Proceedings of 2021 Japan-Poland International Workshop on Technologies supporting rehabilitation and medical services

Scientific Meeting of Polish Chapter of the IEEE Robotics & Automation Society

The workshop was conducted on October 5th, 2021, from 9:30 Central European Time (4:30 JST).

Schedule:

October 5th 2021

Time	Presentation	Authors
9:30	Introduction by Grzegorz Granosik	
9:35	Introduction by Igor Zubrycki	
9:40 – 10:00	iWakka and its various applications	Yoshifumi Morita
10:00 - 10:15	Luna – a new promising tool for reeducation of gross motor function of the upper limb instroke patients. Rationale, design, and feasibility study results.	Ewa Zasadzka, Tomasz Trzmiel, Renata Marchewka, Sławomir Tobis, Dominika Kozak, Katarzyna Hojan

Time	Presentation	Authors
10:15 – 10:20	short break	
10:20 – 10:35	iWakka can enhance cortical excitability of motor related areas in stroke patients	Toshiaki Wasaka, Kazuya Toshima, Kohei Ando, Masakazu Nomura, Keishi Omori, Moe Nishiya, Tsukasa Tamaru, Yoshifumi Morita
10:35 – 10:50	Passive hand exercises in post-stroke rehabilitation	Ilona Czyż, Magdalena Halsagard, Maja Śmietańska, Julia Wojdyn, Justyna Redlicka, Elżbieta Miller
10:50 – 11:05	Evaluation and Training Device for Adjustability of Pinching Force “iWakka-pinch”: Application to Upper Limb Training in Hemiplegic Stroke Patients	Moe Nishiya, Keishi Omori, Yoshifumi Morita, Kazuya Toshima, Tsukasa Tamaru
11:05 – 11:20	Automatic device for hand rehabilitation	Wioletta Chmurska
11:20 – 11:35	Relationship between MP Joint Angle and Muscle Activity in Training with a Finger Extensor Facilitation Training Device “iPARKO”	Shota Ishigaki, Ai Nakamura, Yoshifumi Morita, Hirofumi Tanabe
11:35 - 11:50	Active Range of Motion Digital Testing Device of Finger Joints Using an RGB-D Camera	Huu-Hieu Quang, Yoshifumi Morita, Noritaka Sato, Makoto Takekawa
11:50 —12:05	Considerations and architecture of hand measurement system for post-stroke patients	Igor Zubrycki
12:05 – 12:20	Discussion and final words	

We would like to congratulate **Moe Nishiya** from Morita's Lab in Nagoya Institute of Technology in Japan for winning the Student Contest. Her presentation: "**Evaluation and Training Device for Adjustability of Pinching Force "iWakka-pinch": Application to Upper Limb Training in Hemiplegic Stroke Patients**" was rated as best by the Scientific Council.

Call for papers

It's a pleasure to invite you to submit your early research to the 2021 Japan-Poland International Workshop on Technologies supporting rehabilitation and medical services. The aim of the workshop is to bring together medical doctors and robotic engineers to strengthen collaboration between medicine and robotics. The main focus will be post-stroke medical services and technologies. Exchanging different forms of knowledge can give great results such as new thoughts, ideas, and joint projects. The workshop is also an opportunity for young researchers to present the results of their work and participate in a discussion that may be useful in later scientific and publishing work.

The 5th edition of Japan-Poland meeting will be held online. The final program of the workshop will be the result of a review process to extract the most exciting research in areas of robotics in rehabilitation medicine. Submissions will be evaluated in terms of their novelty, technical quality, significance and potential impact. The program will include oral presentations of accepted papers.

Participants should submit an abstract of the presentation, written in English (1-2 pages), according to included template.

> As a part of the workshop, The Student Contest will be organized. Presentations will be evaluated in terms of their originality, importance of the topic and presentation quality. The award winner will be announced during the workshop.

> **The award winner will be announced during the workshop.**

Subject Areas

We invite submissions in areas of robotics and medicine, including healthcare, rehabilitation and medical robotics, control and dynamics, sensing, human-robot interaction.

Important dates:

- September 15th, 2021: Abstract Submission Deadline
- September 25th, 2021: Abstract Acceptance Notification
- October 5th, 2021: Virtual Japan-Poland Workshop 2021

Submitting

Please submit your abstracts using e-mail:

conf2021@roboterapia.eu

Abstract format

Please use the following template for your abstract

Paper template

We encourage everyone interested in medical and rehabilitation robotics to participate in the workshop.

In the case of listeners who do not deliver presentations, the willingness to participate should be sent to the e-mail address of the event: conf2021@roboterapia.eu providing your name and e-mail address.

Organizers

- dr inż. Igor Zubrycki, Lodz University of Technology
- prof. Yoshifumi Morita, Nagoya Institute of Technology
- dr inż. Katarzyna Koter, Lodz University of Technology
- mgr Justyna Redlicka, Medical University of Lodz

Scientific Council

- prof. dr hab. Elżbieta Miller, Medical University of Lodz
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- prof. Yoshifumi Morita, Nagoya Institute of Technology
- dr hab. n. med. Katarzyna Hojan, FEBPRM
- dr inż. Igor Zubrycki, Lodz University of Technology
- dr inż. Katarzyna Koter, Lodz University of Technology

iWakka and its various applications

Yoshifumi Morita (Nagoya Institute of Technology, Japan)
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1. Aims

Hands are required in our daily life for essential activities, such as holding a cup, using chopsticks, a knife, or a fork, and operating a mobile phone. Therefore, hand paralysis and hand injuries hinder a person's ability to perform daily tasks. We propose to develop testing and training devices for restoring normal motor function to paralyzed hands, for example, a testing and training device for the adjustability of grasping force called iWakka, a piston device for fingers called PDFin to reduce spasticity in paralyzed hands, a finger extensor facilitation training device for paralyzed hands called iPARKO, and a digital goniometer of fingers using a depth camera.

We are currently conducting collaborative research using iWakka with six universities, including Lodz University of Technology and Medical University of Lodz, two rehabilitation centers, and one rehabilitation hospital. The application of iWakka depends on the medical institution. Moreover, iWakka can be used to treat a variety of hand conditions, such as hemiplegic patients after stroke, children with developmental coordination disorder, persons with mental disorders, and so on. In this paper, the various uses of iWakka are discussed, along with practical examples.

2. iWakka

The proposed iWakka, shown in Fig. 1, consists of an elastic body named Wakka and a grasping force measurement device. The grasping force measurement device comprises a control box, an iPad, and an application called "iWakka Viewer." Testing and training with iWakka primarily involve grasping the Wakka with a weak force and adjusting the grasping force to the target value in the range of 0 to 400 g. When the user grasps the Wakka with a force of 400 g, the Wakka deforms by 10 mm. The user adjusts the grasping force by mainly controlling the flexor muscle strength while the measured grasping force and the target force line are displayed on the monitor (Fig. 2). The harder the user grips the Wakka, the higher is the measured grasping force. The target force line moves to the right of the monitor over time. As the Wakka is operated by controlling muscle strength, the users should have the optimum motor function, cognitive function, attention function, etc. The mean absolute error between the measured and target values of the grasping force during iWakka operation was defined as the adjustability of grasping force (AGF). As shown in Fig. 2, the AGF score of the hemiplegic patient was 25.6 g. The AGF is one of quantitative assessments of the skillful movement of hand. In addition, we developed two different types of iWakka, namely iWakka-pinch and iWakka-extensor. The former is used for testing and training for the adjustability of the pinching force, where the user mainly controls the intrinsic muscle strength. The latter is used for testing and training for the adjustability of the extensor force, where the user mainly controls the extensor muscle strength.

3. Applications of iWakka to various diseases and disorders

3.1 Developmental disorder

The iWakka viewer application, iWakka Game, shown in Fig. 3, was developed to evaluate the dexterity of children with autism [1]. We are investigating the relationship between iWakka testing with the iWakka game and the movement assessment battery for children (M-ABC), and discussing the possibility of adding iWakka testing to M-ABC. M-ABC is widely used to evaluate the movement of developmental coordination disorders. It is also known that some children in a juvenile reformatory have poor manual dexterity. We are verifying this fact by using iWakka testing. We plan to add iWakka training to cognitive social training, which the collaborators have developed for children with some cognitive problems.

3.2 Mental health disorder

We are currently using iWakka testing to assess mental health disorders in people who have difficulty working owing to mental health disorders. We are also using iWakka testing and training in the rework support program developed by the collaborators.

3.3 Hemiplegic after stroke

We are currently using iWakka training as a preparatory exercise for training commonly performed on paralyzed upper limbs in the collaborative hospital [2]. By analyzing the brain waves, we investigated the effect of iWakka training as a preparatory exercise. Moreover, it was found that in some hemiplegic patients, motor functions of the unparalyzed (healthy) hands can also be impaired after a stroke. We are using iWakka training for the unparalyzed hands.

3.4 Mild cognitive disorder

We found that changes in motor learning of skillful movements during iWakka training were associated with cognitive function. Based on this fact, we are developing a mild cognitive impairment (MCI) screening system using iWakka.

4. Conclusion

In this study, various applications of iWakka in medical institutions were discussed. iWakka may have many other potential applications. I look forward to conducting collaborative research to discover new applications. This work was partially supported by a JSPS Grant-in-Aid for Scientific Research (19K12878).

Reference

[1] M. Nomura, N. Kucharek, I. Zubrycki, G. Granosik, Y. Morita, Adjustability for Grasping Force of Patients with Autism by iWakka: A Pilot Study, Proc. of the 12th international Workshop on Robot Motion Control (RoMoCo'19 in Poland), pp. 50-55, 2019.

[2] K. Toshima, Y. Morita, T. Tamaru, Study on Dexterity Movement Training by Grasping Device (iWakka) Used on Upper Limb Paralysis after Stroke and Its Combined Effect with CI Therapy, 13th Int. Society of Physical and Rehabilitation Medicine World Congress (ISPRM 2019), pp. 3-995, 2019.

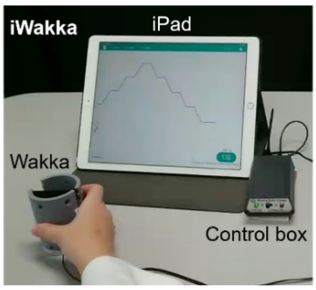

Fig. 1 iWakka

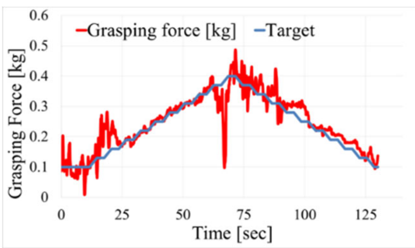

Fig. 2 Grasping force of hemiplegic patient

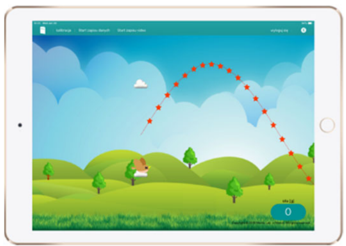

Fig. 3 iWakka Game

Ewa Zasadzka[1], Tomasz Trzmiel[1], Renata Marchewka[2], Sławomir Tobis[1], Dominika Kozak[3], Katarzyna Hojan[1,2]

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Luna – a new promising tool for reeducation of gross motor function of the upper limb instroke patients. Rationale, design, and feasibility study results.

In recent years using new technology as a rehabilitation tool, especially with biofeedback is increasing. The Luna device is an example of such tool. It can not only provide visual feedback during the exercises, but also (with the use of EMG) can help to reeducate movement. The device can amplify movement based on EMG recordings from muscle, helping patients with very low muscle strength to perform movement. However to asses the effects of such intervention clinical trial are required. Feasibility study was conducted on 10 participants with hemiparesis after ischemic stroke to prepare for clinical trial. Participants were included if stroke occured 0-2 months before screenig for enrolling into the study. All participants reported no adverse effect during the exercises performed on Luna device. Measurements were taken at the baseline and at the end of the study. All participants improved in regard to FIM score (with mean improvement 45% ± 17,34%) and most of the participants improved in regard to strength of biceps brachii (mean improvement 109,74% ± 88,5%). Therefore Luna may be usefull tool in improving gross motor function of upper limb in patients after stroke. More studies involving more participants and aimed at improving different muscles functions should be conducted.

iWakka can enhance cortical excitability of motor related areas in stroke patients

Toshiaki Wasaka[1)], Kazuya Toshima[1, 2)], Kohei Ando[1)], Masakazu Nomura[1)], Keishi Omori[1)], Moe Nishiya[1)], Tsukasa Tamaru[2)], Yoshifumi Morita[1)]

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Aims: iWakka is a device to train the motor function of paralyzed fingers in stroke patients. In fact, rehabilitation using iWakka showed the improvement of motor function. However, it is unclear how usage of iWakka acts on their brain. The aim of present study is to elucidate modulation of cortical activities in motor related areas induced by grasping movement using iWakka. We hypothesized that the abnormal sensorimotor integration of paralyzed hand was recalibrated by the visual tracking task and enhanced cortical activity ipsilateral to the damaged hemisphere.

Methods: This experiment consisted of visuomotor and control conditions. Each condition was conducted on a different day. In visuomotor condition, patients normally used iWakka. In control condition, they repeated grasping and releasing iWakka without visual feedback of exerted force. Each condition was conducted on a different day. In both conditions, we measured cortical activity of motor areas, movement related cortical potentials (MRCPs) before and after iWakka. For recording of MRCPs, the participants performed a hand grip as quickly as possible for short time and then relaxed. They instructed to repeat the hand grip every 5 to 7 s at their own pace. The target force level was 4N. We compared the amplitude of MRCP between visuomotor and control conditions.

Results and Discussion: In control condition, there was no difference in amplitude of MRCPs before and after usage of iWakka. In contrast, under visuomotor condition, MRCP amplitude after iWakka showed a significant enhancement in comparison of that before iWakka. The cortical generators of MRCPs are the primary motor are and supplementary motor area. Although the activity of motor areas ipsilateral to lesion is reduced in stroke patient, our notable results indicated that normal usage of iWakka (visual tracking task) can facilitate the activation of motor related areas innervating paralyzed fingers.

Conclusion: iWakka is an effective device for facilitating the brain activity in stroke patients.

Reference:

Shibasaki H, Hallett M. What is the Bereitschaftspotential? Clinical Neurophysiology, 2006; 117: 2341-2356

Passive hand exercises in post-stroke rehabilitation

Ilona Czyż[1,2], Magdalena Halsagard[1,2], Maja Śmietańska[1,2], Julia Wojdyn[1,2]
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Aims:
Over 60 thousand Polish people suffer from stroke every year, 70% of those who survive have a permanent disability. Therefore, post-stroke rehabilitation plays a key role in restoring the patient's mobility. To achieve this, it is necessary to have an individual approach to the patient and to implement comprehensive rehabilitation. Despite the research on stroke and treatment schemes for stroke, there is still a place in therapy for the use of modern devices that will diversify and, above all, accelerate the process of the patient's recovery. Therefore, the aim of our research is to broaden the knowledge about rehabilitation of people suffering from stroke by including a new rehabilitation device.

Methods:
The patient was admitted to a hospital on 9th of August on a six - week rehabilitation program and given passive hand exercises with a prototype device that is currently being tested. Apart from extensive treatment on Neurological Ward the patient has a series of everyday 80 minute exercises with the device from Monday to Saturday. The whole exercise cycle is divided into four sections of 5 minute exercises with a 15 minute break between. Before and after the exercising session the patient has an examination. There are measurements that are checked during examination.

- examination of superficial and deep sensation
- measurements of wrist and metacarpals in both hands; left (paralyzed) hand is checked before and after exercising
- ROM examination
- skin condition check
- muscle tension examination
- active movement observation

Results:
After three weeks of rehabilitation with the device it was observed that the patient’s muscle strength of the upper limb affected by paresis has increased (0/5 vs 2-/5 distal and 1+/5 proximal for left hand in Lovett scale). In addition, active movement of the fingers appeared in the paresis hand. It was also noticed that the edema of the wrist and hand has lowered down after everyday passive exercises. Concerning superficial and deep sensation no change was observed.

Conclusion:
The latest findings show that the key role in treatment for patients with stroke is the quickest possible access to medical help in a Neurological Ward of a hospital. The medical assistance should include cooperation of a multidisciplinary team of specialists as recommended by the Polish Model of Rehabilitation. This kind of cooperation allows the patient to restore motoric and locomotor efficiency together with a range of self service activities accompanied by everyday life routine. Appropriate physiotherapy improves the quality of a patient's life and their daily functioning.
Our research shows that the use of a rehabilitation device helps to restore hand function in patients after stroke.

Bibliography:

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2.. I. Rambabova, D. Vasileva, V. Atanasova-Rambabova, M. Rambabova, 2020, "The effect of kinesitherapy on balance and functional independence after ischemic stroke"

3. Małgorzata Wiszniewska, Adam Kobayashi, Anna Członkowska "Postępowanie w udarze mózgu Skrót Wytycznych Grupy Ekspertów Sekcji Chorób Naczyniowych Polskiego Towarzystwa Neurologicznego z 2012 roku"

4. Rafał Kaczorowski, Barbara Murjas, Halina Bartosik-Psujek "Rozwój i nowe perspektywy leczenia udaru mózgu w Polsce The development and new perspectives of stroke treatment in Poland"

Evaluation and Training Device for Adjustability of Pinching Force "iWakka-pinch": Application to Upper Limb Training in Hemiplegic Stroke Patients

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1. Aims

In recent years, evidence-based medicine (EBM) has received a great deal of attention in rehabilitation medicine [1]. The author's group has defined the concept of adjustability of grasping force (AGF) as the ability to control the contraction of hand muscles and adjust the grasping force, and developed a device called the iWakka to quantitatively evaluate the AGF and provide training to realize EBM [2]. The hospital that currently uses iWakka needed a device to quantitatively evaluate the adjustability of pinching force (APF) and provide training. In this paper, we describe the development of the iWakka-pinch and verify the effectiveness of the APF as a training device.

2. Methods

2.1 Development of the iWakka-pinch

The grasping body of the iWakka, i.e., the Wakka, has an elastic property achieved by splitting a cylinder into two parts. One side of one part and one side of the other part are fixed with a hinge, while the other two sides are not fixed, i.e., they are the open sides. The two parts are also connected by four plate springs. Two pinch plates are attached to the open side to form the iWakka-pinch. Because the iWakka-pinch requires training the pinching force from 0 to 180 g, the distance from the pinch plate attachment point to the pinching point was set to 13.5 mm. The tilt angle of the pinch plate was set to 11° so that the pinch plates would be parallel when the pinching force was 180 g. These designs were based on the relationship between the pinching force and pinch-plate spacing obtained from the theoretical equations of the cantilever beam and geometric angle relationship.

The fabricated iWakka-pinch is shown in Fig. 1. The user evaluates and trains the APF by adjusting the pinching force and tracking the pinching force displayed on the iPad to the target value. The mean absolute error between the pinching force and target value was used as the index for the quantitative evaluation of the APF [g].

2.2 Validation of the effectiveness of the iWakka-pinch

To verify the effectiveness of the iWakka-pinch, we applied it in the rehabilitation of a hemiplegic stroke patient. Regular training was provided to improve hand function. To confirm the effect of the iWakka-pinch training, a comparative study was conducted between the training period without iWakka-pinch training (the baseline period) and the training period with iWakka-pinch training (the training period). Both the baseline and training periods were four days. The subject was a woman in her 50s with right hemiparesis due to cerebral hemorrhage. The Fugle–Myer Assessment (FMA) was conducted before and after each period to measure the training effect. The FMA method assesses the functional disability to quantitatively evaluate the recovery of hemiplegic stroke victims, with a score of 66 for the upper extremity.

3. Results

The FMA scores before and after each period are shown in Fig. 2. The FMA score of 31 was maintained during the baseline period; however, it increased by 6 points from 32 to 38 during the training period. In particular, the shoulder/elbow/forearm score increased from 23 to 26, while the hand score increased from 2 to 5. Thus, the FMA score was improved by the iWakka-pinch intervention.

4. Conclusion

This study demonstrated the potential of improving the effectiveness of rehabilitation by incorporating training with the iWakka-pinch device in regular rehabilitation. Our future plan is to verify the effectiveness of using the iWakka-pinch with many patients. This work was supported by a JSPS Grant-in-Aid for Scientific Research (19K12878).

References

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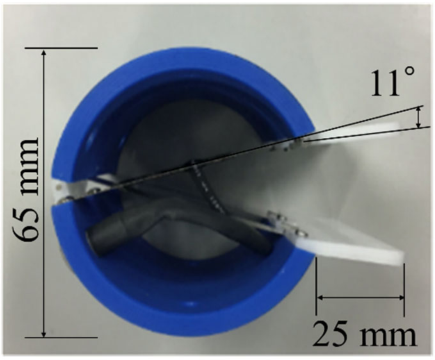

Fig. 1 iWakka-pinch

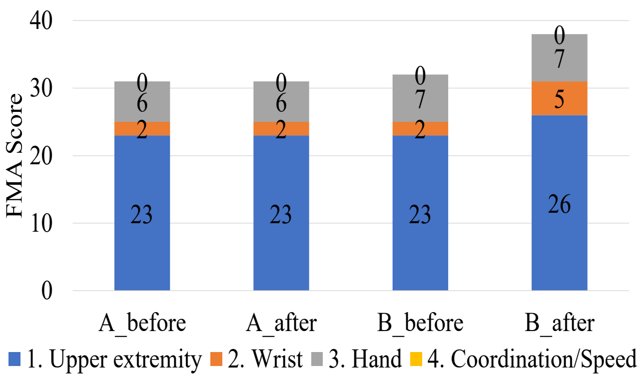

Fig. 2 FMA Score

Automatic device for hand rehabilitation

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Medical robotics is one of the most growing fields of science. Its main objective is to speed up the rehabilitation process, improve the efficiency of rehabilitation-related exercises and assist surgeons. Today, robotic devices make the work of doctors of many specialties easier [1]. Their main applications are general surgery and rehabilitation. Robots are used in the medical field because they allow for increased precision, reduced surgery time, and reduced medical personnel needed during the procedures performed. In addition, the ability to supply them with diverse sensors and the ability to perform multiple activities simultaneously has made the surgeons' work much easier. Often, more complicated operations takes several hours. It is human nature that at some point he will get tired or tremor. Robots have the advantage over humans that they can work without any interruptions. Rehabilitation robots have the ability to support therapy of lower limbs (ankle, knee, hip, gait) and upper limbs (single fingers, whole hand, wrist, elbow joint or whole hand). Additionally, spinal and jaw rehabilitation is also available. The use of this type of robot makes it possible to achieve greater repeatability of performed exercises and to reduce the number of therapists involved in the improvement of a single patient. The following thesis focuses on the use of rehabilitation robotics to support hand therapy. A rehabilitation glove has been designed for this purpose. It has artificial pneumatic muscles. In addition, research was conducted into the force generated by McKibben's muscles and a PLC program was written to control the glove.

The rehabilitation glove uses pneumatic muscles (McKibben muscles). It is a type of single acting actuator. With increasing air pressure there is a simultaneous increase in the circumference and decrease in the length of the muscles, so that the contraction of the muscles increases and an axial pulling force is produced, corresponding to the stress in the elastic net [2]. The main features of the rehabilitation glove are:

-The glove will be responsible for straightening the fingers and wrist. This is because the straightening movement, according to physiotherapists, is the most crucial movement in terms of rehabilitation of the upper limb,

-Possibility to create a glove on your own. Files in STEP/ STL format will be made available on the platform, where every user will be able to download them and print them on their 3D printer.

-Easy to assemble glove components.

-The components provided will have the ability to be adjusted for different finger lengths.

-Using the glove should be safe for patient.

The concept of the rehabilitation glove (Figure 1) is based on a parallelogram structure. For the proposed design, finger phalanges and brackets are defined as sides of the parallelogram.

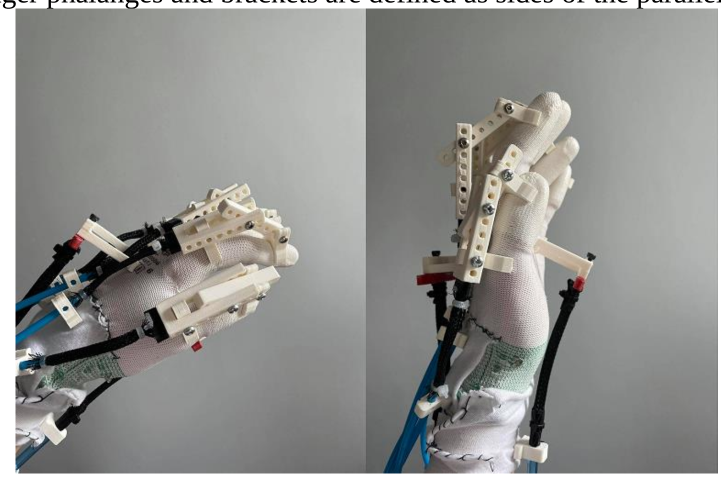

Figure 1 Rehabilitation glove

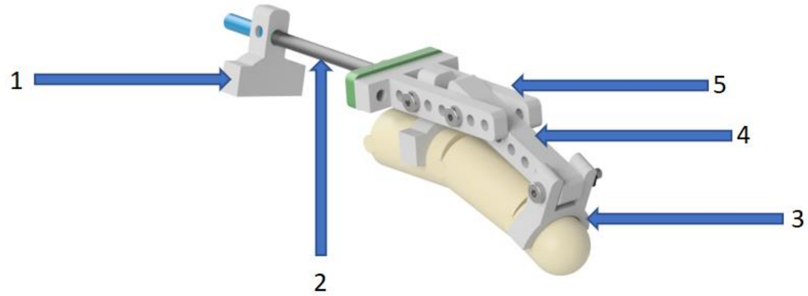

Figure 2 Device prototype. 1- Pneumatic tube support, - McKibben muscle, 3- support, 4- tendon I, 5- tendon II

In addition, its key feature is the ability to adjust the length of the cables, through holes that have been created in the printed parts. This gives an adjustment range of 35-55 mm for the length of the long phalanx. By using this solution, it will not be necessary to create a glove for an individual patient order. In addition, only 7 pneumatic muscles (5 responsible for finger movement and 2 for the wrist) will be needed to build the glove. The issue of limiting the range of motion during straightening of individual members has also been resolved. This depends on the contraction of the McKibben muscle selected earlier in the work, which is about 10 mm. What has been further improved is the way the muscle is mounted to the glove. Just bolt it on with 2 M2 bolts to tendon II. If it happens that a muscle is damaged, we can easily replace it with a new one. The glove has 3 modes of rehabilitation:
- Extend fingers and wrist at the same time
- Interval finger and wrist extension
- Wrist extension and flexion.

The work resulted in the construction of a rehabilitation glove, the selection of appropriate McKibben muscles, and the writing of a PLC program. Thanks to the appropriate adaptation of the proposed device's construction, it is not necessary to create it according to the individual patient's order - it has adjustable finger length, thanks to which the solution gains versatility. Additionally, assembling the components for the glove is simple enough that we can do everything ourselves at home. The prototype can facilitate hand rehabilitation and speed up the recovery process.

[1] Maciejasz, P., Eschweiler, J., Gerlach-Hahn, „A survey on robotic devices for upper limb rehabilitation.," January 2014.
[2] Yoko Kadowaki, Toshiro Noritsugu, Masahiro Takaiwa,, „Development of Soft Power-Assist Glove and Control," February 2011.

Relationship between MP Joint Angle and Muscle Activity in Training with a Finger Extensor Facilitation Training Device "iPARKO"

Shota Ishigaki[1)], Ai Nakamura[1)], Yoshifumi Morita[1)], Hirofumi Tanabe[2)]
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1. Aims

Spasticity is one of the most common after-effects of a stroke. Hand spasticity is characterized by abnormal muscle tone, which causes constant flexion of the wrist joint and fingers. To treat hand spasticity, it is necessary to increase the strength of the extensor digitorum muscle and open the flexed hand. However, patients cannot open their hands on their own. Therefore, another way to generate electrical activity in the extensor digitorum muscle is required to open the flexed hand. The fourth author of this manuscript found that electrical activity is generated in the extensor digitorum muscle when an external force is applied to the fingertips of a paralyzed hand in a hyperextended position. As shown in Figure 1(a), the fourth author developed a hand extensor facilitation technique, which is referred to as the facilitation technique in this study, to increase muscle strength. In our previous study, we developed iPARKO, a finger extensor facilitation training device that simulates this facilitation technique [1]. This is illustrated in Figure 1(b). The angle of the metacarpophalangeal (MP) joint affects the amount of electrical activity generated in the extensor digitorum muscle. In this study, we evaluated the relationship between the MP joint angle and the muscle activity of the extensor digitorum muscle in healthy subjects. The results of this study can aid in improving the therapeutic effect of iPARKO.

2. Methods

The amount of electrical activity generated at the extensor digitorum muscle of five young, healthy subjects (No.1: male 21 y/o, No.2: female 22 y/o, No.3: male 21 y/o, No.4: male 22 y/o, No.5: male 22 y/o) during the use of the device was compared for different values of the hyperextension angle of the MP joint. Because the passive range of motion (P-ROM) of the MP joint in the hyperextension position of each subject was different (mean: 63°, maximum: 80°, minimum: 50°), the EMG measurements were conducted with five angles—0, 25, 50, 75, and 100% of the P-ROM of each subject. Figure 2 shows an example of the hand-fixed iPARKO with MP joint angles of 0° and 30°. The measurements were made 3 min apart. Each subject placed their elbow on the upper limb stand in the sitting position and pushed their hand forward to receive resistance on their fingertips. This step was repeated 11 times. No shoulder elevation was allowed, and the wrist angle was kept constant for each subject. The electrical activities of the extensor and flexor digitorum muscles were measured using electromyographic sensors. Each set lasted for 4 s and consisted of 2 s of pushing the springs forward followed by 2 s of relaxation. A total of 11 sets were performed for each measurement, and a metronome was used to measure the period of 2 s. The sampling time for the measurements was 0.001 s.

3. Results

Figure 3 shows the normalized results of the amount of electrical activity detected at the extensor digitorum muscles at the MP joint angle of 0%. Each value is the average of the 11 sets. It was verified that the amount of electrical activity at the extensor digitorum muscle increased as the MP joint became more hyperextended. However, as the electrical activity at the flexor digitorum muscle reduces the effect of training with iPARKO, it is better to reduce the amount of electrical activity at the flexor digitorum muscle. As shown in Fig. 3 (b), the amount of electrical activity at the flexor digitorum muscle decreased as the MP joint became more hyperextended. The average for the five patients decreased by 62%.

4. Conclusion

It was confirmed from the verification experiments on healthy subjects that optimum results are obtained when the training with iPARKO is conducted in the maximum hyperextension position. In future, we plan to increase the number of subjects and validate the performance of iPARKO for other hand conditions. This work was supported by the JSPS Grant-in-Aid for Scientific Research (19K12878).

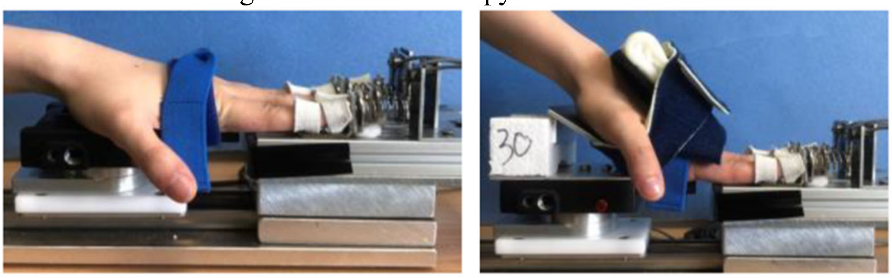
Reference

1 A. Nakamura, Z. Peichen, Y. Morita, H. Tanabe, Finger Extensor Facilitation Training Device "iPARKO" Imitating Manual Treatment Method-Effectiveness Verification on healthy people, Proceedings of the Robotics and Mechatronics Conference, 2021

2 P1-D04 (1)-(2), 2021. (in Japanese)

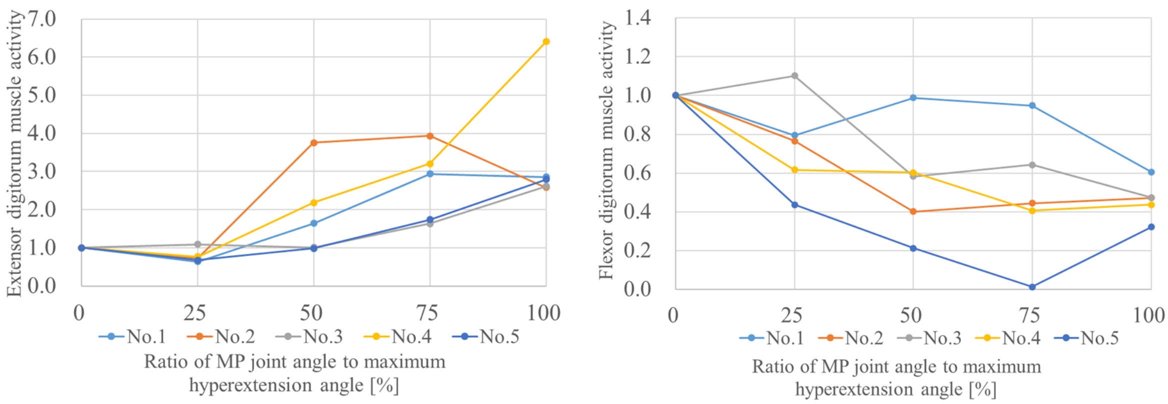
(a) Finger extensor facilitation technique (b) iPARKO

Figure 1. Manual therapy and iPARKO



(a) 0° (b) 30°

Figure 2. MP joint angle at measurement



(a) Extensor digitorum muscle (b) Flexor digitorum muscle

Fig. 3. Relationship between the MP joint angle and muscle activity.

Active Range of Motion Digital Testing Device of Finger Joints Using an RGB-D Camera

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Range of motion (ROM) is an essential index in clinical practices to assess the effectiveness of therapeutics. Rehabilitation therapists commonly use a goniometer to measure the ROM of finger joints manually. Since many finger joints need to be measured, the measurement is time consuming and burdensome to the patients. The required measurement accuracies of general rehabilitation and hand therapy tests are less than 5° and 2°, respectively. Therefore, we developed an active range of motion (A-ROM) digital testing device to reduce the measurement time and the burden on both patients and rehabilitation therapists during the measurement.

The proposed digital testing device is a non-invasive automatic test device for measuring A-ROM of finger joints that comprise an Intel RealSense depth camera and a computer. Rehabilitation therapists point the camera toward the patient's finger joints and capture the RGB and depth images. By using the RGB and depth images of the target joint obtained with the Intel RealSense depth camera, an A-ROM's angle is computed. The calculation algorithm of joint angles installed in the device is based on the measurement principle using a goniometer, which the angle of the target joint is computed by obtaining the three-dimensional coordinates of the point cloud on the centerline of the finger bones that make up the joint and the center point of the joint. The centerline detection algorithm consists of the proper pose detection and center point detection algorithms, which were developed by using SSD (Single shot multibox detector) algorithm, and Hand Keypoint detection, respectively. This device has to be pointed by a therapist at the target joint in the proper position. However, if the device is not pointed correctly, the device will output a warning message to the therapist. The effectiveness of the proposed device was verified on one healthy person by comparing with the results obtained with the goniometer. The error of the proposed digital testing device was less than 2°.

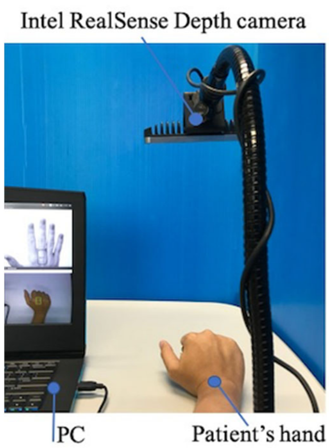
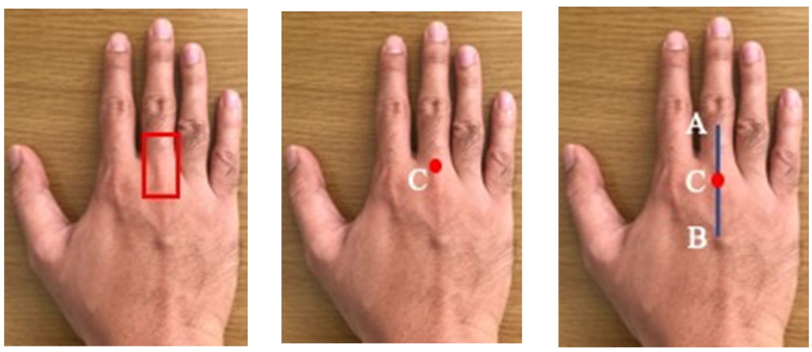


Fig. 1 Digital testing device.



(a) Proper pose detection

(b) Center point detection

(c) Centerline detection

Fig. 2 Centerline detection procedure.

Considerations and architecture of hand measurement system for afterstroke patients

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1. Aims

For our project „Single-use and personalizable devices for hand rehabilitation" we aim at creating a pipeline for automatic or semi-automatic hand data acquisition, that would provide an input in CAD for physiotherapist system. Using this system therapis could manage various diagnostic inputs and use them to create a personalised therapy and therapeutic device for particular patient needs. In first step towards this goal we aimed at understanding current state of diagnostics, needs and possibilities. Based on that architecture of the system was created.

2. Methods

To understand current state of the diagnostics we conducted three interviews with therapists. Diagnostic methods were recorded. We then discussed the resulting mind-maps and proceeded with user moddeling, need sketching and scenario design. Based on this data, basic components list, sequence diagram for a measurement procedure was created as well as software-hardware diagram.

3. Results

Diagnostics and measurement of the hand should consist of: hand geometry measurement, range of motion measurement, hand active strength, limpness-spasticity measurement, swelling, intelectual control of the hand, ability to feel, touch sensibility, noting of other medical conditions (heart, skin, etc).

Whole system would be used by (system users): patients, medical doctor, therapist, researchers, patient guardians.

Based on this findings we propose a system based on 3D vision system and haptic device for hand measurement.

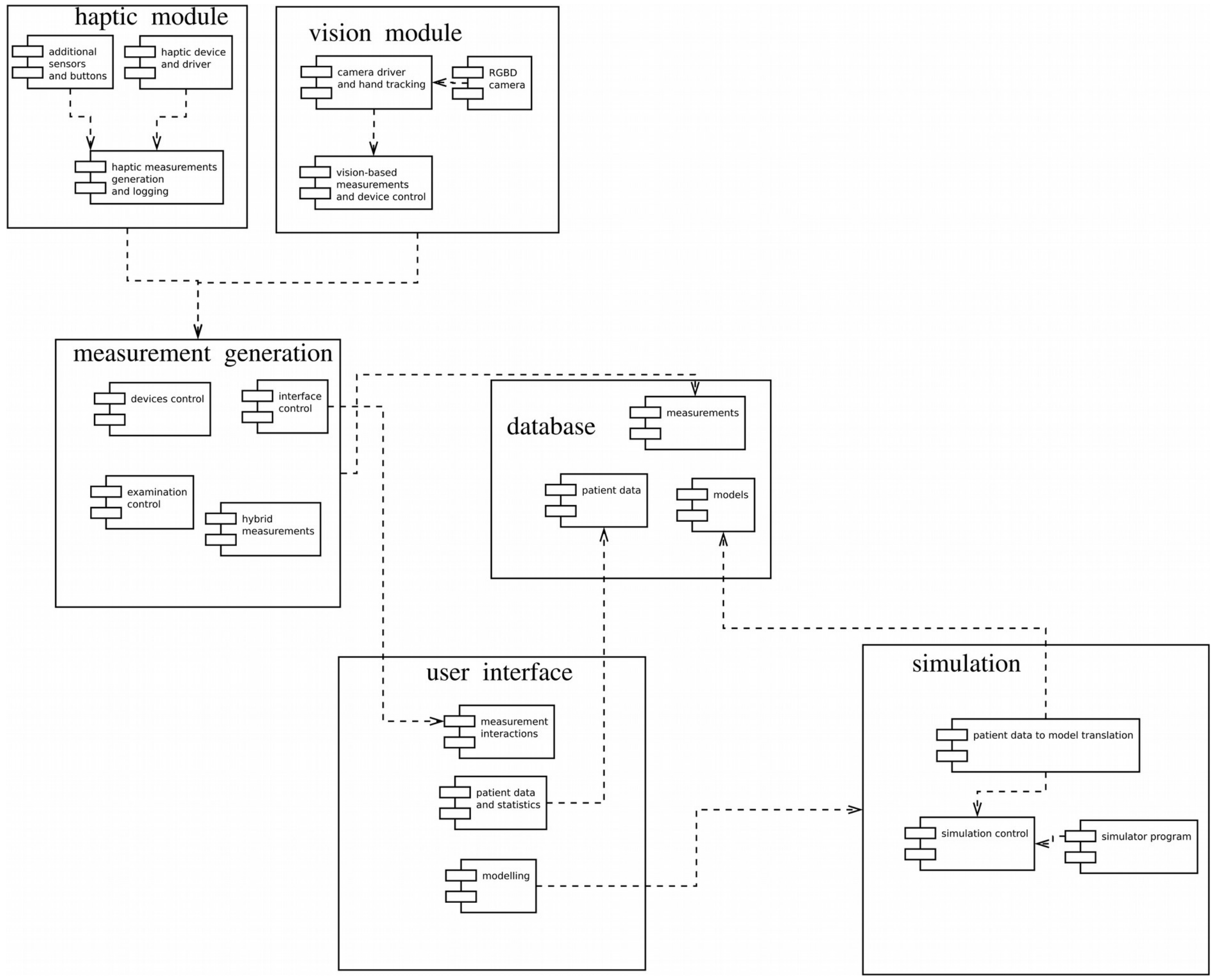
Main system components would be: 3D vision system for hand pose, position estimation and vision-based hand diagnostics (hand swelling based on comparision between healthy and disabled hands, skin state), range of motion. Haptic device: the device would be used in providing active measurements of hand spasticity/ limpness/elasticity. Potential additional measurement devices that would replace haptic device functionality and be more specialised: for spasticity, range of motion, dynamic force measurement. All of these devices could be connected to make a virtual sensor that would provide measurements based on multiple sensor readings. Centralised interface for measurement lookup and diagnostics. Furthermore, data would be sent to simulator where hand model based on patient data would be used for device and therapy developement.

4. Conclusion

In our work, we devised a system architecture based on multiple devices that would enable diagnostitian to proceed with hand modeling and diagnostics of hand state. The system will be used in designing a soft devices and therapies as well as serve as database for maintaining patient progress.

Images

Software-hardware system diagram



Example sequence diagram during measuring finger widths process (swelling)