Analysis of State of Changes in Human Movement Characteristics due to Triangular Configuration in Load Cell Sensor Structures

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Abstract: Triangular Configuration Measurement Method (TCSM), which measures the weight or force of an object using a balanced central point, is a technology continuously evolving through the use of load cells. This technology, utilizing high-precision and high-sensitivity load cells, is well-suited for extremely precise measurements as nano- and micro-sensors. Conventional measurement methods using load cells require numerous equations to account for errors in the system configuration or detected signals during the stage of collecting load changes at specific points. The Triangular Configuration Measurement Method (TCSM) with a balanced central point measures changes in vertical load (force) at the object's center of gravity. It collects electrical signals representing load changes at the measurement site via load cells and detects variations over time. This system enables smooth measurement of a wide range of change magnitudes. The minute shaking of an object caused by vibration means that even slight sway or balance movement sufficiently reflects the amplitude of change. In TCSM, the load cell signal undergoes amplification and integration of the constant signal in the amplification section before being transmitted to the microprocessor. The transmitted signal is configured for real-time data transmission and remote monitoring via a wireless communication module, sent to the embedded smart module. The measured vibration changes are within a frequency range of 1 to 20 Hz.

Triangular configuration measurement system (TCSMS) with a balanced central point incorporating a load cell produced the following results: The tremor motion-state of the TCSMS-FA-τMAX was 26.03±5.53 units from the sprinkling white-wave-like-dot echo, while the tremor motion-state of the TCSMS-CO-τMAX was 12.13±2.19 units, the tremor motion-state of the TCSMS-FL-τMAX was 4.18±0.74 units, and the tremor motion-state of the TCSMS-VI-τMAX was (0.74±0.11) units.

We can utilize this system, composed of load cells designed in the triangular configuration measurement method (TCSM) with balanced central points, for precision medical devices and measuring instruments. The load cell can serve as an indicator for monitoring similar aspects such as electrocardiogram, tension, compression, pressure, or torque.

Keywords: Tremor Motion-State, Triangular Configuration Measurement Method System, Load Cell Triangular Configuration Measurement Method, Load Cell.

Introduction

The use of a balanced triangular configuration measurement method is a continuously required technique for measurement an object's weight or force. To utilize the displacement of an object's center of gravity (CoG), electrical signals such as tension, compression, pressure, or torque are collected from load cells. These signals, similar to biological signals, are used as indicators to monitor changes in force (Lahasan et al., 2018). A recent trend involves observing the repetitive movement of blood flowing through blood vessels during heartbeats in the human body. Analyzing this movement helps assess the impact on cardiac function. The cycle of blood ejected from the ventricles passing through the heart into the aorta is influenced by the transmitted signal's effect on the body's response. Signals obtained by measurement vibrations caused by changes in cardiac blood flow manifest as biological signals within the approximate frequency range of 1 to 20 Hz, reflecting the mechanical motion of the heart (Best-Rowden and Jain, 2018).

Load cell technology, which measures the weight or force of an object, utilizes nano- and micro-sensors to enable highly precise measurements. This technology is employed in precision medical devices and advanced industrial electronic measurement instruments for its high accuracy and sensitivity. Smart load cells with built-in wireless communication modules enable real-time data transmission and remote monitoring. This system is expanding beyond industrial sites into diverse fields integrating IoT, such as smart logistics, agriculture, and food inspection (Guikema, 2017). It is also used in automation and manufacturing processes for tasks like product weight measurement, quality inspection, and robotic manipulation. It is implemented throughout the logistics distribution process, automatically loading and unloading all objects, packaging goods, and verifying items.

The triangular configuration load cell system employs patterns for evaluating sway or vibration in motion from structural, data, or analytical perspectives (Telke and Beitelschmidt, 2015). The triangular configuration measurement method, balanced at the central point, is a three-point measurement technique. It uses three load cells arranged in a triangular formation to precisely detect changes in load distribution on a planar object within the triangular configuration. It measures the change in vertical force at the load cell's three points as the object's center of gravity (centroid) shifts. Minor object oscillations represent sway caused by vibration, while load changes over time manifest as balance movement. The concept of the triangular configuration method lies in its advantage of detecting changes in an object's load distribution in real-time by arranging three load cells in a triangular formation.

Triangular configuration measurement method with balanced center points is being implemented. This system estimates the center of pressure (CoP) and ground reaction force (GRF) at a three-point configuration by arranging load cells—typically used in force plates with four or more points—in a three-point layout (KoBler et al.,). Variables applied to evaluate balance include path length, average velocity, RMS, area, and frequency spectrum. By identifying the movement of the swaying center of gravity based on the CoP, these variables are used to assess measurement methods in biomechanics. Load cell is designed using the triangular configuration measurement method (TCSM), which achieves balance at the three points of a triangular configuration, enabling its use in precision medical devices and measurement instruments. Measurement the phenomenon of object vibration in the load cell involves detecting forces generated by tension, compression, pressure, and torque that vary over time at the points of the triangular configuration (Tamura et al., 1978). The application of load cells utilizing TCSM enables the measurement of precise weight changes in motion. This is employed in the medical and biotechnology fields for weighing the human body and is used in health-related devices for wearable healthcare.

Materials and Methods

Triangular Configuration Technology (TCT)

Triangular Configuration Technology (TCT) estimates the trajectory of movement from the object's center of pressure (CoP) using load changes, as shown in Figure 1, and reflects the movement pattern of the center in dynamic stability, vibration characteristics, and sway patterns. A uniaxial load cell using a three-point configuration enables a more mobile platform compared to a multi-axis load cell. Load cells using a three-point configuration utilize the central axis between the pressure center and ground reaction force as a variable for evaluating changes. The types of variables used—path length, average velocity, RMS, area, frequency, and spectrum—facilitate the implementation of actual phenomena or analysis through mechanical changes (Augustine et al., 2014; Malekzadeh et al, 2009). When using a three-point load cell on a force plate for human subjects, it detects object sway based on the center of pressure (CoP) on the force plate.

Triangular Configuration Technology (TCT) consists of three load cells arranged in an equilateral or isosceles triangle configuration. Each load cell measures forces F_1, F_2, and F_3. When the object sways or its center of gravity shifts, output values are generated from the three sensors, producing signals that change proportionally to form a varying value. The load cells used in the three-point configuration have their primary axis aligned with the Z-direction, where the applied load force acts.

Load cells used in the three-point configuration are positioned at the vertices of a triangle. This configuration is designed to measure the object's Center of Gravity (CoG) or Center of Pressure (CoP). It enables precise detection of subtle signals, allowing for accurate measurement of vibrations, oscillations, and minute weight shifts.

In human movement, load cells measure load changes at each tree-point, calculating shifts in the center of gravity through minute load variations. When an object sways, the trajectory changes in the CoP are calculated over time, breaking down vibration, translation, and rotation components into distinct patterns (Shadnam et al., 2002; VaseghiAmiri . et al., 2013).

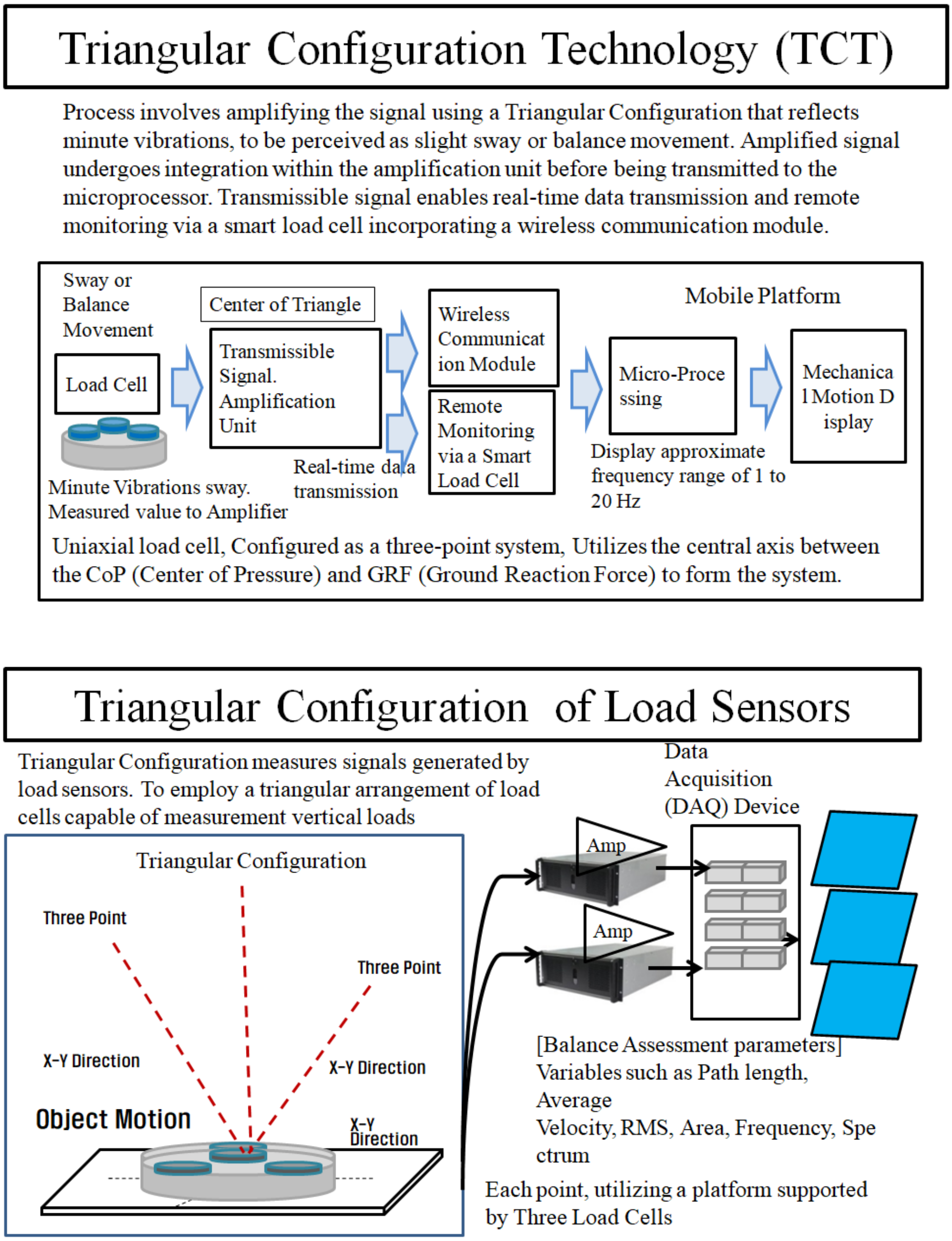

Figure. 1 Mutational Status of Triangular Configuration Technology (TCT) from CoP (Center of Pressure) functions at the body location detecting sway.

Tremor Triangular Configuration Methods

Triangular Tremor Triangular Configuration (Tre-TC) system's characteristics dictate that the operational waveform is considered in terms of its frequency pattern according to the output pattern. Since it represents actual movement, it is measured by adjusting the frequency range to 200 to 1000 Hz or lower depending on the measurement purpose, necessitating the use of an anti-aliasing filter. Considering the high-frequency or low-frequency characteristics of the signal, noise is removed in the 0.1 to 20 Hz band. The frequency components of the signal are analyzed using PSD or FFT, focusing on the CoP region and specific time intervals, to assess the tremor state (Kim. et al., 2017).

In the Tre-TC system, estimation and calibration techniques collect data by limiting reconstruction to the horizontal component of lateral force and moment between the CoP movement confirmed at the three-point and the GRF. The collected signals are then calibrated using machine learning or deep learning. Furthermore, using the calibration model, the system was configured to generate the force plate reference value by utilizing the center axis based on the CoP, ensuring the Tre-TC system forms a uniform velocity change in the object.

Tremor Triangular Configuration Form

Tremor Triangular Configuration Form (Tre-TCF) in a three-point triangular configuration detects loads in the Z-direction between load cells, confirming the object's lateral or front-to-back sway through the sensor's load signal. Within Tre-TCF, a mechanism occurs that identifies static or quasi-static states from the equilibrium state of forces or moments and reconstructs the triangular configuration signal. The Tremor Triangular Configuration Measurement Level (Tre-TCML) represents the recognized signal from the blur motion-state-changing-status as a measured value. The Tre-TCF shown in Figure 2 is composed of the blur motion-state-changing-status signal, calculated based on the recognition rate observed in the triangular configuration measurement.

Triangular Configuration Technology (TCT) for load cells arranged in a three-point configuration uses forces F1, F2, and F3, which are selected as the forces moving the CoP vertically in each direction, and calculates the total vertical load as F1 + F2 + F3. The CoP coordinates are determined from the values of each axis (XCo1, YCo2, ZCo3) in the platform coordinate system using the load cell positions (xi, yi) and moment equilibrium based on the applied forces (Eq. 1~4). Even under asymmetric loads or dynamic conditions, measurements were made considering inertial effects based on the relationship between the axial sensitivity and transverse response of the load cells.

For signals generated by loads based on blur motion-state-changing-status of moving objects, triangular configuration measurement centered on the CoP was modeled and monitored using tremor triangular configuration methods for estimation (Kim J. and Kim K., 2017; (Kim. et al., 2014). Total Weight was calculated using the formula Ftotal(t) = FA(t) + FB(t) + FC(t). This formula was used to determine the load cell position at the Center of Pressure (CoP) from the Triangular Configuration Technology (TCT), facilitating easy calculation. The coordinates of each axis were then calculated in the (xA, yA), (xB, yB), and (xC, yC) directions. The force trajectories (xCoP(t), yCoP(t)) over time were evaluated as microvibrations of the sway (Eq. 3, 4).

$$\mathrm{Cop}_x = \frac{(F3-F2)}{F1+F2+F3} \qquad \mathrm{Cop}_y = \frac{(F3-F2)}{F1+F2+F3} \tag{1}$$

$$x_{CoP}(t) = \frac{F_A(t)x_A + F_B(t)x_B + F_C(t)x_C}{F_{total}(t)} \tag{2}$$

$$y_{CoP}(t) = \frac{F_A(t)y_A + F_B(t)y_B + F_C(t)y_C}{F_{total}(t)} \tag{3}$$

$$\sum \sqrt{(\Delta x_{Cop})^2 + (\Delta y_{Cop})^2} \tag{4}$$

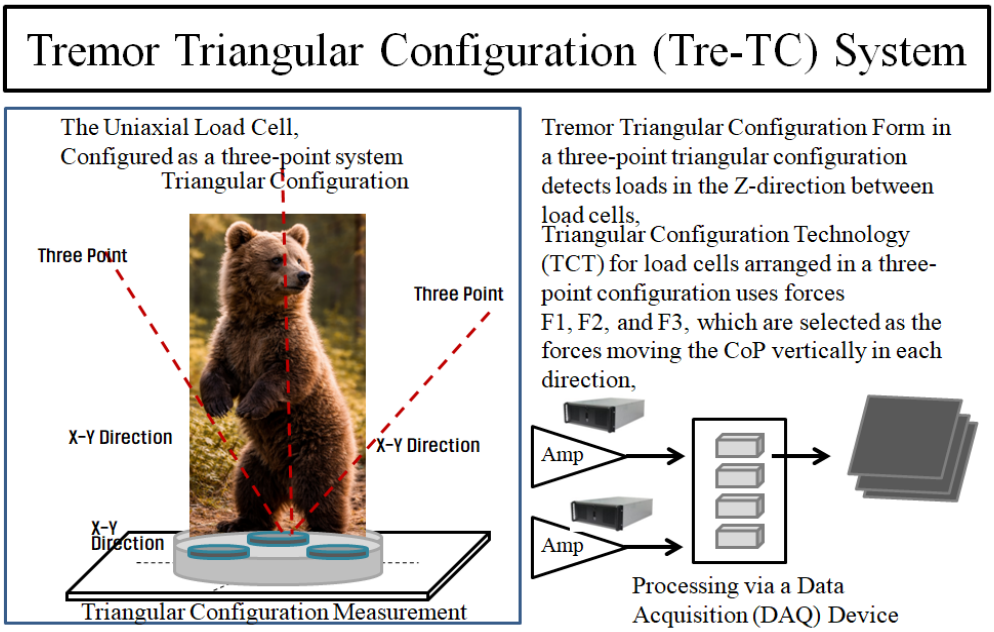

Figure 2. System block of Tremor Triangular Configuration Form (Tre-TCF) is technology on the tremor triangular configuration measurement with by blur motion-state-changing-status technology

Triangular configuration measurement Technique Dot

Triangular Triangular Configuration Measurement Technique Dot (Tri-CMTD) maintains stability when positioned at the center point of a triangle. It utilizes triangular configuration measurement motion to express dot scores as ratios. Using position and force from the load cell, it represents the far-side triangular ratio (FSTR) based on equilibrium and the near-side triangular ratio (NSTR) appearing on the peripheral side. As sway increases, the CoP trajectory widens outward. The standard deviation is measured from the load cell as the CoP (center of pressure). It is expressed as the ratio of the white-wave-like-dot from the center layer to the lateral layer, and the ratio of the position path relative to the surrounding boundary surface, using the units (Kim J. and Kim K., 2016; Bekkali . et al., 2015).

Static accuracy of the Triangular Configuration Measurement Technique Dot (Tri-CMTD) ranges from several millimeters to several centimeters in CoP position error, evaluated using a system incorporating balance assessment, vibration analysis, and stability. The three-point system, which defines the error deviation range based on position, improved the new changes affecting the force plate during interpolation correction and regression correction between calibration matrices. The dynamic response of Tri-CMTD is characterized by components arising from sensor and structural resonance phenomena and noise at frequencies above 20 Hz. At frequencies between 0.1–5 Hz, it exhibits balanced or compensatory behavior, resulting in energy amplification according to its characteristics.

Triangular configuration measurement Form

Triangular Configuration Measurement-Form (Tri-CMF) represents the sustained vibration state over time from the center of mass displacement. It is expressed as the average of Tri-CMF-FV and Tri-CMF-FC at the center position, derived from the load cell output (t) at the corner of the Tremor Triangular Configuration during equilibrium between $\bar{x}$ and $\bar{y}$ for the Mean CoP under load variation. The sum of load cells reaching the three-point system from the total load expresses the load of minute changes as the Tri-CMF value and is represented by the Ψ-Tri-CMTD value.

In FV and FC, Ψ-Tri-CMTD was shown to be based on Tri-CMF as in Equation (5). In the triangular configuration measurement-form (Tri-CMF), the tremor layer was expressed as the sum of Tri-CMF-FV and Tri-CMF-FC (DiGiampaolo and Martinelli, 2014).

$$\mathrm{Tri-CMF} = \sum \sqrt{(\Delta x \Psi_{\mathrm{Tri-CMTD}})^2 + (\Delta y \Psi_{\mathrm{Tri-CMTD}})^2} \quad (5)$$

Mean Velocity in Tri-CMF measured path length by calculating center-of-mass displacement based on load distribution at the center of pressure (CoP), with temporal variation appearing as the object's sway velocity.

The Root Mean Square (RMS) displacement at the CoP from the Tri-CMF was represented by the amplitude magnitude, and the Power Spectrum Density (PSD) measured periodic vibration frequency components for FFT processing. The frequency of the Tri-CMF was measured as the object's vibration period using the maximum peak frequency of the PSD (Fujino et al., 2011).

Results and Discussion

Tremor triangular configuration-form data sequence

Tremor Triangular Configuration-Form System (Tre-TCFS) constructs the object's trembling time from the CoP trajectory into a pattern comprising vibration, translation, and rotational components. It forms a tremor triangular configuration within the Tri-CMT and arranges the load cells in a three-point configuration as an equilateral or isosceles triangle to measure vertical load. A platform with a fixed three-point load cell configuration was placed on a plane. The measured response signals were analog signals, and the load signal changes were digitized via an A/D converter. Data acquisition synchronized the signals from the three-point load cells using DAQ, and the signal processing module performed noise removal, filtering, and PSD analysis via FFT. The converted signal was analyzed using software to identify vibrations as shifts in the center of gravity. Vibration period and amplitude magnitude were calculated to characterize the configuration's behavior.

Tremor triangular configuration-form technology

Triangular Configuration Measurement Technology (Tri-CMT) analyzes object tremors along the CoP trajectory over time by forming a tremor triangular configuration-form. It employs a Butterworth filter below 5 Hz and uses a low-pass filter to eliminate high-frequency noise. Signals requiring drift correction undergo DC offset removal and synchronized signal calibration. They are then aligned by time step from the signals received from the three load cells. During signal processing, the converted signals undergo coordinate-to-frequency analysis for CoP computation, yielding consistent results that represent vibration, translational, and rotational components.

In CoP, the Tremor motion-state-changing-status (Tre-MSCS) forms a white-wave-like-dot pattern, which visualizes load cell output fluctuations over time on a stable trajectory as a blur motion-state-changing-status level (Blu-MSCSL). The Tre-MSCSF configuration form analyzes the evaluation pattern of tremor using the white-wave-like-dot rate (Ws-DR). The tremor motion-state-changing-status system (Tre-MSCSS) collects and generates data as blur motion-state rate (SDR) from changes in position at CoP(t). .

The force signal from the load cell generated at the three-point was measured as a triangular configuration activity (Tri-CA) with a sensing configuration rate (SCR) that shifted along the trajectory as the object swayed, forming a pattern resembling a distorted shape during the experiment. In the configuration-form, the Tre-DTF values were categorized by sampling frequency into Tre-DTF-ΨMAX-MED, Tre-DTF-ΨMED-MIN, and Tre-DTF-ΨMED. The collected database configured the tremor signal into a Tre-DTF activity form. Table 1 shows the signals transformed from the tremor signal configuration-form (Matlab 6.1 experimental calculations).

Table 1. Average of tremor reorganize configuration-forms: the BLU-MSCSL (Tre-MSCSF-FA$\Psi_{MAX-MED}$), BLU-MSCSL (Tre-MSCSF-CO$\Psi_{MAX-MED}$), BLU-MSCSL (Tre-MSCSF-FL$\Psi_{MAX-MED}$) and BLU-MSCSL (Tre-MSCSF-VI$\Psi_{MAX-MED}$) condition. Average of Tre-MSCSF-Ψ_{MED} and Tre-MSCSF-$\Psi_{MED-MIN}$.

Average Ψ	FA Ψ Avg-BLU-MSCSL	CO Ψ Avg-BLU-MSCSL	FL Ψ Avg-BLU-MSCSL	VI Ψ Avg-BLU-MSCSL
Tre-MSCSF-ΨMAX	22.59±4.5	10.92±1.31	4.54±1.7	0.69±0.21
Tre-MSCSF-ΨMED	12.83±2.42	7.27±1.21	2.48±0.36	0.40±0.05

Improvements of tremor triangular configuration-form sequence selections

Comparison Database of BLU-MSCSL: Tre-MSCSF-Ψ_{MAX} and Tre-MSCSF-Ψ_{MED} and Tre-MSCSF-Ψ_{MIN} :

Database of Far (FA-Ψ) of tremor motion-state-changing-status sequence selections

Load cell at the tremor motion-state-changing-status point in the three-point system detects changes in the object's load distribution in real time. At the point where the object shakes, the load changes fluctuate over time, and the trajectory of these load changes manifested as a shift in the object's Center of Pressure (CoP). Sampling frequency of Far(FA-Ψ) in tremor motion-state-changing-status (Tre-MSCS) was typically adjusted within the range of 100 to 1000 Hz. By arranging three-point load cells in a triangular configuration to detect changes in the object's load distribution in real time, the resulting values at the blur motion-state-changing-status level (Blu-MSCSL) were expressed as Tre-MSCSF-FA-ΨMAX, Tre-MSCSF-FA-ΨMED, and Tre-MSCSF-FA-ΨMIN. Tre-MSCSF-FA-ΨMED showed large flank-vicinage (FV) movements in the interpolation correction and regression correction between calibration matrices using Tre-MSCSS in Tremor. The interpolation correction of Tre-MSCSF-FA-ΨMAXN for Tre-MSCSF, with a value of 4.62±1.45, significantly impacts the load ratio calculation in Far(FA-Ψ)BLU-MSCSL. Figure 3 shows the reconstruction between calibration matrices in Far(FA-Ψ)BLU-MSCSL as a tremor pattern, appearing as the trajectory shape of Tre-MSCSF-Far in the Far(FA-Ψ) configuration. Tre-MSCSF-FA-ΨMIN, where the interpolation correction in Tre-MSCSS is 4.62±1.45, showed slight changes in the tremor-shaped trajectory due to load cell output variations over time. The triangular configuration of the Tre-MSCSF direction for Far(FA-Ψ)BLU-MSCSL showed a trajectory shape where Tre-MSCSF-FA-ΨMED exhibited a change of 8.98±1.32.

Database of Convenient (CO-Ψ) of tremor motion-state-changing-status sequence selections

The magnitude of the load applied to the three-point contact on the oscillating object varied over time relative to the load cell output, and changes in the displacement trajectory from the reference axis were estimated. The load cell output variation over time for the tremor motion-state-changing-status (Tre-MSCS) showed differences between the center and edge regions. The load cell output measured the center's displacement pattern, focusing on areas exhibiting high dynamic stability within the trembling pattern. Convenient (CO-Ψ) of tremor motion-state-changing-status (Tre-MSCS) expressed the changes applied to the force plate as BLU-MSCSL values of Tre-MSCSF-FA-ΨMAX, Tre-MSCSF-FA-ΨMED, and Tre-MSCSF-FA-ΨMIN. Tre-MSCSF based on BLU-MSCSL identified Tremor values between the center and edge regions of the trajectory, starting from the center of CoP(t) in Tre-MSCSS, through interpolation correction and regression correction between correction matrices, as Tre-MSCSF-CO-ΨMAX and Tre-MSCSF-CO-ΨMED. In Tre-MSCSF-FA-ΨMAX, the interpolation correction and regression correction of Tremor formed a very large value of 19.30±8.77 units. Tre-MSCSF-CO-ΨMAX identified the trajectory size of CoP(t) under Tremor load as 8.05±0.90 based on object sway. In BLU-MSCSL, the magnitude relative to the load in the Tremor motion-form, composed of Tremor, showed interpolation correction in Tre-MSCSF-CO-ΨMED, and the value generated in the Tremor region of Tre-MSCSF was 5.31±0.51.

Database of Flank(FL-Ψ) of tremor motion-state-changing-status sequence selections

In a trembling object, the CoP(t) starts from the center. The load cell system evaluates the object's trembling pattern, where the change in velocity for the structural three-point load differs, and the change in the trajectory with constant slope is estimated. In the tremor motion-state-changing-status (Tre-MSCS), the evaluation pattern of Flank (FL-Ψ) confirms that the trajectory varies with the object's sway, exhibiting fluctuations in the sampling frequency between 10 and 1000 Hz due to changes in velocity relative to the structural three-point load. Tremor motion-state-changing-status In Tre-MSCS, the evaluation pattern of Flank (FL-Ψ) showed that the changes in force plate readings under three-point loading represented blur motion-state-changing-status level (Blu-MSCSL) values corresponding to Tre-MSCSF-FA-ΨMAX, Tre-MSCSF-FA-ΨMED, and Tre-MSCSF-FA-ΨMIN based on velocity. When Tre-MSCSF activity was measured in BLU-MSCSL using interpolation correction and regression correction between calibration matrices, tremor appeared less in Tre-MSCSF-FL-ΨMIN and Tre-MSCSF-FL-ΨMED depending on speed. Tre-MSCSF-FL-ΨMAX was found to be 2.46±0.42, and Tre-MSCSF-FL-ΨMAX was constructed at a tremor-corrected speed by Tre-MSCSS in the FV direction. Tre-MSCSF-FL-ΨMIN was 1.17±0.11, and CoP(t) starting from the center showed small changes in trajectory speed according to object shaking, indicating that tremor slightly occurred in the FC direction due to interpolation correction in Tre-MSCSS. Tre-MSCSF-FL-ΨMED showed a value of 1.49±0.11, confirming that Tre-MSCSF activity exhibited minimal tremor relative to speed.

Database of Vicinage (VI-Ψ) of tremor motion-state-changing-status sequence selections

The pattern for evaluating object tremor is one that includes oscillatory, translational, and rotational components over time in the CoP trajectory when the object trembles, as observed in the Vicinage (VI-Ψ) of tremor motion-state-changing-status (Tre-MSCS) configuration of the object. In tremor motion-state-changing-status (Tre-MSCS), the Vicinage (VI-Ψ) sampling frequency indicates changes applied to the force plate, with tremor manifested as Tre-MSCSF-FA-ΨMAX, and Tre-MSCSF-FA-ΨMED, and Tre-MSCSF-FA-ΨMIN showed blur motion-state-changing-status level (Blu-MSCSL) values. When an object wobbles, changes in motion relative to the CoP trajectory were measured using Tre-MSCSF-VI-ΨMAX, Tre-MSCSF-VI-ΨMED, and Tre-MSCSF-VI-ΨMIN. We confirmed that Tre-MSCSF activity in the adjacent BLU-MSCSL region exhibits tremor during interpolation correction and regression correction between calibration matrices. Tre-MSCSF-VI-ΨMAX exhibited very low tremor, confirming a value of approximately (0.44±0.10), and it was confirmed that the configuration form tremors in the FC direction due to Tre-MSCSS. Tre-MSCSF-VI-ΨMIN exhibited a very low tremor state with a value of (0.21±0.02). In Tre-MSCSF-VI-ΨMIN, interpolation correction showed that changes in movement relative to the CoP trajectory in Tre-MSCSS proceeded in the FC direction when the object shook. For Tre-MSCSF-VI-ΨMED, the interpolation correction showed that the Tre-MSCSF activity exhibited a very slight tremor value (0.27±0.01).

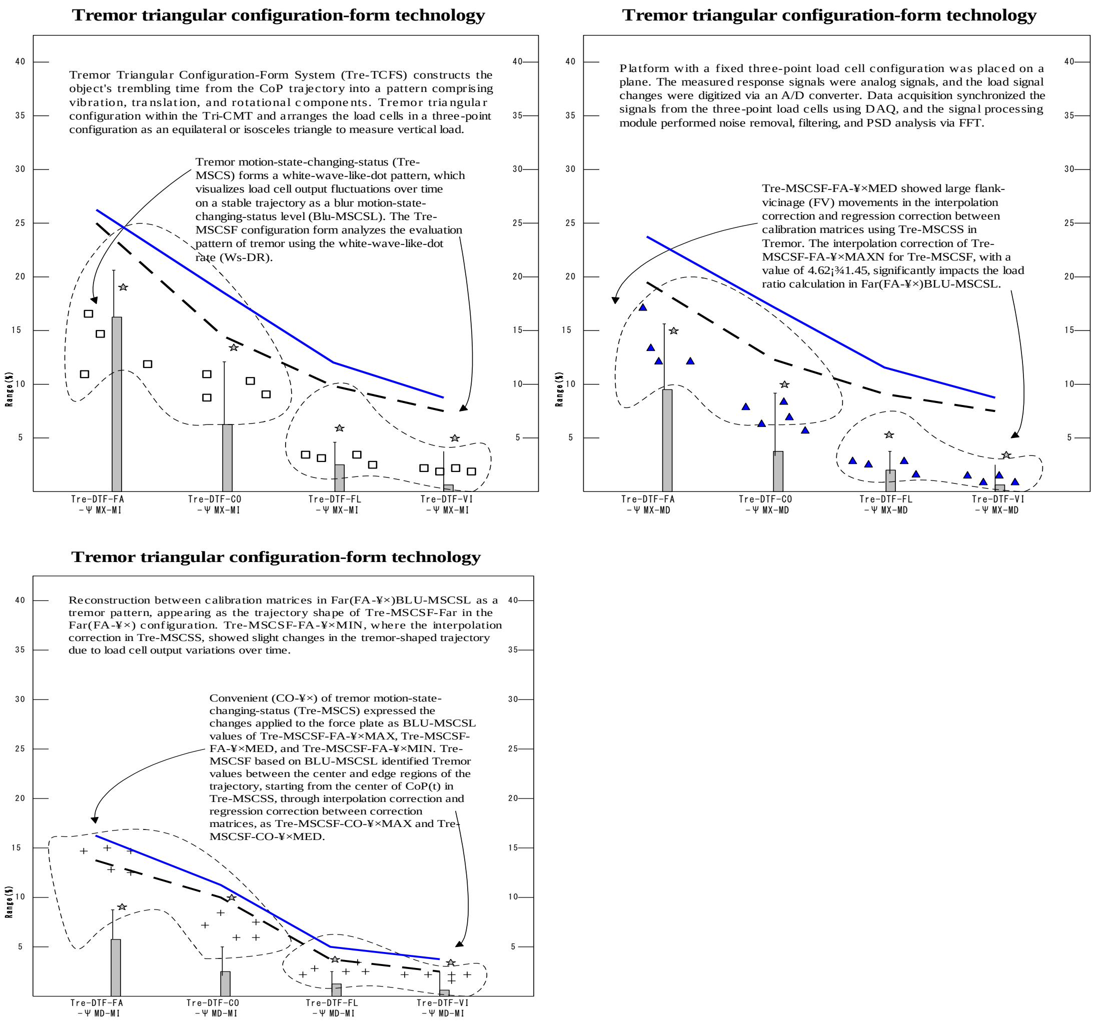

Figure 3. Tre-MSCSF of the data of Tre-MSCSF-Ψ_{MED} and Tre-MSCSF-Ψ_{MIN} and Tre-MSCSF-Ψ_{AVG}: (a) Min-FA-CO-La-Mi-Sm, Min-FL-VI-La-Mi-Sm (b) Med-FA-CO-La-Mi-Sm // Medx-FL-VI-La-Mi-Sm, (c) (L-3) Med-FA-CO-La-Mi-Sm // Medx-FL-VI-La-Mi-Sm

Discussion

Process of evaluating the tremor triangular configuration-form (Tre-MSCSF) in tremor triangular technology requires analyzing the load cell's output fluctuation patterns over time. The pattern analysis method employed evaluation tools based on shape, size, and speed to assess the tremor. The load cell system forming the triangular configuration confirmed that the sampling frequency during the process of collecting the load cell's force signal as data generally ranges from 100 to 1000 Hz. It was composed of a CoP coordinate formula that calculates the ratio to the load and performs CoP transformation using equations. The calibration process between correction matrices in the three-point system analyzed the temporal pattern of input signals through interpolation correction and regression correction applied to the force plate. This involved identifying and analyzing trajectory shape, amplitude magnitude, and the periodicity of the input signal. The evaluation process, which confirmed object sway through load cell output over time, employed quantitative methods to assess stability, vibration characteristics, and balance control quality.

The calibration matrix for Far(FA-Ψ) in Tre-MSCS is derived from verifying the orbital path using a triangular arrangement of three-point load cells. Through Tre-MSCSF in BLU-MSCSL, changes affecting the force plate were identified as small tremor movements using Tre-MSCSF-FA-ΨMAX and Tre-MSCSF-FA-ΨMIN. In Convenient (CO-Ψ), calibration matrix correction at the center and edge of Tre-MSCS exhibited greater configuration variation than Tre-MSCSF-CO-ΨMED, reflecting the fluctuating state of BLU-MSCSL. In both interpolation and regression corrections, the Convenient (CO-Ψ) pattern was identified as shifting from a wobble pattern to a moving pattern at the center, where dynamic stability significantly increased. In Flank (FL-Ψ), the calibration matrix correction for tremor motion-state-changing-status (Tre-MSCS) confirmed that the change in BLU-MSCSL velocity for structural three-point loading produces values in Tre-MSCSS that form tremor-like patterns in the same direction as Tre-MSCSF-FL-ΨMAX. In Vicinage (VI-Ψ), the calibration matrix correction for tremor motion-state-changing-status (Tre-MSCS) confirmed that trajectory wobbling, as Tre-MSCSF activity, produces extremely minute tremor-like values in both interpolation correction and regression correction. This affects BLU-MSCSL, with Tre-MSCSS occurring in the same direction.

Conclusion

Tremor triangular technology for the tremor triangular configuration-form (Tre-MSCSF) was configured to establish a triangular motion-state from the load cell. The tremor pattern for triangular motion measurement quantitatively assessed the stability of the tremor, its vibration characteristics, and the quality of balance control. Using the proposed tremor configuration form, an evaluation method was obtained through the triangular configuration. The measurement system for the triangular configuration measurement method (TCSM) with three-point balance measures changes in vertical load due to object weight shifts. It acquires electrical signals from the load cell to obtain load changes over time, displaying the calculated values required for measurement on the triangular configuration measurement method system. Load cell output values generated by minute object sway or vibration reflected and amplified subtle signals from sway or balance movements. These signals underwent a process of constant integration before passing through the microprocessor stage. The integrated data is converted into a digital signal through calculations by the ADC and microprocessor, enabling the identification of usable data. The three-point TCSMS employs Tre-MSCSF for tremor motion-state leveling on the force plate during interpolation correction and regression correction between calibration matrices. The process of evaluating tremor by analyzing trajectory patterns identifies tremor locations distributed across the shape, size, and velocity of the material. The identified tremor configuration was confirmed using a triangular configuration measurement method that balances the central point's ability, collecting variables generated by triangular configuration technology for the tremor triangular configuration-form.

We anticipate that when using load cells, the Triangular Configuration Measurement Method will be employed for configuration measurements across various fields. It is expected to serve as a core technology for precision medical devices and advanced measurement instruments, enhancing accuracy and precision.

REFERENCES

Lahasan B., Lutfi S.L., Venkat I., et al., Optimized symmetric partial facegraphs for face recognition in adverse conditions, Inf. Sci., 429 (2018), 194–214.

Best-Rowden L., Jain A.K., Learning face image quality from human assessments, IEEE Trans. Inf. Forensic Secur., 13 (12) (2018), 3064–3077.

Guikema S.D., Risk analysis for critical infrastructure systems: an approach based on statistical learning theory, Reliab. Eng. Syst. Saf., 94 (4), (2017), 855–860.

Telke C., Beitelschmidt M., Edge detection based on fractional order differentiation and its application to railway track images, Pamm, 15 (1) (2015), 671–672.

KoBler J., Schneider M., Ospald F., et al., Fiber orientation interpolation for the multiscale analysis of short fiber reinforced composite parts, Comput. Mech.

Tamura H, Mori S, Yamawaki T. Texture features corresponding to visual perception. IEEE Trans Syst Man Cybern, 8 (1978), 460–73.

Augustine R., Dominic E.A., Reju I., Kaimal B., Kalarikkal N., Thomas S., Investigation of angiogenesis and its mechanism using zinc oxide nanoparticle-loaded electrospun tissue engineering scaffolds, RSC Adv., 4 (2014), 51528–51536.

Malekzadeh P., Fiouz A.R., and Razi H., “Three-dimensional dynamic analysis of laminated composite plates subjected to moving load,” Compos. Struct., 90 (2009), 105–114.

Shadnam M.R., Rahimzadeh Rofooei F., Mofid M., and Mehri B., “Periodicity in the response of nonlinear plates under moving mass,” Thin-Walled Struct., 40 (2002), 283–295.

VaseghiAmiri J., Nikkhoo A., Davoodi M.R., and Ebrahimzadeh Hassanabadi M., “Vibration analysis of a Mindlin elastic plate under a moving mass excitation by eigenfunction expansion method,” Thin-Walled Struct., 62 (2013), pp.53–64.

Kim J.L., Choi J.S, Hwang K.S., A Study on Anticipation System of Shudder Distinction by the Physical Shape Alteration in Static Condition, The Journal of IIBC (JIIBC), 17(3) (2017), 115-120. DOI 10.7236/JIIBC.2017.17.3.115

Kim J.L., Kim K.D., Prediction of shiver differentiation by the form alteration on the stable condition, International Journal of Internet Broadcasting and Communication (IJIBC), 9(4) (2017), 8-13. DOI 10.7236/IJIBC.2017.9.4.8

Kim J.L., Hwang, K.S., Nam Y.S., Implementation of the F-B function comparison on the body changing-status, International Journal of Advanced Smart Convergence (IJASC), 3(1) (2014), 20-24. DOI 10.7236/IJASC.2014.3.1.5

Kim J.L., Kim K.D., Presentation of central motion techniques: limpness motion function and limpness sensory unit function, International Journal of Advanced Culture Technology (IJACT), 4(3) (2016), 56-61. DOI 10.17703/IJACT.2016.4.3.56

Bekkali A, Zou SC, Kadri A, Crisp M, Penty RV., Performance analysis of passive UHF RFID systems under cascaded fading channels and interference effects. IEEE Trans Wirel Commun., 14 (3) (2015), 1421–33.

DiGiampaolo E, Martinelli F., Mobile robot localization using the phase of passive UHF RFID signals. IEEE Trans Ind Electron, 61(1) (2014), 365–76.

Fujino, K., Hashida, S., Ogawa, T., Natsume, T., Uchiyama, T., Mikami, T., Kishima, Y., Temperature controls nuclear import of Tam3 transposase in Antirrhinum. Plant J. 65 (2011), 146–155.