Chewing Jockey:
Augmented Food Texture by using sound based on the cross-modal effect

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ABSTRACT
We focus on the dining and show how to improve dining experience. We use sound effects to augment food texture, creating a cross-modal illusion.

Our system is composed of a bone-conduction speaker and microphone, a photoreflector to measure the motion of jaw, and a computer to design the sound effect or filtering.

We focus on the texture of food, an important component of deliciousness, to enhance the eating experience without modifying the physical or chemical feature of the food. We use prevailing technologies to detect chewing action and to feedback and process the chewing sound and design some chewing augmentation filter for each foods. These combinations create the cross-modality effect for food texture.

We have developed three elements. First is a bite-detection sensor, utilizing a photoreflector, to measure the movement of the lower jaw. Second is a sound filter for each type of food that will be used to control food texture. Third is a self-feedback system to enhance the chewing action that records the chewing sound and the jaw motion, and delivers it to the user using bone-conduction speakers.

Our aim is redesign the experience of eating. We believe this technology is useful for following situations. For a start, it is a challenge to improve the eating QoL for dentures users. As they cannot bite strongly, they get a reduced sensation of food. Chewing Jockey helps to restore that sensation. Another application is to moderate the chewing speed. Chewing too fast is not good for digestion and also leads to over-eating. With our technology, we can provide the most suitable chewing speed to alter such habits. Lastly, chewing can be a form of interaction for a novel game design, in which you could role-play a monster chewing on “living” things.

Categories and Subject Descriptors
K.8 PERSONAL COMPUTING, H.5.2 User Interfaces : Auditory (non-speech) feedback, J.3 LIFE AND MEDICAL SCIENCES : Health

General Terms
Design, Human Factors

Keywords
Chewing, Eating experience, cross-modality, food texture, sound effect

1. INTRODUCTION
There is no love sincerer than the love of food." (Man and Superman (1903) by George Bernard Shaw).

Eating is most important behavior for human being. But how can we redesign eating experience? Or how can we provide someone who uses artificial teeth to get real teeth sensation? And how can we control chewing speed and count, to attain healthier eating habits?

Our technology is a breakthrough to answer these questions.

Taste is composed of many elements. There are not only basic tastes like sweetness, sourness, umami, bitterness and saltiness but also pungency, astringency, smell, texture, temperature, color, shape, environment, experience and physical condition. In this research, we focus on texture of food. We use sound effects to augment texture, creating a cross-modal illusion.

2. Related works
Improving QoL (Quality of Life) is important. For this issue, we focus on the dining and show how to improve dining using our technology. Recently, there are some researches on improving the dining experience by applying computer interaction method [1]. For example, Mori et al has developed the Dining Presenter [2], an Augmented Reality system for a dining tabletop. Their aim is to enhance the visual appearance of food, dishes, and a tabletop in a dining room. It detects the position of dishes and the amount of food to overlay a variety of information using a camera and a projector attached over a dining table. Our technology also enhances the eating experience by controlling food texture. It is a

system to change food texture for everyone including people with weak jaws.

Previously, there is a texture display device called the Food Simulator [3]. The Food Simulator generates force to the user's teeth to display food texture. It generates force according to the force profile captured from a real food. The device is integrated with auditory and chemical display for multimodal sensation in taste. Their method is a multi-modal approach, but our approach use cross-modal effect between auditory and haptics. Therefore, in the case of a person with weak jaws, our system may be more useful than the Food Simulator.

From the view point of cognitive science, Charles Spence found that if participants eat potato chips while listening to chewing sound or white noise that has been processed with high-pass filter, it will be perceived to be more crispy [4] because of cross-modality effect. We expanded that knowledge to other foods such as toast, cucumber, fresh salad, and so on. Furthermore we combined other sound effects with food to create entertaining chewing experience, for example, pairing breaking glass sound with potato chip, bursting balloon sound with Gummi candy.

MetaCookie [5] is one such taste display that uses the cross-modal effect. It realizes computer generated augmented flavors and establishes a method to integrate gustatory information into computer human interactions. It changes the perceived taste of a cookie by overlaying visual and olfactory information onto a real cookie with a special AR marker pattern. And they use an air-pump-type head mount olfactory display. Because of this, the number of olfactory stimuli they are able to replicate depends on the number of fragrance composition installed in the system.

Our approach has several advantages. One is that we do not require any haptic display system to express the food texture.

3. Chewing Jockey

3.1 System block

Our system is composed of a bone-conduction speaker (TEMCO, HG40SIM-TU28721) and condenser microphone (Sony, ECM-TL3), a photoreflector (Hamamatsu Photonics RPR-220) to measure the motion of jaw, and a computer to design the sound effect.

We have developed three elements. First is a bite-detection sensor, utilizing a photoreflector, to measure the movement of the lower jaw. And also we use this data to control the volume of sound. Previously, there is KOMEKAMI switch [8] to detect the bite times or wink. But this method detects only after bite timing, so we put same sensor under jaw, then we can measure the jaw motion and predict the timing of biting. Second is a sound filter for each type of food that will be used to control texture. We can augment or diminish the hardness of cucumber or the crispiness of potato chips. Third is a system that records the sound of chewing and the jaw motion, and delivers it to the user using bone-conduction speaker.

The reason why we choose bone-conduction speakers is to use this system for normal dining experiment and augmentation. Because if user wears normal earphone or headphone, they cannot enjoy talking with others.

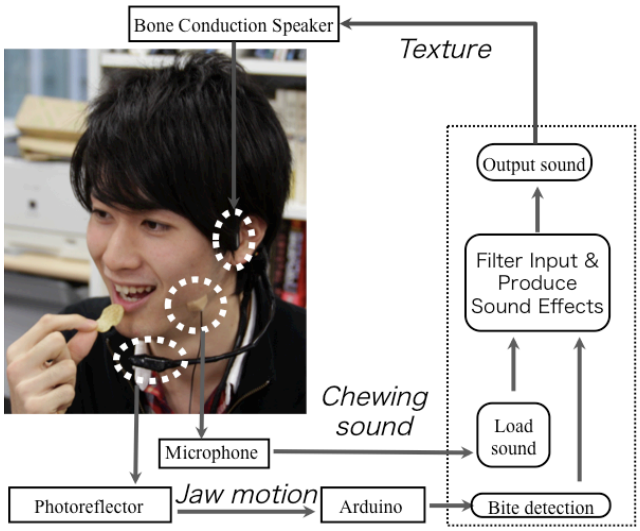

Figure 1. System block. This is a kind of feedback system. Human inputs the chewing sound and motion, computer outputs the suitable sound to feel augmented food texture.

3.2 Bite Detection sensor

We measure jaw motion to detect chewing action. User fix the photoreflectorunder under his jaw, to measure the distance between photoreflector and skin. Photoreflector signal goes to AD converter embedded in Arduino. Arduino sends the AD data to computer. Finally computer calculates the motion and to detect and predict bite timings.

The technology key is splitablity of human talk and chewing action to filter human voice and record just only chewing sound. Because chewing action is larger than talking action, we can recognize the talking or chewing by this method. So this technology can use for daily dining experience.

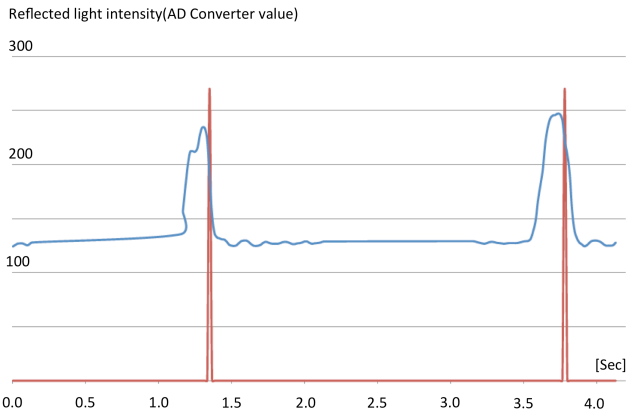

Figure 2. Graph for biting sensor, blue line is AD converter data and red line show the timing of bite.

3.3 Sound filter

There are two sound processing in this system.

One is chewing sound feedback system. This system uses pure Data to filter the sound from microphone. We use high pass filter which cut off frequency is 10k [Hz] to enhance potato chips feature, crispiness. On the other hand, 800 [Hz] low pass filter can diminish the crispiness. And this low pass filter is effective to augment hardness of the food like fresh vegetable, cucumber and carrot.

For this second presentation, we control the sound length. We need to cut the voice sound and output only processed chewing sound. So we output the chewing sound only 3 seconds after bite detection. Therefore, if user talks something in dining, the voice sound does not feedback to user. This voice cutting system improves comfortability of this system. Normally, human bite pitch is around 0.5 to 0.9 second. So this audio tuning seems no need over 1 second. But from the results of our demonstration, user bite food slowly with our system, so we use 3 second long sound.

And we also implemented sound fading effect for chewing sound. Normally, the more you chew, the chewing sound become small. So we control the volume of feedback chewing sound, to match the feeling of food size in oral cavity.

On the other hands, we use sound effect to realize chewing games. The system outputs sound effect, installed in computer, at the timing of bite.

3.4 Experience Design

There are two applications.

One is a chewing game experience. Participants will be given gummi sweets to chew on. As they begin to chew, they will hear screaming sounds. The food is just ordinary candy but because of the sound effects, the candy feels like living creatures. This is a kind of weird experience that is similar to horror movies. User can use any kind of Sound effect for this purpose.

Another one is augmented food texture. We control the sound of chewing and feedback to user to create the sensation of “Super crispy potato chips” or “Stale potato chips” or super hard rice cracker or ultra tender gummi candy. People can feel strong illusion of augmented food texture simply by sound effects from this demonstration.

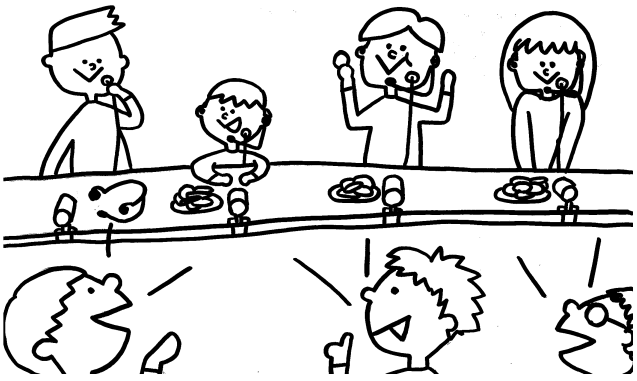

Figure 3. Experience Design, we design this microphone and speaker system to be use with talking someone. Jaw motion sensor can recognize the chewing action and talking motion.

4. DISSCUSION

We designed this system in the loop of tinkering and user test cycles from early stage. In this section I describe the interview and observation result.

4.1 Pilot study and observation

We have already done a pilot study to know what kind of experience we can provide and to discuss with user about applications.

We have done demo to young graduate school students from age 23 to 31. Almost all user enjoyed Chewing game. According to user feedback, they like the broken sound for food like “broken glass sound” with crispy food, "hopping sound" with gummi sweets, or insect figured candy with “screaming voice”. Near future, we would like to combine this kind of sound effect with illustrated/decorated food like Japanese kyaraben, Sugar craft or Marzipan as a novel entertainment.

And it seems large and highly value to augment food texture. We actually try to test it to a family, including elder person who uses 5 dentures, aged 81. According to our interview, she cannot feel good taste because of those dentures, and she cannot eat some hard type food like rice cracker or elastic food like Takuan, Japanese traditional pickled vegetable. In test, she can get better feeling for toast eating. From this observation, we guess this technology is suitable for improvement QoL of such elder person.

Figure 4. Pilot user study, we have done a few people to observe their reaction.

4.2 Contribution

Our contributions are followings.

Firstly, we propose augmented chewing as a novel computer entertainment. It is useful for daily life because the system and interaction are simple.

Secondly, we propose a proper method to control chewing sound. The combination of jaw motion sensor, microphone to record the sound and computation system realizes natural chewing sound augmentation.

Thirdly, according to pilot study, this is one of useful idea to improve QoL for elder person who uses dentures.

4.3 Limitation

From the test and user requirement, we also find some limitation of our technology.

Firstly, it can control only texture but cannot change the basic taste. Secondly, we cannot control food texture of tender food like pasta without artificial sound, because it doesn't make chewing sound and we cannot record and modify. Thirdly, we need to prepare a suitable filter or sound effect for every food. For example, high passed filter is suitable to enhance crispiness, so it is better for potato chip or cracker, but it is not suitable for fresh vegetable. On the other hand, it is effective to use low-pass filter for fresh vegetable. So we need to change filter for each food. Currently, we use But in the near future, we may be able to clear this problem by assigning sounds from a database to the chewing profile based on analysis of the chewing motion.

5. CONCLUSION & FUTURE WORK

We have made the "Chewing Jockey" system. This system augments food texture by introducing sound, based on the cross-modality effect. Users can experience munching "super" crispy potato chip, biting "live" food or eating "artificial" materials. We aim to improve eating experience for artificial teeth users, to encourage healthy eating habits, and to make the eating process entertaining.

We have several future plans with using our technology. Firstly, we hope to present virtual food eating experience by introducing echo sound. There are so many people who need dietary restriction. We would like to augment the amount of eating. For example, we guess using echo filter make illusion of food amount. Secondly, we would like to navigate the users chewing speed to taste by controlling sound. For example, it is better to bite slowly for beefsteak, but highly speed is better for fresh vegetable. So we guess chewing speed navigation helps to taste deeply. Thirdly, it leads sound rendering machine to develop new snacks, to know what kind of combination of taste and food is not clear now, this technology helps to find novel snack. In this way, there are so many possibilities for this technology.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Marcelo Coelho , DinnerWare: Why Playing with Food Should Be Encouraged, CHI Extended Abstracts'2009. pp.3505, 3506

[2] Maki Mori, Kazutaka Kurihara, Koji Tsukada Itiro Siio, Dining Presenter: Augmented Reality system for a dining tabletop, *Supplemental Proceedings of the 11th Ubicomp 2009*, pp. 168 -- 169, Orlando, Florida, USA, September 30 - October 3, 2009

[3] Hiroo Iwata, Hiroaki Yano, Takahiro Uemura, Tetsuro Moriya, Food Simulator: A Haptic Interface for Biting, *Proceedings of the IEEE Virtual Reality 2004*, 2004

[4] Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of Sensory Science*, 19, 347-363

[5] Takuji Narumi, Shinya Nishizaka, Takashi Kajinami, Tomohiro Tanikawa and Michitaka Hirose, Augmented Reality Flavors: Gustatory Display Based on Edible Marker and Cross-Modal Interaction, *CHI2011*, May 2011

[6] Taniguchi, K., Nishikawa, A., Kawanishi, S., & Miyazaki, F. , KOMEKAMI Switch: A Novel Wearable Input Device Using Movement of Temple. *Journal of Robotics and Mechatronics*, *20*(2).2008