction of high effectiveness and adaptability is the base of the preeminent collaborating system. Tailored to the contextual information and types of human intention data that are required, various interaction interface is utilized in HCC/HMC systems. For the interaction absent of human intention, [34] introduces a multimodel perception interface for humans in the Human-Robot Collaboration scenario, by which the robots' active motion is enabled through high-speed actuators and high-speed sensory feedback, by means of exchanging information of human visual and haptic perception. For interaction including human intention, on the other hand, interface like Brain-Computer Interface (BCI), gaze detecting camera and motion capture device has the potential to contribute deeper insight of human's intuitive and psychological intention, promoting the development of existing Human Machine/Computer Collaboration or human-in-the-loop system on the aspects of adaptability and humanization.

4 CONCLUSION AND DISCUSSION

The rapid development of artificial intelligence and robotics catalyzes research in the field of Human-Machine/Computer Collaboration, Adaptive AI and Human-in-The-Loop et al., where both the potential and limitations of intelligent agents are studied and human's intelligence is introduced to enhance the performance and intelligence of the whole cooperative system. Research on this cross-field area has made much progress, and adaptive hybrid intelligence human-machine systems were realized, bringing hope and bright prospects for industries about further improvement of productivity and optimization of people's lives. However, limitations still exist that most of the HMC/HCC framework is too specific to be extended applied to other scenarios, or too general to be realized in one specific environment. Besides, research on human intention detection and recognition is still immature, requiring continuing study based on newly developed devices or technology like Brain-Computer Interface (BCI) and affective computing.

One key issue in HMC/HCC system that should be noticed is the trust problem of human to intelligent agents. [36] shows that when cooperating with partners that are unknown to be human or AI, humans tended to lack confidence and trust in AI, reckoning that AI is natively less intelligent, less likeable and less creative. In the human-AI context, these social perceptions did not impact the collaboration outcomes (i.e. game win/loss), while in more complex scenarios such as encountering an obstacle when driving a self-driven car, would humans be able to avoid the influence of lack of trust to the car and conduct rational decision if the self-driven car control system is able to make relatively good decision in an emergency? The consequences of lack of trust to intelligent agents still need further research, and approaches that enhance trust level may be required such as making agent acting more like human and performing emotions.

Although still having much future work to do, with innovation in HMC/HCC mechanism, the machine/computer can be utilized with higher efficiency when co-working with human operators, with expectable higher intelligence and greater performance. It is also possible for intelligent agents to present fake emotion patterns when cooperating with human, as long as the HCC/HMC system is designed delicately.

REFERENCES

[1] M. Maher, S. Deweerth, M. Mahowald, and C. Mead, “Implementing neural architectures using analog vlsi circuits,” IEEE Transactions on Circuits and Systems, vol. 36, no. 5, pp. 643–652, 1989.

[2] C. Mead, “Neuromorphic electronic systems,” Proceedings of the IEEE, vol. 78, no. 10, pp. 1629–1636, 1990.

[3] W. M. Brodey and N. Lindgren, “Human enhancement through evolutionary technology,” IEEE Spectrum, vol. 4, no. 9, pp. 87–97, 1967.

[4] M. Camilli et al., "Towards Risk Modeling for Collaborative AI," 2021 IEEE/ACM 1st Workshop on AI Engineering - Software Engineering for AI (WAIN), 2021, pp. 51-54, doi: 10.1109/WAIN52551.2021.00014.

[5] S. Nicholls, S. Cunningham, and R. Picking, “Collaborative artificial intelligence in music production.” New York, NY, USA: Association for Computing Machinery, 2018. [Online]. Available: https://doi.org/10.1145/3243274.3243311

[6] D. Francois, D. Polani, and K. Dautenhahn, “Towards socially adaptive robots: A novel method for real time recognition of human-robot interaction styles,” in Humanoids 2008 - 8th IEEE-RAS International Conference on Humanoid Robots, 2008, pp. 353–359.

[7] C. Torrey, A. Powers, S. R. Fussell, and S. Kiesler, “Exploring adaptive dialogue based on a robot’s awareness of human gaze and task progress,” in 2007 2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2007, pp. 247–254.

[8] A. Xu and G. Dudek, “Towards efficient collaborations with trust-seeking adaptive robots.” New York, NY, USA: Association for Computing Machinery, 2015. [Online]. Available: https://doi.org/10.1145/2701973.2702711

[9] M. I. Ahmad, O. Mubin, and J. Orlando, “Understanding behaviours and roles for social and adaptive robots in education: Teacher’s perspective.” New York, NY, USA: Association for Computing Machinery, 2016. [Online]. Available: https://doi.org/10.1145/2974804.2974829

[10] J. Nelles, S. Kuz, A. Mertens, and C. M. Schlick, “Human-centered design of assistance systems for production planning and control: The role of the human in industry 4.0,” in 2016 IEEE International Conference on Industrial Technology (ICIT), 2016, pp. 2099–2104.

[11] ISO 9241-210:2019(en) Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems.

[12] S. Robla-Gomez, V. M. Becerra, J. R. Llata, E. Gonz ´ alez-Sarabia, ´ C. Torre-Ferrero, and J. Perez-Oria, “Working together: A review on safe ´ human-robot collaboration in industrial environments,” IEEE Access, vol. 5, pp. 26 754–26 773, 2017.

[13] M. C¸ oban and G. Gelen, “Realization of human-robot collaboration in hybrid assembly systems by using wearable technology,” in 2018 6th International Conference on Control Engineering Information Technology (CEIT), 2018, pp. 1–6.

[14] U. E. Ogenyi, J. Liu, C. Yang, Z. Ju, and H. Liu, “Physical human–robot collaboration: Robotic systems, learning methods, collaborative strategies, sensors, and actuators,” IEEE Transactions on Cybernetics, vol. 51, no. 4, pp. 1888–1901, 2021

[15] A. Makhkamova, P. Ziegler, and D. Werth, “Augmenting collaboration with invisible data: Brain-computer interface for emotional awareness,” in Proceedings of Mensch Und Computer 2019, ser. MuC’19. New York, NY, USA: Association for Computing Machinery, 2019, p. 783–787. [Online]. Available: https://doi.org/10.1145/3340764.3344908

[16] A. Sharath Chandra, M. Plasch, C. Eitzinger, and B. Rinner, "Context enhanced multi object tracker for human robot collaboration," in Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction, ser. HRI '17. New York, NY, USA: Association for Computing Machinery, 2017, p. 61–62. [Online]. Available: https://doi.org/10.1145/3029798.3038406

[17] J. Quintas, L. Almeida, M. Brito, G. Quintela, P. Menezes, and J. Dias, "Context-based understanding of interaction intentions," in 2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication, 2012, pp. 515–520.

[18] J. Quintas, P. Menezes, and J. Dias, "Information model and architecture specification for context awareness interaction decision support in cyber-physical human–machine systems," IEEE Transactions on Human-Machine Systems, vol. 47, no. 3, pp. 323–331, 2017.

[19] A. Doan, "Human-in-the-loop data analysis: A personal perspective," in Proceedings of the Workshop on Human-In-the-Loop Data Analytics, ser. HILDA'18. New York, NY, USA: Association for Computing Machinery, 2018. [Online]. Available: https://doi.org/10.1145/3209900. 3209913

[20] J. Colgate, M. Peshkin, and S. Klostermeyer, "Intelligent assist devices in industrial applications: a review," in Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003) (Cat. No.03CH37453), vol. 3, 2003, pp. 2516–2521 vol.3.

[21] A. Campeau-Lecours, S. Foucault, T. Laliberte, B. Mayer-St-Onge, and ´ C. Gosselin, "A cable-suspended intelligent crane assist device for the intuitive manipulation of large payloads," IEEE/ASME Transactions on Mechatronics, vol. 21, no. 4, pp. 2073–2084, 2016.

[22] B. Song, Y. Peng, R. Luo, and R. Liu, "An attention transfer model for human-assisted failure avoidance in robot manipulations," in 2021 IEEE 17th International Conference on Automation Science and Engineering (CASE), 2021, pp. 2293–2298.

[23] N. Sriranga, B. Geng, and P. K. Varshney, "On human assisted decision making for machines using correlated observations," in 2020 54th Asilomar Conference on Signals, Systems, and Computers, 2020, pp. 1502–1506.

[24] C. Wang, T. H. Weisswange, and M. Kruger, "Designing for prediction-level collaboration between a human driver and an automated driving system," in 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI '21 Adjunct. New York, NY, USA: Association for Computing Machinery, 2021, p. 213–216. [Online]. Available: https://doi.org/10.1145/3473682.3481873

[25] J. Prado, C. Simpl´ıcio, N. Lori, and J. Dias, "Visuo-auditory multimodal emotional structure to improve human-robot-interaction," I. J. Social Robotics, vol. 4, pp. 29–51, 11 2012.

[26] M. Baltzer, D. Lopez, and F. Flemisch, "Towards an interaction pattern ´ language for human machine cooperation and cooperative movement," Cognition, Technology Work, vol. 21, 11 2019.

[27] Z. Tang and A. Zhang, "Human-machine cooperation for control and decision in information fusion system," in 2008 Chinese Control and Decision Conference, 2008, pp. 1250–1254.

[28] T. Hanratty, R. J. Hammell II, J. Yen, and X. Fan, "Utilizing concept maps to improve human-agent collaboration within a recognition-primed decision model," in 2007 IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT'07), 2007, pp. 116–120.

[29] M. James, P. Dudley, A. Fox, P. Carmichael, B. Marshall, R. Procter, P. Black, D. Frost, J. Macbeath, and D. Pedder, Learning how to learn. Learning how to learn, 1984.

[30] M. P. Pacaux-Lemoine, D. Trentesaux, G. Z. Rey, and P. Millot, "Designing intelligent manufacturing systems through human-machine cooperation principles: A human-centered approach," Computers Industrial Engineering, vol. 111, no. sep., pp. 581–595, 2017.

[31] J. Quintas, P. Menezes, and J. Dias, "Information model and architecture specification for context awareness interaction decision support in cyber-physical human–machine systems," IEEE Transactions on Human-Machine Systems, vol. 47, no. 3, pp. 323–331, 2017.

[32] M. Chen, S. Nikolaidis, H. Soh, D. Hsu, and S. Srinivasa, "Trust-aware decision making for human-robot collaboration: Model learning and planning," J. Hum.-Robot Interact., vol. 9, no. 2, Jan. 2020. [Online]. Available: https://doi.org/10.1145/3359616

[33] F. Lygerakis, M. Dagioglou, and V. Karkaletsis, "Accelerating human-agent collaborative reinforcement learning," in The 14th PErvasive Technologies Related to Assistive Environments Conference, ser. PETRA 2021. New York, NY, USA: Association for Computing Machinery, 2021, p. 90–92. [Online]. Available: https://doi.org/10.1145/3453892. 3454004

[34] S. Huang, M. Ishikawa, and Y. Yamakawa, "Human-robot interaction and collaborative manipulation with multimodal perception interface for human," in Proceedings of the 7th International Conference on Human-Agent

Interaction, ser. HAI ’19. New York, NY, USA: Association for Computing Machinery, 2019, p. 289–291. [Online]. Available: https://doi.org/10.1145/3349537.3352795

[35] S. Mahmud, X. Lin, and J.-H. Kim, “Interface for human machine interaction for assistant devices: A review,” in 2020 10th Annual Computing and Communication Workshop and Conference (CCWC), 2020, pp. 0768–0773.

[36] Z. Ashktorab, Q. V. Liao, C. Dugan, J. Johnson, Q. Pan, W. Zhang, S. Kumaravel, and M. Campbell, “Human-ai collaboration in a cooperative game setting: Measuring social perception and outcomes,” vol. 4, no. CSCW2, 2020. [Online]. Available: https: //doi.org/10.1145/341516

[37] S. Ravindranath, R. Baburaj, V. N. Balasubramanian, N. Namburu, S. Gujar, and C. V. Jawahar, “Human-machine collaboration for face recognition,” in Proceedings of the 7th ACM IKDD CoDS and 25th COMAD, ser. CoDS COMAD 2020. New York, NY, USA: Association for Computing Machinery, 2020, p. 10–18. [Online]. Available: https://doi.org/10.1145/3371158.3371160

[38] E. Boschee, S. Miller, L. Ramshaw, and R. Weischedel, “Rapid annotation through human-machine collaboration,” in Proceedings of the Second International Conference on Human Language Technology Research, ser. HLT ’02. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2002, p. 187–189.

[39] S. Jhaver, I. Birman, E. Gilbert, and A. Bruckman, “Human-machine collaboration for content regulation: The case of reddit automoderator,” ACM Trans. Comput.-Hum. Interact., vol. 26, no. 5, Jul. 2019. [Online]. Available: https://doi.org/10.1145/3338243

[40] B. G. Woolley and K. O. Stanley, “A novel human-computer collaboration: Combining novelty search with interactive evolution,” in Proceedings of the 2014 Annual Conference on Genetic and Evolutionary Computation, ser. GECCO ’14. New York, NY, USA: Association for Computing Machinery, 2014, p. 233–240. [Online]. Available: https://doi.org/10.1145/2576768.2598353

[41] M. Lowe and S. Risi, “Accelerating the evolution of cognitive behaviors ¨ through human-computer collaboration,” in Proceedings of the Genetic and Evolutionary Computation Conference 2016, ser. GECCO ’16. New York, NY, USA: Association for Computing Machinery, 2016, p. 133–140. [Online]. Available: https://doi.org/10.1145/2908812.2908928

[42] A. Chortaras, A. Christaki, N. Drosopoulos, E. Kaldeli, M. Ralli, A. Sofou, A. Stabenau, G. Stamou, and V. Tzouvaras, “With: Human-computer collaboration for data annotation and enrichment,” in Companion Proceedings of the The Web Conference 2018, ser. WWW ’18. Republic and Canton of Geneva, CHE: International World Wide Web Conferences Steering Committee, 2018, p. 1117–1125. [Online]. Available: https://doi.org/10.1145/3184558.3191544

[43] C. Wang, T. H. Weisswange, M. Kruger, and C. B. Wiebel-Herboth, ¨ “Human-vehicle cooperation on prediction-level: Enhancing automated driving with human foresight,” CoRR, vol. abs/2104.03019, 2021. [Online]. Available: https://arxiv.org/abs/2104.03019