Statistical Analysis of Index Values Extracted from Outdoor Agricultural Workers Motion Data

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***Abstract*—We have been developing various kinds of promising applied sensing systems to resolve difficulty in achieving agricultural advancement, technical tradition (teaching), and safety issues. Existing methods and systems are not enough to analyze human motion minutely, simply, and at low-cost. For the purpose, we have also been developing Wearable Sensing Systems (WSs), including advanced devices, to secure real-time data related to worker motion by analyzing human dynamics and statistics in rice fields, meadows, and gardens. We have obtained and observed those time-line data, computed by some statistical methods, discussed about them, and make some suggestions concerning them. Our plans would make it possible for us to improve worker agricultural skills and to enhance their safety level.**

***Index Terms*—wearable sensing system, statistical analysis, tradition of skill, support for workers, detecting crisis, integrated sensor system**

I. Introduction

According to Nanseki's team (2003), there are modern problems about the critical shortage of young, beginning (novice) agricultural workers and methods concerning tradition of skills from mature (experienced) workers to immature (inexperienced) [1]-[4].

On the other hand, in proportion to the expansion and complication of methodologies, the field of "Agricultural Informatics" is growing and advancing [5], [6].

In past studies, however, there is no research concerning "concrete user suggestions" for improving physical motions in agricultural work, especially for beginners and immature workers.

Therefore, our research supports such agricultural workers (and their daily actions) by utilizing electronic technologies, human dynamics and statistical methods (etc. using major indicators of statistics and of wave analysis), and by providing them with concrete feedback (etc. by oral, visual, and some pieces of data-paper).

For the future, several sensing techniques and existing large-size farming machinery, the newest IT services (cloud services, etc.), and other tools should be integrated, with ubiquitous tools breaking through. Under these circumstances, we have been building integrated systems to raise productivity, accuracy, and the quality concerning the tradition of skills in those fields by analyzing recorded data and extracting useful insights and clues for the future at outer fields.

II. Materials and Method

A. System

We reviewed past accomplishments of industrial goods, patents, and academic papers and we discussed our findings with researchers in Agricultural Informatics, actual workers, and farmland managers. What became evident was that past studies and politics prove insufficient when considering such problems.

In light of our results (Kawakura 2013), we shaped plans [7].

We designed system constructs to measure and to analyze acceleration (and angular velocity) data by general human dynamics and statistics [8]. In addition, we provide direction to users and their managers simultaneously, and to improve and to upgrade their skills and safety.

After designing the system, we selected some existing, promising techniques and modules. We made approximate schedules and designed each part (e.g. mechanical constructions, computer systems, and kinds of procedure to process). In light of this, we have been doing some indoor operational testing to estimate systems' utility and suitability.

Our members especially want to develop new integrated structures by utilizing original Wearable Sensing Systems (WSs) aiming to enhance the utility, flexibility, and endurance in event of sudden accidents and tough conditions in real situations (see Fig. 1-Fig. 3). We obtained basic time series of acceleration and angular velocity data (after that, FFT (Fast Fourier Transform) analysis was also performed to certify these validity). And angular velocity data related to subjects' various daily, typical postures and typical actions (e.g. standing

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upright, sitting on chair, lying down, walking, running, etc.) of subjects were also analyzed by original programs using Visual Basic 2010, Visual C++2010, Java 5.0.

Figure 1. Microcomputers with various devices, store-bought sensing modules, and original vest-shaped and belt-shaped WSs

Figure 2. Hoe connected to sensors and laptop PC

Figure 3. One subject equipped with measuring modules and knapsack with laptop PC connecting to various modules

Figure 4. Subject digging up field

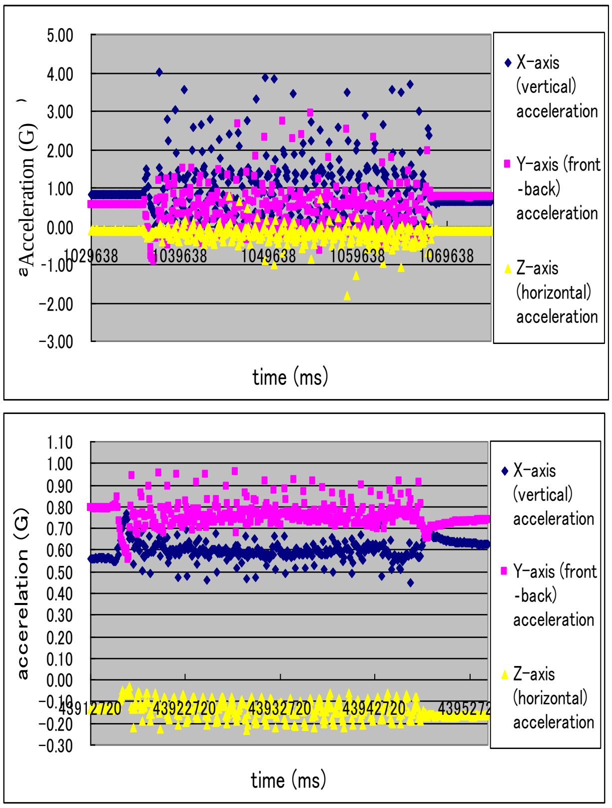

Figure 5. One example set of graphs concerning acceleration values (upper: from the sensor on holding position of a hoe; lower: from the sensor on the right side of subject's waist)

B. Selection of Task

We categorized common agricultural tasks (see Table I). And, we selected "2. Work in a semi-crouching position: Cultivating (digging up) by a hoe (see Fig. 4 and Fig. 5), because this movement is repetitive and rather large "full-body motion".

Every trial was "30 swings" (digging up), and every subject tried three trials successively on the same day (see Fig. 6). We observed their daily tasks and conducted various hearings, and the style and number of sets seemed appropriate for this study.

TABLE I. CATEGORIZATION OF AGRICULTURAL TASKS (IN THIS STUDY)

Categorization of tasks	Description
1. Work in a sitting position	Harvesting from general root plants by hand, cumbersome; successive procedures (e.g. digging holes and overlaying clay, spraying water)
2. Work in a semi-crouching position	Cultivating (digging) by a hoe
3. Work in a standing position	Cutting branches by shears and saw
4. Work alternating in a sitting and a standing position	Suspending onions or garlic on beams in an outhouse

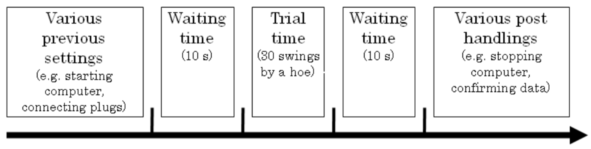

Figure 6. Time line of each trial

C. Survey Sheet

We chose major items (indicators) in the field of "human dynamics" and "exercise physiology", to obtain the "features" and "changes" of agricultural workers (see Table II).

"VAS" is a psychometric response scale that can be used in questionnaires [9]. It is an instrument for subjective characteristics or attitudes. But these cannot be directly measured. When responding to a VAS item, respondents specify their level of agreement to a statement by indicating a position along a continuous line between two end-points. This continuous (or "analogue") aspect of the scale differentiates it from discrete scales.

"The Borg RPE Scale (RPE)" measures perceived exertion, in sports and particularly in exercise testing [10]. In medicine, this scale is used to document the patient's exertion during a test, and sports coaches use the scale to assess the intensity of training and competition. The original scale rated exertion on a scale of 6-20. (For instance, a perceived exertion of 12 would be expected to coincide with a heart rate of roughly 120 beats per minute.) We also asked about subjects' fitness habits, smoking habits, and their backache, just to make sure about subjects.

D. Indicators

After basic trials, we defined some major indicators, concerning acceleration value of vertical direction: 1) Maximum value, 2) Minimum value, 3) S.D. (Standard Deviation), and 4) DC (Direct Current) component.

Bao (2003) [11] and other researchers have been used such things. Especially, "S.D." and "DC component" have been shown as useful values.

We probatively used large-sized "correlation matrix", "analysis of principal component". Because these are considered valid methods to categorize catch-call persons and their data.

TABLE II. SURVEY SHEET ITEMS

Type	Description
Basic information about subjects	Name, mature or immature, age, years of experienced (including frequency of work), stature, weigh
VAS (Visual Analogue Scale)	measuring level of fatigue,
RPE (Borg RPE Scale)	measuring intensity and perceived exertion concerning each task

E. Subject

We selected 10 subjects (see Table III). They do not have remarkable (serious) characters both mentally and physically. Because they did not have serious diseases, remarkable habits, and specific careers. Mature worker S.D. values concerning each index are rather higher than those of immature workers.

TABLE III. SUBJECT'S BASIC INFORMATION

Group	Index	Value	S.D.
mature (N = 5)	age	31～74 years old	14.39
	experience	2 ～60 years	18.15
	stature	155 ～ 173 cm	5.9
	weigh	55 ～ 85 kg	8.9
	status	full-time farmer and part-time farmer	-
	sex	male	-
immature (N = 5)	age	23～38 years old	3.59
	experience	0 years	0
	stature	170 ～ 180 cm	3.88
	weigh	58 ～ 78 kg	7.01
	status	graduate student, researcher	-
	sex	male	-

III. RESULTS AND DISCUSSION

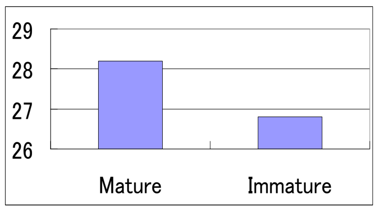

Figure 7. Average values of VAS (0 - 100 points)

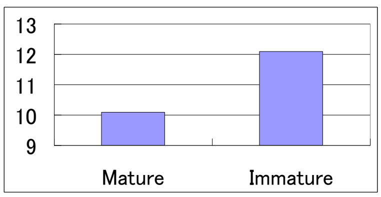

Figure 8. Average values of RPE (6 - 20 points)

We have conducted necessary operating verifications concerning each function of the aforementioned systems' factors and essential experimental results concerning WSs. Each performance observed as appropriate only for actions not containing "moving over" such as walking or cycling, targeted in this study.

TABLE IV. SUBJECT'S BASIC INFORMATION

Index	Age (year)	Experience (year)	Stature (cm)	Waight (kg)	VAS (point) (%*100)	RPE (Point)	Max of the hoe (1st trial (G))	Min of the hoe (〃)	S.D of the hoe (〃)	DC Component of the hoe (〃)	Max of the hoe (3rd trial (G))	Min of the hoe (〃)	S.D of the hoe (〃)	DC Component of the hoe	Max of the waist (1st trial (G))	Min of the waist (〃)	S.D of the waist (〃)	DC Component of the waist	Max of the waist (3rd trial (G))	Min of the waist (〃)	S.D of the waist (〃)	DC Component of the waist (〃)
Age (year)	1.00																					
Experience (year)	0.89	1.00																				
Stature (cm)	-0.69	-0.80	1.00																			
Weight (kg)	-0.45	-0.39	0.67	1.00																		
VAS (point) (%*100)	-0.22	-0.47	0.42	-0.34	1.00																	
RPE (Point)	-0.29	-0.47	0.03	-0.50	0.73	1.00																
Max of the hoe (1st trial (G))	0.87	0.89	-0.65	-0.42	-0.11	-0.21	1.00															
Min of the hoe(〃)	0.81	0.64	-0.64	-0.35	-0.40	-0.25	0.44	1.00														
S.D of the hoe(〃)	0.68	0.85	-0.60	-0.53	-0.16	-0.39	0.77	0.32	1.00													
DC Component of the hoe(〃)	0.84	0.98	-0.83	-0.35	-0.53	-0.44	0.88	0.59	0.78	1.00												
Max of the hoe (3rd trial (G))	0.54	0.54	-0.65	-0.31	-0.14	0.20	0.72	0.27	0.23	0.65	1.00											
Min of the hoe(〃)	0.91	0.72	-0.44	-0.24	-0.24	-0.43	0.62	0.88	0.51	0.62	0.20	1.00										
S.D of the hoe(〃)	0.79	0.88	-0.64	-0.56	-0.04	-0.23	0.93	0.35	0.94	0.84	0.49	0.55	1.00									
DC Component of the hoe(〃)	0.90	1.00	-0.78	-0.33	-0.51	-0.50	0.88	0.66	0.80	0.99	0.57	0.73	0.85	1.00								
Max of the waist (1st trial (G))	-0.49	-0.34	0.56	0.74	-0.03	-0.14	-0.14	-0.73	-0.35	-0.24	0.08	-0.56	-0.27	-0.30	1.00							
Min of the waist (〃)	0.53	0.48	-0.55	-0.38	-0.43	-0.33	0.13	0.85	0.36	0.39	-0.15	0.68	0.22	0.47	-0.86	1.00						
S.D of the waist(〃)	0.18	0.54	-0.62	-0.50	-0.20	-0.05	0.47	-0.13	0.71	0.58	0.36	-0.15	0.65	0.49	-0.06	0.01	1.00					
DC Component of the waist(〃)	0.67	0.64	-0.75	-0.56	-0.42	-0.24	0.33	0.88	0.51	0.58	0.09	0.70	0.41	0.63	-0.88	0.96	0.20	1.00				
Max of the waist (3rd trial (G))	-0.79	-0.88	0.76	0.46	0.20	0.14	-0.97	-0.37	-0.75	-0.91	-0.81	-0.47	-0.90	-0.88	0.11	-0.09	-0.63	-0.33	1.00			
Min of the waist(〃)	0.78	0.86	-0.53	0.10	-0.67	-0.71	0.75	0.58	0.56	0.88	0.51	0.70	0.61	0.90	0.00	0.33	0.22	0.42	-0.72	1.00		
S.D of the waist(〃)	-0.88	-0.95	0.69	0.18	0.61	0.65	-0.76	-0.75	-0.72	-0.92	-0.40	-0.83	-0.72	-0.96	0.35	-0.61	-0.30	-0.70	0.72	-0.93	1.00	
DC Component of the waist(〃)	0.83	0.75	-0.42	0.05	-0.55	-0.67	0.58	0.83	0.44	0.70	0.24	0.93	0.46	0.78	-0.32	0.62	-0.13	0.62	-0.47	0.87	-0.91	1.00

Average VAS and RPE values are described (see Fig. 7 and Fig. 8). The average value of VAS was differenced little. On the other hand, RPE showed a distinct difference (about two points of 15 degrees). We thought these results were due to "experience" and "skill" of the mature group. Total correlation matrix is Table IV.

1) Only concerning matrix from a hoe's and waist's time series of acceleration data, there were many strong correlations (over 0.8 points and under -0.8 points of correlation coefficients).

2) In particular, there were eminently strong correlations (0.8 ～ 0.99 points or -0.8 ～ -0.99 points) when Index about "S.D." and "DC component" were concerned.

We think, as Bao (2003) and other researchers have been mentioned, these indexes are effective for grasping such repetitive, dynamic actions.

3) Interestingly, user weights, VAS points, and RPE points show any have correlation concerning indexes of movements.

In other words, weight, fatigues and movement intensity were little concerned with objective indexes extracted from acceleration data noted in the foregoing.

4) Index "Age" and "Experience" are likely to affect almost all hoe acceleration indexes concerning those of 1st and 3rd trials and waist acceleration indexes only concerning 3rd trial.

The level of proficiency, skills, and their ages in themselves may be likely to affect only their hand movement for a long time, but not likely to affect their movement concerning waist (trunk) so long a time.

We also think that these tendencies are due to user "postures". In other word, the changes in time-line styled data concerning time line of acceleration data of mature workers are completely more gradual and smoother. Sudden movements are virtually absent. The nature could be observed visually too.

After this research, we have been trying the aforementioned "analysis of principal component" (from standardized data because of future scientific developments and versatilities).

We could call "the primary ingredient" (Fig. 9) as "The (hidden) factor that affects hoe (hand) motions for a long time"; on the other hand, "the secondary ingredient" as "The factor that affects waist (trunk) motions from the beginning, but hardly affects after that".

We think that these two indexes may have resulted from characteristics of mature and immature workers, their traditional skills, and the experience of 20 or more years.

Of course, their physical (muscle) strength, stature, and weight must be considered.

Many problems remain with this analysis. Those may be solved by increasing subject number and variation, or by limiting their stature and weight to the extent possible. But, both in this and in other research, those must be challenging problems.

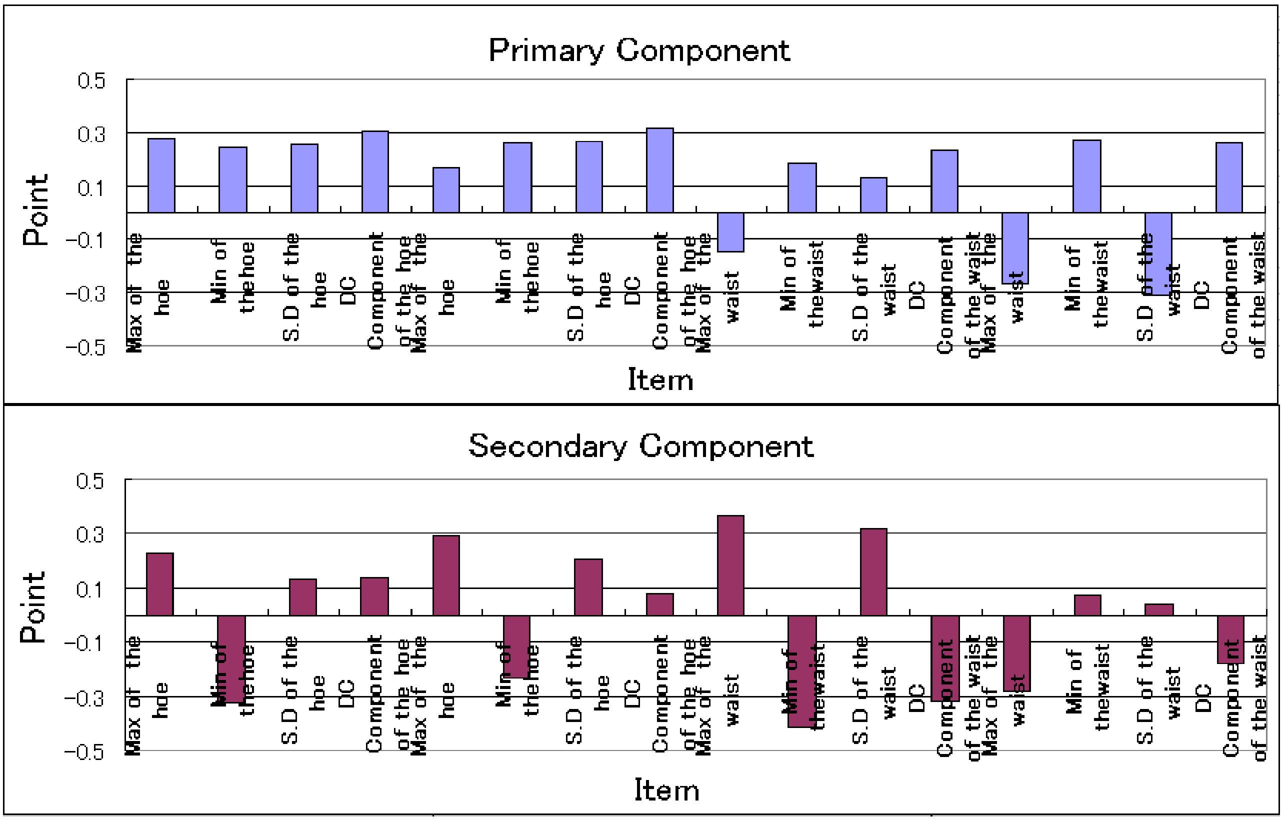

Figure 9. Results from analysis of principal component; Eigenvector (upper: only from the values concerning worker acceleration (hoe, waist); lower: including subject's basic information in Table III)

IV. Conclusion and Future Work

Our studies have exemplified several basic steps of the aforementioned styles of systems and methods by examining actual work sites. Our research has obtained promising prospects, especially concerning the fusion of Agricultural Informatics, statistics, and Human Dynamics to some extent. But their endurance and validity must be confirmed later; above all, we should add a greater variety of worker data into these statistical data.

And, other recent methodologies of human dynamics and visual data analysis (e.g. higher mathematics) should be tested and incorporated. What is more, we have been obtaining more various data, and been sending instructions to actual workers, particularly about "skill tradition" and their daily tasks, after certifying their usefulness.

We also think that, reviewing the entire results and work products will prove that the measure of precision for diagnosing critical situations (e.g. heavy diseases, injuries) will be improved. The stability of the whole system against sudden accidents will also be improved in the future. The reason is that irregular posture data can certainly be diagnosed.

In addition, we plan to involve other natural outdoor farms, artificial indoor farms, and other industries (situations) in considering robustness and stability. Furthermore, utilizing these results and many sets of experimental evidence, we plan to launch practical supporting projects for workers. And, from the view point of global agricultural dynamics, we have some plans to launch to other countries.

These trials have been certainly challenging so far; however, they will cover worker contribution to agricultural industries comprehensively.

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