Paper:

Quantitative Evaluation of Automatic Parts Delivery in "Attentive Workbench" Supporting Workers in Cell Production

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The attentive workbench (AWB) is a new cell production system that supports human workers physically and informationally. Here we focus on physical assembly support through parts delivery, using automatically-moving parts trays. We quantitatively evaluated processing time in actual assembly experiments employing an implemented AWB system.

Keywords: cell production system, assembly support, attentive workbench (AWB)

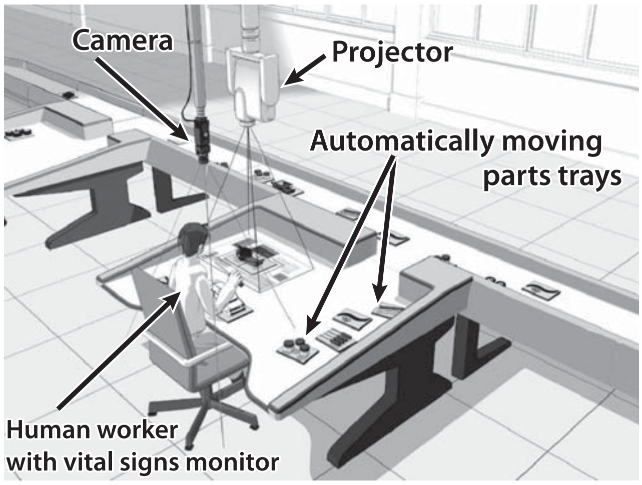


Fig. 1. Attentive workbench (AWB).

1. Introduction

In line with changing consumers needs, manufacturers have gradually replaced automated manufacturing lines mass-producing specific products using special machines with flexible manufacturing systems (FMS), and then with cell production systems in which skilled individual operators manually assemble individual products from start to finish [1, 2]. Cell production systems accommodate diversified products and production quantity more flexibly than fully automated manufacturing systems, but dynamic changes in the age distribution of the working population lead to a shortage of skilled workers and increasing difficulty in maintaining the cell production system. This tendency may be accelerated by zero or negative population growth and the avoiding of manufacturing jobs by younger workers.

The attentive workbench (AWB) helps meet diverse needs with a smaller labor force by supporting production workers through informational and physical assistance (**Fig. 1**).

In addition to monitoring intents and conditions and feeding these back to workers, the AWB delivers required assembling parts. Conventional cell production systems, with their static parts trays stored side by side on desktop shelves, require that workers reach out for parts in parts trays. Motion and time studies [3] show that reaching and pick up movement takes more time, the greater the distance between a worker and parts trays. Optimizing of the spatial layouts solves only part of the problems, since not all trays can be placed closest to operators and mistakes in picking may cause assembly errors. To solve the tray-access problems, we propose the use of automatically moving trays delivering required parts to workers, speeding up production and reducing assembly failures.

Not only does the AWB support workers already on the job, it opens the way to employing less experienced workers regardless of age.

In related work, Roland DG Corp. (Hamamatsu, Japan) uses a "Digital Yatai"[1] to monitor assembly work and present information on the next assembly process via a visual display [1]. The Digital Yatai helps prevent assembly errors by telling workers via LED indicators which trays have required assembly parts. Reinhart and Patron [4] introduce augmented reality to information presentation using a semitransparent head-mounted display.

Physically oriented assembly support in cell production has drawn less attention than informational support. In

1. The word "yatai," a nickname for production cells originally meant a portable food stall providing all ingredients required to make a meal.

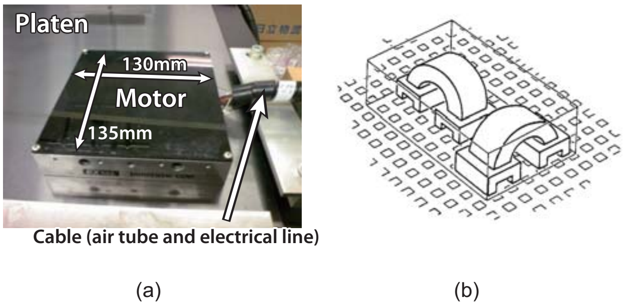


Fig. 2. (a) Sawyer-type planar motor and passive iron platen. (b) Mechanism of a Sawyer-type motor.

several studies, manipulators help workers handle heavy [5, 6] or long [7] objects, targeting production involving much more arduous work than that in usual cell production.

As stated, we focus on physical assembly support of automatic parts delivery to workers using automatically moving trays. This paper is organized as follows: Section 2 gives an overview of the attentive workbench (AWB), its key components, an implemented prototype, and description of automatic parts delivery. Section 3 discusses actual assembly experiments using the AWB prototype and quantitatively evaluates productivity. Section 4 presents conclusions and Section 5 projected work.

2. Attentive Workbench (AWB) Overview

2.1. Automatically Moving Parts Trays

Parts trays in conventional cell production are passive in all cases. The "active" alternatives we propose are automatically moving trays driven by high-speed, highly accurate 2-DOF Sawyer stepping motors [8] (Shindenshi Corp.) as shown in **Fig. 2-(a)**. These motors move on an iron platen having grid-like grooves filled with insulating plastic (**Fig. 2-(b)**), floated by compressed airlifts about 20 μm above the platen.

2.2. AWB Prototype

Our AWB prototype (**Fig. 3**) uses a projector and a plasma display to present assembly information to workers. The AWB can monitor workers' activities via ceiling cameras, which will be dealt with elsewhere. Six parts trays, i.e., Sawyer motors, occupy a 1200 mm $\times$ 900 mm platen. The motor platen faces a 1200 mm $\times$ 300 mm worktable.

Trays move 1 m/s at maximum for each axis, i.e., over 1 m/s diagonally. Due to motor controller specifications, tray trajectories are limited to connected straight line segments. The number of vertices on a trajectory is desired to be small, because trays must stop completely at vertices to change their direction of movement. A cable on each tray supplies compressed air and electricity to a motor. Cables must be taken into account in motion planning to keep trays from colliding and tangling.

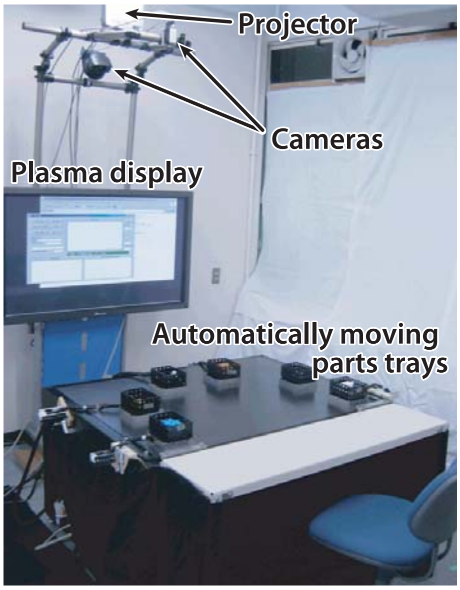


Fig. 3. AWB prototype.

Allowing for the motor features and constraints as mentioned above, we have introduced a new motion planning method [9] for the self-moving parts trays, based on priority scheme [10] proposed by Erdmann and Lozano-Pérez, to generate efficient paths for collision-free tray operation.

2.3. Assembly Support Demonstration

In an example of automatic parts delivery (**Fig. 4**), a worker assembles simple toy blocks. Each assembly process uses two or more parts (**Fig. 4-(b)**). Motion planning, as indicated, generates parallel collision-free tray paths.

A footswitch is used as an input interface. The AWB delivers parts required for the next assembly process within 1 second when the footswitch is pressed by the worker.

3. Experiments

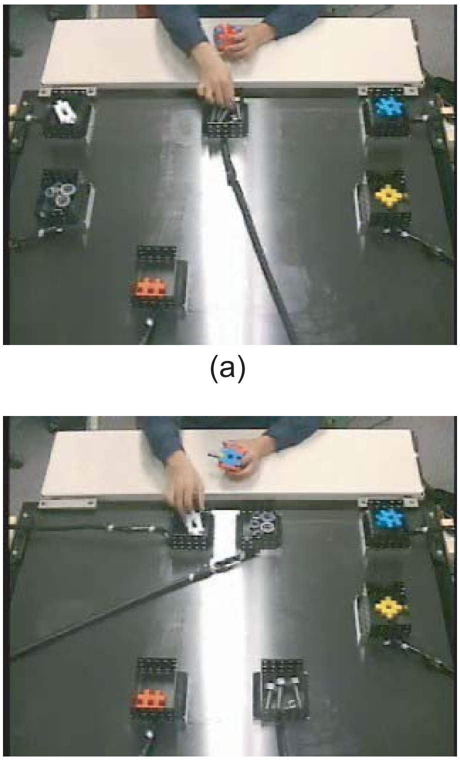
We have investigated to improve productivity by speeding up automatic parts delivery to workers. Here we evaluate the results in experiments.

3.1. Experimental Setup

3.1.1. Sample Product

It is expected that the assembly speed improvement ratio depends on the assembly task details, and that this ratio increases as assembly tasks continue longer and parts assembled become larger and heavier. In this section, we design an appropriate product that is suitable for experimental evaluation.

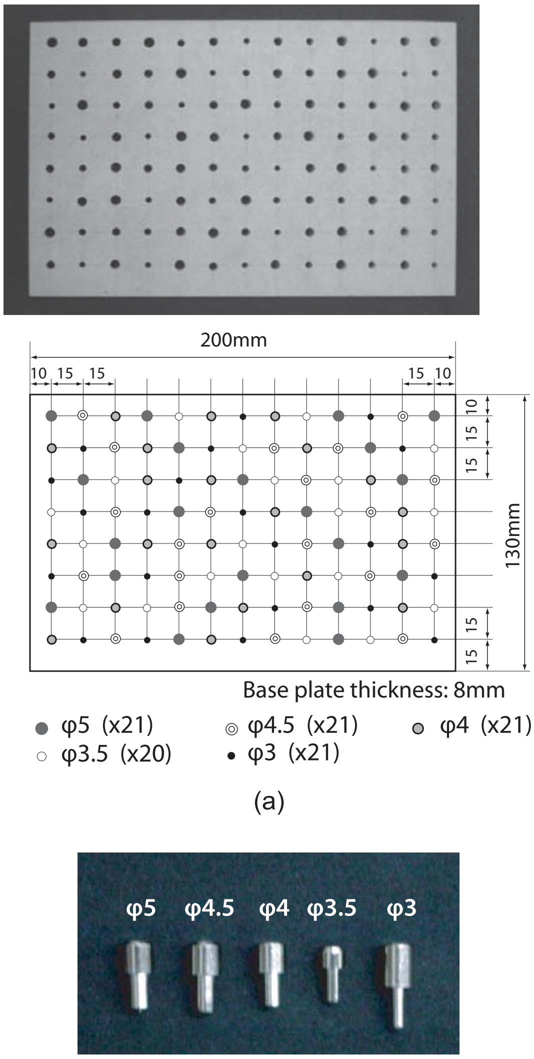
Our experimental assembly product (**Fig. 5**) consisted of a wooden "base" plate and 104 small metal (originally shelf-support) pins made in five diameters – 3, 3.5, 4, 4.5, and 5 mm.



(a)

(b)

Fig. 4. Example of assembly support.



(a)

(b)

Fig. 5. Assembly product. (a) Wooden base plate with 104 holes. (b) Five types of small metal pins.

For evaluating experiments, the “pin-into-hole” task is suitable, since it does not require any special skills. Subjects were ten persons – 9 men and 1 woman – volunteering to take part.

The five types of pins (**Fig. 5-(b)**) essentially all look alike. Subjects will find it very difficult to memorize assembly and disassembly sequences. This conveniently reduces the systematic deviations and noises due to learning-curve effect.

3.1.2. Experimental Task

In the experimental setup, subjects assemble products (**Fig. 5**) by putting each pin into a corresponding hole in the base plate in the sequence of left to right, then top to bottom, starting with 5 mm pin in the top left hole and working on down (**Fig. 5-(a)**) to the last 3 mm pin in bottom right hole.

After putting 104 pins into the holes, subjects wait 30 seconds and then disassemble the product by removing the pins and returning them to the tray in front of them. The sequence in disassembly processes is the same as that in the assembly – left to right, top to bottom.

We call the entire assembly/disassembly ensemble (**Fig. 8-(a)**) a task.

3.1.3. Comparison: No Automatic Parts Delivery

For comparison, we prepared a second experimental environment a la “Digital Yatai” [1], without automatic parts delivery. As is the case with Digital Yatai, the system tells subjects which parts trays is to be used.

Without parts delivery (**Fig. 6**), trays are arranged at approximately 20 cm intervals in a row in front of subjects. The system tells subjects which trays have required parts via a transparent screen on which an arrow indicates the tray together with the part name and process number – information enabling experimenters to tell whether subjects do tasks correctly and to interrupt subjects making mistakes. Subjects do not need character-based information, conduct the task based on arrows indicating required trays, and are instructed to watch arrows only (Section 3.1.5). A footswitch (Section 2.2) is used as an input interface between subjects and the AWB system, as is the case with automatic parts delivery,

In the parts delivery case, we did not present information because tray movement serves to do so.

3.1.4. Wrist Weights for Additional Physical Load

To simulate tasks with larger physical load, we introduce a pair of wrist weights each weighing about 0.5 kg

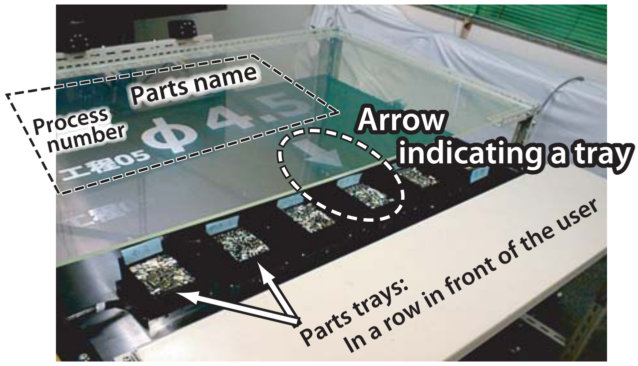
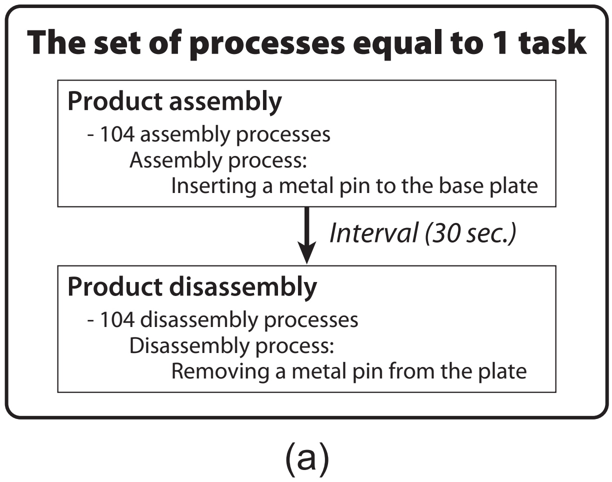


Fig. 6. Experimental setup in the case without parts delivery. Assembly information is projected on the desk. Trays in front of the subject do not move.

Fig. 7. Wrist weights used in experiments.



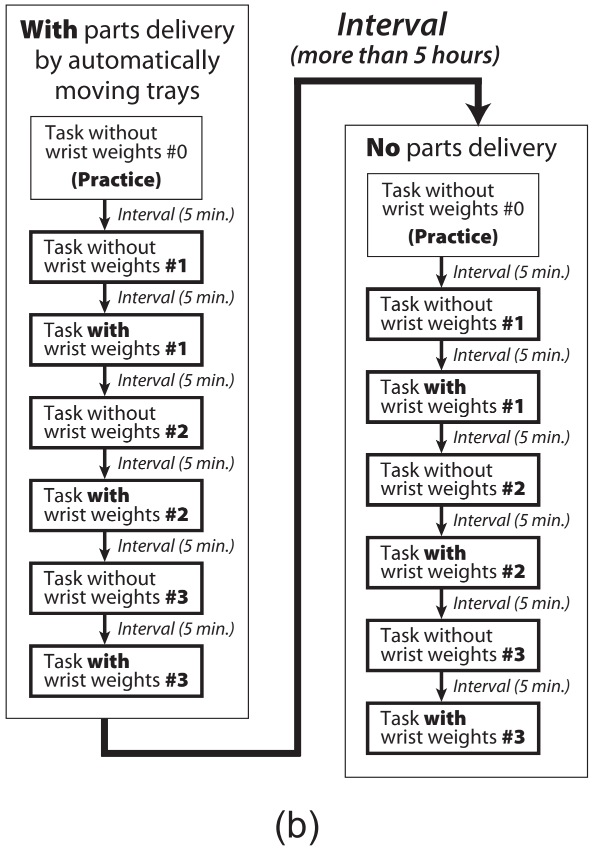


Fig. 8. (a) Experimental task. (b) Individual experimental procedure.

(**Fig. 7**) taken from the “Aged Simulation Set” (Koken Co. Ltd.) that is usually used for younger persons to experience inconveniences felt by older persons due to decay of body function. The subjects wear the wrist weights in the experiment.

3.1.5. Experimental Protocol

Experiments involve two factors – whether trays deliver parts and whether subjects wear wrist weight – the number of experimental conditions is $2 \times 2 = 4$. Subjects complete the same task under all conditions (**Fig. 8-(b)**).

In experiments, after first practicing how to use the system, subjects do tasks in which trays delivered parts, then those in which parts are not delivered (**Fig. 8-(b)**).

In practice, subjects are told by experimenters to keep their eye on the base plate (**Fig. 5**), since nonessential movement of the eye and head lowers the production efficiency. In the case with parts delivery, required trays arrive at a fixed spot near subjects, who then no longer need to track trays. In the case without parts delivery, an arrow projected on a screen showing the correct tray (**Fig. 6**) is so large and clear that subjects are not necessary to concentrate on the screen.

During assembly practice in the case with parts delivery, subjects are told to press the footswitch after picking up a part from the tray, not after inserting the part into the hole on the base plate. Similarly, during disassembly, subjects are told to press the footswitch immediately after returning the part to the tray. Otherwise subjects have to wait an extra second for the assembly or disassembly process, since it takes about 1 second for automatically moving trays to go from their initial position to in front of the user (Section 2.2). By pressing the footswitch after picking up or returning parts, subjects can do their tasks in parallel with parts tray delivery.

When subjects make a failure, the experiment is once interrupted and then resumed by experimenters. The typical failures are as follows:

- Failing in picking or returning parts in assembly or disassembly by pressing the footswitch too soon.

Table 1. Mean time required and standard deviation per process (assembly).

Subject (age/gender)		With parts delivery No wrist weights [s]	With parts delivery With wrist weights [s]	No parts delivery No wrist weights [s]	No parts delivery With wrist weights [s]
S1	Mean	2.329	2.355	2.479	2.573
(33/M)	StdDev.	0.236	0.233	0.323	0.344
S2	Mean	2.112	2.120	2.277	2.290
(24/M)	StdDev.	0.342	0.330	0.433	0.355
S3	Mean	2.378	2.465	2.627	2.694
(22/M)	StdDev.	0.505	0.499	0.513	0.532
S4	Mean	2.306	2.385	2.706	2.822
(28/M)	StdDev.	0.298	0.315	0.466	0.357
S5	Mean	2.180	2.280	2.146	2.283
(25/M)	StdDev.	0.300	0.293	0.485	0.429
S6	Mean	2.376	2.465	2.585	2.850
(23/M)	StdDev.	0.429	0.473	0.549	0.569
S7	Mean	2.184	2.178	2.259	2.340
(22/M)	StdDev.	0.447	0.411	0.439	0.448
S8	Mean	2.578	2.570	2.795	2.867
(25/M)	StdDev.	0.525	0.545	0.511	0.661
S9	Mean	2.213	2.187	2.302	2.353
(23/F)	StdDev.	0.406	0.380	0.486	0.425
S10	Mean	2.471	2.568	2.560	2.605
(27/M)	StdDev.	0.317	0.390	0.445	0.463
Average		2.313	2.357	2.474	2.568

M: male
F: female

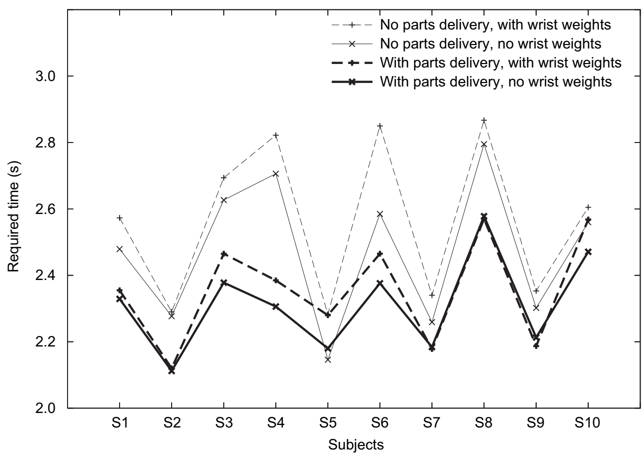


Fig. 9. Mean time required for assembly process.

Table 2. Mean time required and standard deviation per process (disassembly).

Subject		With parts delivery No wrist weights [s]	With parts delivery With wrist weights [s]	No parts delivery No wrist weights [s]	No parts delivery With wrist weights [s]
S1	Mean	1.296	1.320	1.392	1.497
	StdDev.	0.074	0.071	0.130	0.133
S2	Mean	1.259	1.257	1.453	1.491
	StdDev.	0.178	0.142	0.291	0.340
S3	Mean	1.499	1.472	1.585	1.643
	StdDev.	0.482	0.468	0.388	0.380
S4	Mean	1.416	1.391	1.716	1.654
	StdDev.	0.182	0.410	0.390	0.324
S5	Mean	1.349	1.371	1.247	1.238
	StdDev.	0.157	0.155	0.288	0.229
S6	Mean	1.321	1.303	1.556	1.719
	StdDev.	0.205	0.204	0.322	0.317
S7	Mean	1.245	1.248	1.213	1.310
	StdDev.	0.178	0.162	0.223	0.220
S8	Mean	1.362	1.377	1.477	1.478
	StdDev.	0.198	0.193	0.218	0.270
S9	Mean	1.334	1.342	1.427	1.448
	StdDev.	0.185	0.199	0.286	0.292
S10	Mean	1.560	1.607	1.403	1.531
	StdDev.	0.156	0.211	0.201	0.238
Average		1.364	1.369	1.447	1.501

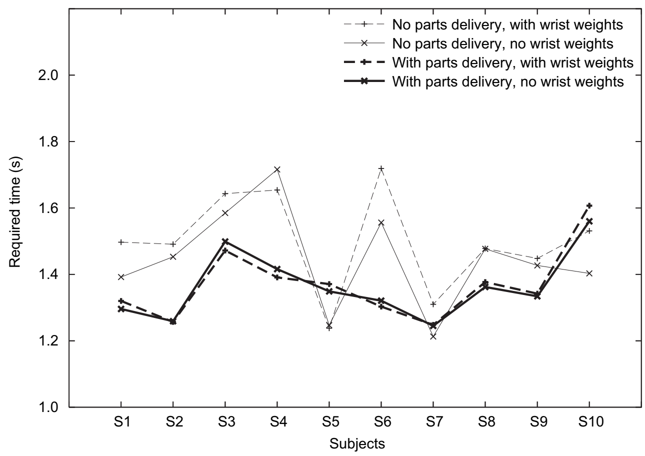


Fig. 10. Mean time required for disassembly process.

- Picking or returning parts from/to incorrect trays by forgetting to press the footswitch or pressing it twice. Such errors are rare in the case with parts delivery, since tray movement helps subjects to press the footswitch correctly.
- Trying to put pins in incorrect holes by violating the “left to right, top to bottom” sequence.
- Failing in inserting pins to holes due to jamming.

Time required for each individual step in assembly or disassembly sequence is measured as the interval for pressing the footswitch. When failures occur, the required time of the corresponding step becomes very large. These large values are removed as outliers from the experimental statistics.

3.2. Experimental Results

In calculating mean times and standard deviations (**Tables 1** and **2** and **Figs. 9** and **10**), highest and lowest 5% values are excluded as outliers, some being due to the failures discussed above.

We analyzed results based on the analysis of variance (ANOVA) using the following factors and levels:

- Factor **A**: Process type

Table 3. Table of ANOVA (necessary time for each process).

Source	SS	df	MS	F-ratio	p-value
S: Subjects	1.2807	9	0.1423		
A: Assembly or disassembly	20.3072	1	20.3072	655.3641	0.0000*
Error (**S**×**A**)	0.2789	9	0.0310		
B: Existence of parts delivery	0.4295	1	0.4295	12.3731	0.0065*
Error (**S**×**B**)	0.3124	9	0.0347		
C: Existence of wrist weights	0.0487	1	0.0487	20.2247	0.0015*
Error (**S**×**C**)	0.0217	9	0.0024		
Interaction (**A**×**B**)	0.0306	1	0.0306	10.7120	0.0096*
Error (**S**×**A**×**B**)	0.0257	9	0.0029		
Interaction (**A**×**C**)	0.0080	1	0.0080	4.4703	0.0636
Error (**S**×**A**×**C**)	0.0161	9	0.0018		
Interaction (**B**×**C**)	0.0122	1	0.0122	8.4167	0.0176*
Error (**S**×**B**×**C**)	0.0130	9	0.0014		
Interaction (**A**×**B**×**C**)	0.0000	1	0.0000	0.0001	0.9936
Error (**S**×**A**×**B**×**C**)	0.0067	9	0.0007		
Total	22.7914	79			

SS: sum of squares
df: degree of freedom
MS: mean square

∗: Significant at 5% level ($p < 0.05$)

- Level **a1**: Assembly
- Level **a2**: Disassembly

- Factor **B**: Presence of parts delivery by automatically moving trays (Section 3.1.3)
  - Level **b1**: Present
  - Level **b2**: Absent
- Factor **C**: Use of wrist weights (Section 3.1.4).
  - Level **c1**: Used
  - Level **c2**: Not used

Factors **A**, **B**, and **C** are within-subject, so we used three-way within-subject ANOVA to analyze data.

Table 3 details ANOVA for the time required for each process, demonstrating statistically significant differences with a 5% level in time required for each process between assembly and disassembly (**A**), parts delivery with and without automatically moving trays (**B**), and subjects wearing or not wrist weights (**C**). The significant difference in factor **B** confirms that parts delivery by automatically moving parts trays positively influences productivity.

Significant differences also arise in the interaction of the following:

1. Process type – assembly or disassembly – and presence of parts delivery (**A**×**B**)
2. Presence of parts delivery and use of wrist weights (**B**×**C**)

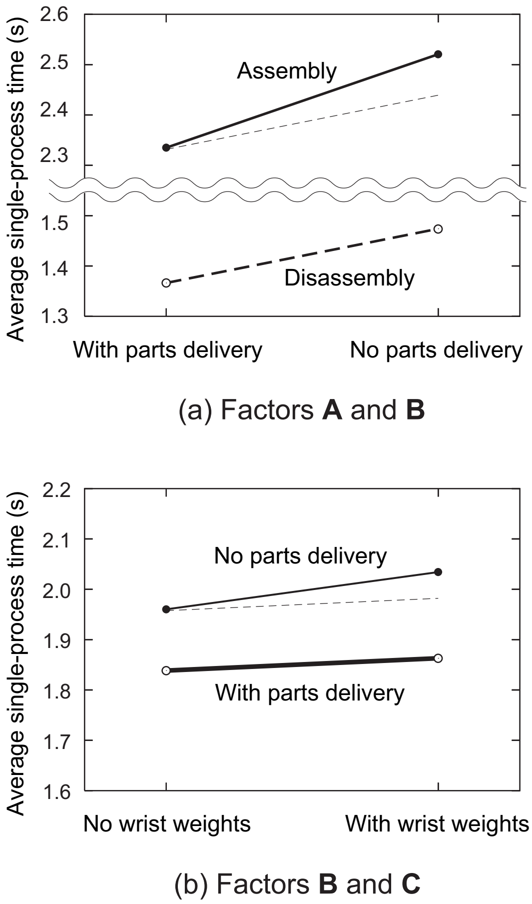


Fig. 11. Average times required for individual processes.

The average times required for individual processes with respect to interaction **A**×**B** are shown in **Fig. 11-(a)**, in which thin broken line represents an auxiliary line parallel to line for disassembly. In **Fig. 11-(a)**, note that the interval between top and bottom lines is greater without parts delivery than with it. In other words, the time required for each process by using automatic parts delivery is greater is more greatly improved in assembly than in disassembly. The average times required for individual processes with respect to interaction **B**×**C** are shown in **Fig. 11-(b)**, where thin broken line is an auxiliary line parallel to line for the case with parts delivery. In **Fig. 11-(b)**, note that the interval between the two lines is greater with wrist weights. In other words, deterioration in processing time due to the use of wrist weights is reduced by using parts delivery. This also suggests that our proposed physical assembly support using parts delivery by automatically moving trays is more effective when the physical load of workers is greater as when workers are, for example, comparatively old or very young.

4. Conclusions

To solve anticipated problems in the manufacturing industry, we have proposed the attentive workbench (AWB), a cell production system supporting human workers both informationally and physically.

We have implemented the prototype AWB, which consists of automatically moving parts trays, driven by planar motors, which deliver required parts to assembly workers.

We then quantitatively evaluated system productivity through actual assembly experiments, comparing it to conventional cell production. Results indicated that automatic parts delivery significantly reduces the time required for each assembly and disassembly process, especially when physical assembly task loads are larger.

5. Projected Work

In order to evaluate the present system with respect to the worker's feeling. we will carry out sensory evaluation.

We are currently applying biomeasurement for further understanding of the condition of workers in AWB [11]. Kotani has proposed a method for estimating activity of parasympathetic nervous system from the heart rates and respirations in real time, based on the analysis of respiratory sinus arrhythmia (RSA) with respect to respiratory phase [12]. This will be applicable to the monitoring of the mental workload of workers. To monitor the physical workload, we are studying a method for estimating the force and degree of muscle fatigue based on the surface electromyography (sEMG) data [13].

Delivering required materials to workers is assumed to effectively support desk workers in home and office environments. Such users handle highly diverse duties, e.g., computer operation, document reading and writing, and eating. Key issues here involve intuitive interface between users and the system, and estimation of user preferences or intentions.

Sato and Koike have proposed an intuitive interface called EnhancedDesk [14], which is a desk-type human-computer interface with augmented reality. Intention expressed by users through intuitive hand gestures are recognized by the system using cameras [15]. The system supports users by providing information through an LCD projector or plasma display.

Tamura et al. have proposed estimating users' intention by improving the accuracy gesture recognition by integrating sensor observation with the histories of user activity [16].

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References:

[1] S. Seki, "One by One Production in the 'Digital Yatai' – Practical Use of 3D-CAD Data in the Fabrication –," Journal of the Japan Society of Mechanical Engineering, Vol.106, No.1013, pp. 32-36, 2003 (in Japanese).

[2] G. Vasilash, "Cell for Assembly," Automotive Manufacturing & Production, June 1999.

[3] R. M. Barnes, "Motion and Time Study: Design and Measurement of Work," John Wiley & Sons, 7th edition, 1980.

[4] C. Reinhart and C. Patron, "Integrating Augmented Reality in the Assembly Domain – Fundamentals, Benefits and Applications," Annals of the CIRP, Vol.52/1/2003, pp. 5-8, 2003.

[5] Y. Yamada, H. Konosu, T. Morizono, and Y. Umetani, "Proposal of Skill-Assist: A System of Assisting Human Workers by Reflecting Their Skills in Positioning Tasks," Proc. of the IEEE Int. Conf. on Systems, Man and Cybernetics, pp. (IV)11-(IV)16, 1999.

[6] R. D. Schraft, C. Meyer, C. Parlitz, and E. Helms, "PowerMate – A safe and Intuitive Robot Assistant for Handling and Assembly Task," Proc. of the 2005 IEEE Int. Conf. on Robotics and Automation, pp. 4085-4090, 2005.

[7] Y. Hayakawa, T. Ogata, and S. Sugano, "Flexible Assembly Work Cooperating System Based on Work State Identifications by a Self-Organizing Map," IEEE/ASME Transactions on Mechatronics, Vol.9, No.3, pp. 520-528, 2004.

[8] B. A. Sawyer, "Magnetic Positioning Device," US patent 3,457,482, 1969.

[9] M. Sugi, Y. Tamura, J. Ota, T. Arai, K. Takamasu, and H. Suzuki, "Implementation of Human Supporting Production System 'Attentive Workbench'," Proc. of the SICE-ICASE International Joint Conference 2006, pp. 1270-1273, 2006.

[10] M. Erdmann and T. Lozano-Pérez, "On Multiple Moving Objects," Algorithmica, 2, pp. 477-521, 1987.

[11] F. Iida, K. Kotani, M. Sugi, J. Ota, T. Arai, and K. Takamasu, "Assessment of Mental Workload (5th report) – Development of the Extraction method on working scenes –," Proc. of the 2007 JSPE Semestrial Meeting, pp. 87-88, 2007 (in Japanese).

[12] K. Kotani, I. Hidaka, Y. Yamamoto, and S. Ozono, "Analysis of Respiratory Sinus Arrhythmia with Respect to Respiratory Phase," Method of Information in Medicine, Vol.39, pp. 153-156, 2000.

[13] Y. Soo, M. Sugi, H. Yokoi, T. Arai, R. Du, and J. Ota, "Simultaneous Measurement of Force and Muscle Fatigue Using Frequency-Band Wavelet Analysis," Proc. of the 30th Annual International IEEE EMBS Conference (EMBC 2008), pp. 5045-5048, 2008.

[14] Y. Nakanishi, Y. Sato, and H. Koike, "EnhancedDesk and EnhancedWall: Augmented Desk and Wall Interfaces with Real-Time Tracking of User's Motion," Proc. of Ubicomp2002 Workshop on Collaborations with Interactive Walls and Tables, pp. 27-30, 2002.

[15] K. Oka, Y. Sato, and H. Koike, "Real-Time Fingertip Tracking and Gesture Recognition," IEEE Computer Graphics and Applications, Vol.22, No.6, pp. 64-71, 2002.

[16] Y. Tamura, M. Sugi, J. Ota, and T. Arai, "Deskwork Support System Based on the Estimation of Human Intention," Proc. of the 13th IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2004), pp. 413-418, 2004.

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- M. Sugi, I. Matsumura, Y. Tamura, J. Ota, and T. Arai, "Quantitative Evaluation of Physical Assembly Support in Human Supporting Production System 'Attentive Workbench'," Proc. 2008 IEEE Int. Conf. on Robotics and Automation, pp. 3624-3629, 2008.

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- Y. Tamura, M. Sugi, J. Ota, and T. Arai, "Estimation of User's Intention Inherent in the Movements of Hand and Eyes for the Deskwork Support System," Proc. IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, pp. 3709-3714, 2007.
- Y. Tamura, M. Sugi, T. Arai, and J. Ota, "Target Identification Through Human Pointing Gesture Based on Human-Adaptive Approach," Journal of Robotics and Mechatronics, Vol.20, No.4, pp. 515-525, 2008.

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- M. Nikaido, M. Sugi, Y. Tamura, J. Ota, T. Arai, K. Kotani, K. Takamasu, A. Yamamoto, S. Shin, H. Suzuki, and Y. Sato, "Arrangement Planning for Multiple Self-Moving Trays in Human Supporting Production Cell 'Attentive Workbench'," Proc. 2005 IEEE/RSJ Int'l Conf. on Intelligent Robots and Systems, pp. 3880-3885, 2005.

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Main Works:
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- S. Hoshino, J. Ota, A. Shinozaki, and H. Hashimoto, "Improved design methodology for an existing automated transportation system with automated guided vehicles in a seaport container terminal," Advanced Robotics, Vol.21, No.3-4, pp. 371-394, 2007.
- J. Ota, "Multi-agent Robot Systems as Distributed Autonomous Systems," Advanced Engineering Informatics, Vol.20, No.1, pp. 59-70, 2006.

Membership in Academic Societies:
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- K. Kotani, Z. R. Struzik, K. Takamasu, H. E. Stanley, and Y. Yamamoto, "Model for complex heart rate dynamics in health and diseases," Physical Review E, 72, pp. 041904-1-8, 2005.

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- Y. Maeda and T. Arai, "Planning of Graspless Manipulation by a Multifingered Robot Hand," Advanced Robotics, Vol.19, No.5, pp. 501-521, 2005.
- T. Yan, J. Ota, A. Nakamura, T. Arai, and N. Kuwahara, "Development of a Remote Fault Diagnosis System Applicable to Autonomous Mobile Robots," Advanced Robotics, Vol.16, No.7, pp. 573-594, 2002.
- T. Arai, Y. Aiyama, M. Sugi, and J. Ota, "Holonic Assembly System with Plug and Produce," Computer in Industry, Vol.46, pp. 289-299, 2001.

Membership in Academic Societies:
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- K. Kotani, K. Takamasu, Y. Jimbo, and Y. Yamamoto, "Postural-induced phase shift of respiratory sinus arrhythmia and blood pressure variations: insight from respiratory-phase domain analysis," American Journal of Physiology-Heart and Circulatory Physiology, Vol.294, pp. 1481-1489, 2008.
- Y. Kajihara, Y. Inazuki, T. Takeuchi, S. Takahashi, and K. Takamasu, "Evanescent light photopolymerization and measurement of cure depth in nanostereolithography," Applied Physics Letters, Vol.92, 093120, pp. 1-3, 2008.

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Main Works:

- J. Mitani and H. Suzuki, "Making Papercraft Toys from Meshes using Strip-based Approximate Unfolding," ACM Trans. Graphics, Vol.23, No.3, pp. 259-263, 2004.
- H. Suzuki, T. Fujimori, T. Michikawa, Y. Miwata, and N. Sadaoka, "Skeleton Surface Generation from Volumetric Models of Thin Plate Structures for Industrial Applications," Mathematics of Surfaces XII, Lecture Notes in Computer Science, LNCS 4647, Springer, pp. 442-464, 2007.
- Y. Igarashi, T. Igarashi, and H. Suzuki, "Knitting a 3D Model," Proc. Pacific Graphics 2008, J. Computer Graphics Forum, Vol.27, No.7, pp. 1737-1743, 2008.

Membership in Academic Societies:

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- A. Yamamoto, S. Nagasawa, H. Yamamoto, and T. Higuchi, "Electrostatic Tactile Display with Thin Film Slider and Its Application to Tactile Tele-Presentation Systems," IEEE Trans. Visualization & Computer Graphics, Vol.12, No.2, pp. 168-177, Mar. 2006.
- E. van West, A. Yamamoto, and T. Higuchi, "The Concept of "Haptic Tweezer," a Non-Contact Object Handling System Using Levitation Techniques and Haptics Mechatronics," Mechatronics, Vol.17, No.7, pp. 345-356, Sep. 2007.

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- I. Sato, Y. Sato, and K. Ikeuchi, "Illumination from shadows," IEEE Trans. Pattern Analysis and Machine Intelligence, Vol.25, No.3, pp. 290-300, Mar. 2003.
- I. Sato, T. Okabe, and Y. Sato, "Appearance sampling of real objects for variable illumination," International Journal of Computer Vision, Vol.75, No.1, pp. 29-48, Oct. 2007.

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- D. H. Kim and S. Shin, "Local path planning using a new artificial potential function composition and its analytical design guidelines," Advanced Robotics, Vol.20, No.1, pp. 115-135, 2006.
- H. Kuzuya and S. Shin, "Development of robust motor servo control for rear steering actuator based on two-degree-of-freedom control system," Mechatronics, Vol.10, No.1-2, pp. 53-66, 2000.

Membership in Academic Societies:

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- J. Nielsen and F. Kimura, "A Resource Capability Model to Support Product Family Analysis," JSME International Journal, Series C, Vol.49, No.2, pp. 568-575, 2006.
- F. Kimura, Y. Matoba, and K. Mitsui, "Designing Product Reliability based on Total Product Lifecycle Modelling," Annals of CIRP, Vol.56, No.1, pp. 163-166, 2007.

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