STAMPER: Human-machine Integrated Drumming

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Figure 1: Left, Center: a STAMPER installation; Right: Detecting the drummer's motions on OpenPose.

ABSTRACT

STAMPER enables drummers to generate innovative performances by controlling multiple bass drums. STAMPER consists of several "Actuated Pedals (APs)," bass drum pedals embedded with an EC motor, paired with bass drums, and a machine vision system. The APs are used both as input and output. One AP in input mode senses the position of the pedal being used by the drummer. Other APs in actuated mode respond to the input mode AP's motion. Machine vision is used to monitor the drummer's movements to control the behavior of the actuated APs. In this paper, we describe the current prototype of STAMPER and what kind of drum performances can be achieved with the system by reporting a study conducted with an experienced drummer.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

Drums, Human Augmentation, Human-machine Integration, New Interfaces for Musical Expression, Digital Musical Instruments

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1 INTRODUCTION

Drumming is a musical performance using all four human limbs. The drum set is a manual machine designed for the structure of the human body (four limbs), with which the drummer creates various sound expressions. The drummer beats the drums with both arms, while the right leg pedals beat the bass drum and the left foot operates the high-hat. This can be interpreted as an example of a performance achieved through *human-machine integration*.

There are currently several emerging research domains studying integrated and cooperative movement between humans and machines in the HCI community. These are human augmentation (e.g., [7, 14, 15]), human-computer *integration* [3, 13], and human-machine mutual actuation [10, 11]. A common feature of these domains is that they focus on designing and implementing systems for sensing and assisting human movement through computer operated machinery. Previous works have attempted to develop new sports [7, 8], support physical motion [5, 10, 11], generate supernumerary limbs [14, 15, 17], and expand musical expression [2, 6]. We believe that applying these technologies to musical instruments can enable musicians to create new and attractive musical expressions that were previously impossible.

With this background in mind, we invented a human-machine integrated drumming system called "STAMPER" which enables drummers to explore and generate novel drum expressions which cannot be achieved with traditional drum sets.[1] STAMPER consists of a generic drum set with a set of modified bass drum pedals called "Actuated Pedals" (APs: Figure 2), additional bass drums, and a machine vision system that monitors the drummer's motions (Figure 1 Right) and reflects them on controlling APs for the additional bass drums. The APs work together to allow the drummer to play multiple bass drums at the same time. One AP senses the drummer's kicking of the bass drum while the others actively kick the additional drums. The machine vision system allows the drummer to freely control how the bass drums play by opening and closing the knees to control parameters such as 1) counts: how many times the additional bass drums beat and 2) delay time: how long the repeated beats are delayed. Different from playing with the beat of a computer-generated rhythm, a drummer playing STAMPER *is in control* of the computer-mediated machine and is free to investigate and invent new rhythms and unique drum expressions while keeping a sense of agency.

Artistic expressions generated by drummers using STAMPER can be defined as computer/machine mediated music performances [12, 16] as well as human-machine cooperative music performances [1, 9]. In the professional music scene, it is known that Rick Allen (hard rock band Def Leppard's drummer) who lost one of his arms in an accident plays a specially made drum set integrating analog and electric drums. In a similar vein, there is research on robotic drumming using a machine-made arm [6]. The STAMPER project has been conducted to design human-machine integrated musical performances, synthesizing the multiple research areas of technology-enabled musical performances and the human augmentations.

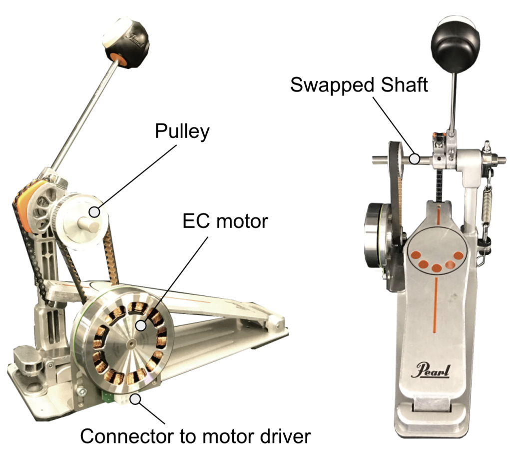

Figure 2: Components of Actuated Pedal

2 THE STAMPER SYSTEM

2.1 Design Rationale

As mentioned, STAMPER, as a human-machine integrated drumming system, consists of an integrated interactive system and a drummer using unique ways to control this new musical instrument. While the hardware part (the APs) was logically designed and implemented (described below), we iteratively conducted trials and errors to investigate how a drummer could control multiple APs. Before deciding on the way of opening and closing the knees, there were other ideas, such as preparing special drumsticks attached with a button to control the APs, sensing the tilt of the upper body during drumming, controlling the APs by raising and lowering the elbows, etc. We prepared rapid prototypes for these ideas and tested them. Finally, we decided to focus on the knee movements that do not interfere with the drumming. After preparing the initial prototype, we invited a drummer and collaboratively updated the system such as the accuracy of sensing the drummer's movements, and the usability as a musical instrument. For example, we found out the swinging of the drummer's upper body center during drumming and this hindered sensing the opening and closing of the knees. To address this, we attached an AR marker (Figure. 6 C) to the drum chair to detect its rotation and reflected the tilt of the drummer's upper body in detecting the knee movements. Our work in progress describes the current version of the STAMPER system and presents the possibility of the construction of future human-machine integrated drum expressions.

2.2 Actuated Pedal (AP)

The AP (Figure 2) is a pedal device with an embedded EC motor. It can be used as both an input interface to sense the drummer's pedaling and a computer controlled actuator. When in input mode, the drummer can use the AP in the same way they might use a normal drum pedal, while it senses the drummer's pedaling via the EC motor's encoder. When in actuated mode, the AP can be actuated through the EC motor. As such, the AP can be controlled both manually and via a computer. The STAMPER system requires one input mode AP and one or more actuated mode APs.

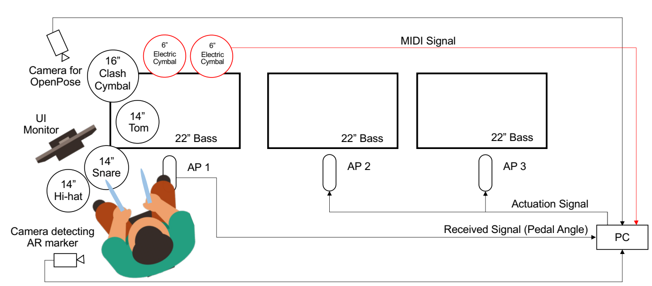

Figure 3: Overview of STAMPER: Three APs are placed on each bass drum. A camera set overhead observes the drummer's movements on OpenPose. Another camera detects an AR marker put on the swivel drum stool to detect its rotation.

[1]Please watch the introductory video for the STAMPER system at https://www.youtube.com/watch?v=4y3OBM9zNIQ.

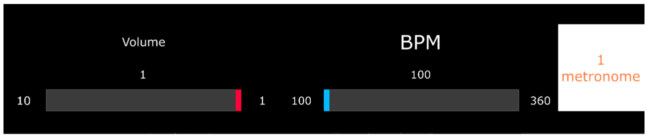

Figure 4: UI in Metronome Mode

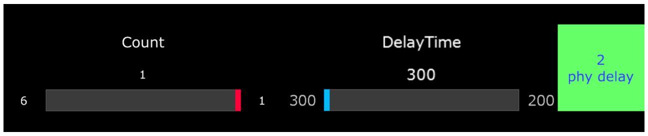

Figure 5: UI in Delay Mode

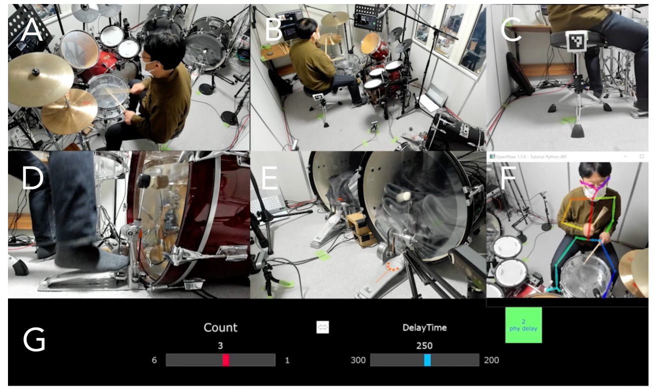

Figure 6: A screen captured image taken from the videos: The Drummer Plays STAMPER (screen capture of the attached videos). A&B: Overview of the system. C: An AR Marker detecting the rotation of the drum chair. D: AP1 in input mode. E: AP2&3: in actuated mode. F: Detecting the drummer's motions on OpenPose. G: UI the drummer is seeing.

2.3 Modes and Functions

2.3.1 Play Modes. STAMPER allows the drummer to choose two modes to manipulate AP2 and 3. The two modes are called Metronome and Delay. Each mode has parameters that can be adjusted by the drummer, and the drummer can manipulate the parameters by moving his knees during the performance. Each mode is described in detail below.

1) *Metronome Mode:* AP2 and AP3 alternately hit the bass drums with a constant rhythm. In this mode, the drummer can adjust the bpm at which AP2 and AP3 are hit. One of the roles of the drummer in a band is to provide the band members with a constant tempo. We created this mode in the hope that, by having a machine replace this role, the drummer will not have to keep the tempo and will be able to play with more variety.
2) *Delay Mode:* AP2 and AP3 hit the bass drums at a slight delay after the drummer hits the bass drum. In this mode, the delay time of AP2 and AP3 can be adjusted by opening and closing the knees. By reproducing the delay effect, which is widely used with guitars and bass guitars, with the APs, we aimed to allow the drummer to express a single sound more profoundly and create a rhythmic effect using overlapping sounds.

2.4 Playing STAMPER

When using the STAMPER system (Figure 3), in addition to performing as they might usually, the drummer controls the behavior of multiple APs by moving their knees. A web camera set in front of the drummer monitors their body movement, and their knee positions are used to determine the behavior of the APs. In Metronome Mode, the right knee is assigned to BPM and the left knee is assigned to the volume, as shown in Figure 4. In Delay Mode, the right knee is assigned to delay time and the left knee is assigned to the number of repetitions (delay count), as shown in Figure 5. While drumming, the drummer can see the status of each parameter on a monitor. By striking the electric cymbals, they can lock the value of each parameter and may lock and unlock the parameters if needed. One may note, however, that drummers may achieve more groovy drumming using STAMPER by learning how to move the knees precisely and independently.

3 DRUM EXPRESSIONS WITH STAMPER

We invited an experienced drummer to play the STAMPER system and observed what kind of drumming expressions he created. In our design process, we sometimes invited him to test and play with our earlier prototypes. He had already adopted STAMPER well throughout the previous practices over five hours, so this section reports a set of drum expressions with STAMPER by a proficient musician instead of a beginner. This submission has videos [V1-4] attached as supplemental materials (Figure. 6).[2] Please refer to each video clip when reading the descriptions below.

3.1 Playing in Metronome Mode

He first selected Metronome Mode and played 8 beats to see how the system worked. During this time, he did not move his left knee but only slightly moved his right knee to control the BPM, trying to match his rhythm of playing. Occasionally, he stopped beating the hi-hat and snare and played only the bass drum to check the speed of AP2's and AP3's beats.

In Metronome Mode, an interesting performance was observed in which he beat the bass drum with a subtle shift from the timing of AP2 and AP3 [V1]. During this performance, he locked the parameters to precisely understand a unique rhythm happening since the blurring of AP2's and AP3's tapping timing was reduced. It seemed that he was trying to create a groovy rhythm with slight shifts between human-made beats and machine-mediated ones.

It happened that the rhythm was shuffled [V2]. This was unintentionally caused by a phenomenon that AP2 and AP3 were not evenly spaced, and only AP3's beats were delayed due to a slight difference in hardware maintenance. Interestingly, he not only accidentally encountered the shuffled rhythms but also sometimes intentionally changed the rhythm by subtly delaying his own drumming to delay from the APs.

[2]The supplementary videos can be found on this YouTube playlist: https://youtube.com/playlist?list=PLUe7uE8VX9nmoGNP96AROYmi19iglTil_.

3.2 Playing in Delay Mode

Next, he selected Delay Mode and checked the system's response. First, he beat the bass drum only. Once he recognized a consistent response, he added the beats of the hi-hat and snare. He was carefully testing the system's operation by subtly adjusting the opening of his knees. Occasionally, he locked the parameter and repeated the same pattern of beats.

In Delay Mode, a scene was observed in which he intentionally generated a 3-beat with the system [V3]. Although there is a slight delay between AP2 and AP3, the system's response was consistent enough and he was able to play a 3-beat on a variety of parameters.

In an interesting performance, he noticed that the AP does not detect weak pedaling, so intentionally combined weak and strong pedaling to make a new sound [V4]. In Delay Mode, AP1 in the input mode senses the rotation angle of the embedded EC motor (Figure 2) when the drummer is pedaling the bass drum. He was able to mix weak pedaling not to beat AP2 and AP3 with strong pedaling to beat them, creating a more complex rhythmic performance.

3.3 Feedback from the Drummer

After he had played STAMPER for one hour, we interviewed him for his impressions. The interview was semi-structured, and three general questions were prepared in advance concerning; 1) overall impression and evaluation, 2) control of knees opening and closing, and 3) the range of the parameter settings.

3.3.1 Overall Impression and Evaluation. "I enjoyed the system as a new instrument. I really liked the gap between the strength and rhythm of AP2 and AP3. Some people might not want this gap, as a less maintained system. But I thought the movements were musical. I felt like they knew the rhythm and groove despite the machines! It was fun to be able to beat in 3 beats. It was very good, very stable. I could see the potential for an interesting level."

We were a little bit worried about the completeness of the current system. In fact, as he said, there was a subtle difference in the beater volume between AP2 and AP3. This was probably caused by differences in the adjustment of the beater angle, beater length, and spring strength between them. Since AP2 and AP3 were originally intended to have the same volume settings, this phenomenon can be viewed as a malfunction. But surprisingly, he interpreted these issues as if humans play the instrument and make natural rhythmic grooves, and totally enjoyed the machine-mediated drumming.

3.3.2 Control of Knees Opening and Closing. "I felt like I could do it because the system response was stable (better than before). I was able to understand how much I needed to open the knee to get the desired reaction. However, I felt that the left knee was more unstable than the right knee. I need more practice."

Operating the parameters by the knees is one of the most unique features of the STAMPER system. Though we do not describe the detailed design process in this paper, we iteratively tested different patterns of control methods. Drummers have to use all limbs when drumming. Thus, we needed to develop a way of controlling parameters without using the limbs. Though we did not conduct formal usability testing with many drummers, he showed an amazing performance with highly unique drumming.

3.3.3 The Range of the Parameter Settings. "The left knee tends to shake easily, and I thought that a smaller range might be acceptable. The right knee is OK in the current setting, but I would like to try a narrower setting. Depending on the value of the parameters, I do not think it is necessary to make it wider. However, I think it is better to keep the function of being able to make it wider. It might be easier to handle a subtle change in groove rather than a big change in tempo.

It is actually difficult for drummers to control the knees accurately and there is a limitation to moving the knees during drumming. As such, throughout the collaborative process with drummers, we were iteratively testing the range of parameters and trying to figure out the best settings. We found issues and reflected them in the subsequent updates.

3.3.4 Others. "Though AP3 seemed to be a little faster than AP2, the rhythmic blurring was regular and consistent. I personally enjoyed the blurring and gaps in the system but felt that it is not suitable for two-bass pedal performances such as in rock and metal music. These need to be in perfect rhythm. The timing of AP2 and AP3 is slightly off, so it is not possible to hit accurately in rapid succession. It would be nice if the drummer could adjust this discrepancy."

While we encountered how he generated new rhythms in this study, we also noticed the limitations of our current STAMPER system as of now. To revise the system to support wider genres of music, we need to refine the system's accuracy and add customizable functions to fit the different requirements of drummers.

4 CONCLUSION

This paper introduced STAMPER, a new instrument to explore human-machine integrated drumming performances. Surprisingly, the drummer we invited adapted to playing the new instrument quickly, passionately sought a new technique for drumming, and sometimes produced highly attractive sounds no one has ever heard before. We believe our findings will contribute to designing human-machine integrated performances, not only for music but for other artistic performances, such as performing arts, and sports, and other everyday activities.

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REFERENCES

[1] Scott Barton, Ethan Prihar, and Paulo Carvalho. 2017. Cyther: a human-playable, self-tuning robotic zither.. In *NIME*. 319–324.
[2] Mason Bretan, Deepak Gopinath, Philip Mullins, and Gil Weinberg. 2016. A robotic prosthesis for an amputee drummer. *arXiv preprint arXiv:1612.04391* (2016).
[3] Valdemar Danry, Pat Pataranutaporn, Adam Haar Horowitz, Paul Strohmeier, Josh Andres, Rakesh Patibanda, Zhuying Li, Takuto Nakamura, Jun Nishida, Pedro Lopes, Felipe León, Andrea Stevenson Won, Dag Svanæs, Florian Floyd Mueller, Pattie Maes, Sang-won Leigh, and Nathan Semertzidis. 2021. Do Cyborgs Dream of Electric Limbs? Experiential Factors in Human-Computer Integration Design and Evaluation. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, Article 123, 6 pages. https://doi.org/10.1145/3411763.3441355
[4] Masahiko Inami, Daisuke Uriu, Zendai Kashino, Shigeo Yoshida, Hiroto Saito, Azumi Maekawa, and Michiteru Kitazaki. 2022. Cyborgs, Human Augmentation,

Cybernetics, and JIZAI Body. In *Augmented Humans 2022* (Kashiwa, Chiba, Japan) *(AHs 2022)*. Association for Computing Machinery, New York, NY, USA, 230–242. https://doi.org/10.1145/3519391.3519401

[5] Shunichi Kasahara, Jun Nishida, and Pedro Lopes. 2019. Preemptive Action: Accelerating Human Reaction Using Electrical Muscle Stimulation Without Compromising Agency. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3290605.3300873

[6] Roozbeh Khodambashi, Gil Weinberg, William Singhose, Shima Rishmawi, Varun Murali, and Euisun Kim. 2016. User oriented assessment of vibration suppression by command shaping in a supernumerary wearable robotic arm. In *2016 IEEE-RAS 16th International Conference on Humanoid Robots (Humanoids)*. IEEE, 1067–1072.

[7] Hideki Koike, Jun Rekimoto, Junichi Ushiba, Shinichi Furuya, and Asa Ito. 2021. Human Augmentation for Skill Acquisition and Skill Transfer. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, Article 93, 3 pages. https://doi.org/10.1145/3411763.3441354

[8] Kai Kunze, Kouta Minamizawa, Stephan Lukosch, Masahiko Inami, and Jun Rekimoto. 2017. Superhuman Sports: Applying Human Augmentation to Physical Exercise. *IEEE Pervasive Computing* 16, 2 (March 2017), 14–17. https://doi.org/10.1109/MPRV.2017.35

[9] Sang-won Leigh and Jeonghyun (Jonna) Lee. 2021. A Study on Learning Advanced Skills on Co-Playable Robotic Instruments. *NIME 2021*. https://doi.org/10.21428/92fbeb44.002be215 https://nime.pubpub.org/pub/h5dqsvpm.

[10] Azumi Maekawa, Seito Matsubara, Sohei Wakisaka, Daisuke Uriu, Atsushi Hiyama, and Masahiko Inami. 2020. Dynamic Motor Skill Synthesis with Human-Machine Mutual Actuation. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376705

[11] Azumi Maekawa, Hiroto Saito, Daisuke Uriu, Shunichi Kasahara, and Masahiko Inami. 2022. Machine-Mediated Teaming: Mixture of Human and Machine in Physical Gaming Experience. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 618, 11 pages. https://doi.org/10.1145/3491102.3517555

[12] Andrew McPherson. 2010. The magnetic resonator piano: Electronic augmentation of an acoustic grand piano. *Journal of New Music Research* 39, 3 (2010), 189–202.

[13] Florian Floyd Mueller, Pedro Lopes, Paul Strohmeier, Wendy Ju, Caitlyn Seim, Martin Weigel, Suranga Nanayakkara, Marianna Obrist, Zhuying Li, Joseph Delfa, Jun Nishida, Elizabeth M. Gerber, Dag Svanaes, Jonathan Grudin, Stefan Greuter, Kai Kunze, Thomas Erickson, Steven Greenspan, Masahiko Inami, Joe Marshall, Harald Reiterer, Katrin Wolf, Jochen Meyer, Thecla Schiphorst, Dakuo Wang, and Pattie Maes. 2020. Next Steps for Human-Computer Integration. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3313831.3376242

[14] Federico Parietti, Kameron Chan, and H. Harry Asada. 2014. Bracing the human body with supernumerary Robotic Limbs for physical assistance and load reduction. In *2014 IEEE International Conference on Robotics and Automation (ICRA)*. 141–148. https://doi.org/10.1109/ICRA.2014.6906601

[15] MHD Yamen Saraiji, Tomoya Sasaki, Kai Kunze, Kouta Minamizawa, and Masahiko Inami. 2018. MetaArms: Body Remapping Using Feet-Controlled Artificial Arms *(UIST '18)*. Association for Computing Machinery, New York, NY, USA, 65–74. https://doi.org/10.1145/3242587.3242665

[16] Gil Weinberg and Scott Driscoll. 2006. Toward Robotic Musicianship. *Comput. Music J.* 30, 4 (dec 2006), 28–45. https://doi.org/10.1162/comj.2006.30.4.28

[17] Nahoko Yamamura, Daisuke Uriu, Mitsuru Muramatsu, Yusuke Kamiyama, Zendai Kashino, Shin Sakamoto, Naoki Tanaka, Toma Tanigawa, Akiyoshi Onishi, Shigeo Yoshida, Shunji Yamanaka, and Masahiko Inami. 2023. Digital Cyborgs: The Collaborative Design Process of JIZAI ARMS. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, 19 pages. https://doi.org/10.1145/3544548.3581169