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A New Counting Method for Measuring and Evaluating Dynamic Loads

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Abstract

The evaluation of dynamic loads could be complex but there exists well implemented evaluation and analyses approaches in an industry context such as counting methods and Fourier transformation. Multiple use cases such as in acoustics, electronics, magnetics, mechanics (durability, CAM machines), … exists. Currently, such long-time standards in evaluation and analyses will be well known. However, new requirements will be caused for example by upcoming big data approaches or long-time data evaluation. In addition, often multiple evaluation methods will be required and often alternative methods with different benefits have to be implemented. Thus, place for evaluation is given to reduce multiple methods used parallel or alternatively and to address new requirements. In this paper, the stage of technology will be discussed, an introduction into a new counting approach will be provided and benefits of the new counting method will be presented. The benefits will be summarized to potential of reduced energy consumption (green technology), cost reduction (economy optimization), further and new evaluation potential.

Keywords: Counting Approach, Dynamics, Statistics, FFT, Rain Flow Counting, Frequency Characteristic, Amplitude Characteristic, Load Characteristic and Samples

Introduction and Challenges

Nondestructive testing (NDT) is an important and required approach for inspecting and evaluating materials, components, or assemblies without destroying their serviceability [1]. For example, in the case of nondestructive vibrational analyses, the measured object should not fail through destruction or loose serviceability during the measurement of dynamic loads. This approach could be applied during the useability check of an object to ensure quality of life. "Nondestructive components testing … will be performed over the entire product life cycle, from development to testing or monitoring in production and use" [2].

The evaluation of such dynamic loads could be complex, for example, in the case of durability focused dynamic load evaluation. In such examples, analyses of hysteresis, amplitudes, middle values and frequencies are standard. The evaluation and analyses of load in the durability example will be required to evaluate the ongoing material and product life behaviors discussed, for example, in [3]. Another example is the dynamic analyses of CAM machines; in this case, frequencies and amplitudes will be evaluated via accelerator measurements. Such an investment will help to identify the conspicuous behavior of a CNC machine to implement early repair and maintenance that protects the CNC process and machine [4]. Further examples can be found in acoustics (instrument tuner), electronics, magnetics, mechanics, etc.
Data analyses, data mining and data collection often involve separate methods; often, different technologies and users know how. Big Data will support such dependencies and improve collaboration. In the future, the implementation of dynamic load evaluations and analyses in the big data context and edge computing will become more important [4]. With this new approach, the data analyses could be accelerated and made more independent of the location.

The Aim of the study was to evaluate the useability, benefits and correctness of the new counting method. **The Method** involves checking and correlating the counting results of the new counting method against known parameters of a curve. **The Experimental Section** uses a synthetic measurement curve based on known parameters. The known parameters of the synthetic measurement curve were compared with the evaluated parameters using the new counting method and the synthetic measurement curve. Background knowledge and details are

presented in the Content: Currently, the standards for evaluating and analyzing dynamic loads are well known and proven. However, new requirements will be met by upcoming big data approaches. Nevertheless, multiple evaluation methods are often needed, and alternative methods with different benefits can often be implemented. Focusing on mechanical use cases such as durability, in capter 2 'Stage of technology' are discussed.
Because multiple evaluation approaches use parallel or alternative and upcoming new requirements, a place for evaluation is given. Such an evaluation could be seen behind a new counting method. In chapter 3 'New counting approach, this new and more modern evaluation and analysis method is presented.
The new counting method can replace different evaluation methods, filter settings and support edge computing. Therefore, there will be differences in the existing evaluation and analysis methods. In chapter 4 Benefits of the new counting approach will be discussed.
The potential behind the new counting method will be demonstrated. In section 5, a summary is given in that area, and an outlook is provided for further work.

Stage of Technology

The relevant stage of technology will be influenced by three topics. We will discuss each topic separately in the three following subchapters.

Frequency Evaluation

The natural frequencies of the system could influence the system itself and possibly neighboring systems massively. Each forcing on the system, such as a single hammer blow, will excite oscillations which can be described in terms of the systems normal modes. The amplitude of such oscillations is determined by the nature, energy and location of such a force, while the eigenfrequencies are determined by properties of the system. In case of periodic excitation near the systems eigenfrequencies, resonance can lead to a energy build up and may force cracking and termination of the system [5].

It seems that the response of a system will be dependent on the frequency of the system and the excitation. To evaluate the influences of natural frequencies, for example, in the case of a response signal, an evaluation of the frequency spectrum of such a signal could be helpful. Therefore, Fourier analyses could be performed. The Fourier analyses and the Fourier transformation results are presented in [6]. Over the years, multiple Fourier transformation approaches and algorithms have been developed for specific and universal use cases, as presented in [7-9]. The natural frequencies massively influence the response of a system. Fourier analyses and transformation approaches could be helpful for evaluating this behavior. Such movement and cycling of the system influence the fatigue behavior of the system. Therefore, the load cycles could be evaluated, as discussed next.

Load Cycle Evaluation

A historical review includs following note: "A. Wöhler is regarded as the grandfather of modern fatigue technology", as well as, who described that the initiation of a fatigue crack is caused by the number of load cycles [10, 11]. Thus, the number of load cycles is an important factor for investigating fatigue. A paper describes the load cycles as follows: "In fatigue testing, the load cycle is characterized by various parameters such as load ratio R ($\sigma min/\sigma max$), stress amplitude σa, mean stress σm, and stress range $\Delta\sigma$ [10]. Fatigue is evaluated in terms of fatigue strength and fatigue limit. Fatigue strength is the value of stress at which failure occurs after Nf cycles, while the fatigue limit shows the limiting value of stress (Sf) at which failure occurs, as Nf becomes very large" [12].

Thus, to take the load cycles into account in the case of fatigue investigation, the loads and the cycling of the loads must be measured and evaluated. Therefore, counting technologies, which include statistical evaluation and reduction methods, have been developed. An overview of the above load cycle counting technologies are presented in [13-16]. For the load cycle evaluation based on random signals, the rainflow counting approach was presented in [17]. Early rainflow counting algorithms were created to evaluate closely sampled data. However, an increasing number of approaches for ongoing data sampling, such as those realized with microcomputers, have been developed [18].

In the case of fatigue investigations, loading cycles of the stress unit type will be an ideal approach because the stress will be closed to be interpretable in a fatigue context. Often evaluated in combination with rainflow counting such as in [19]. However, stresses are forced by loads such as forces, moments and temperatures. Often, especially in High Cycle Fatigue and above, the stiffness of the material will behave linearly, and if needed, local stress behavior can be manipulated, for example, via Neuber Hyperbel. Nevertheless, the nominal stress will behave linearly with respect to such forces, moments, displacements and temperatures [20]. Therefore, load cycle evaluations of forces, moments, displacements and temperatures will be equivalent to stress load cycles but mathematically exclude the stiffness factors. Often, direct dependency between damage and load cycle behavior occurs and can be evaluated [20]. Thus, for a load cycle overview, the evaluation of stress, force, moments, displacements and temperature could be helpful. Today, we step further in the area of big data where such load cycles can be counted over a long time period. We will discuss this next.

Data Handling in the Case of Big Data

The rainflow counting approach will become increasingly important in the context of big data analyses. A use case example implementing in a Big Data framework Fast Fourie Transformation and rainflow counting are presented in [21]. Especially in structural health monitoring (SHM), rainflow counting is helpful for identifying fatigue damage, for example, in the case of crane equipment [22]. Due to its usability in the Big Data context, this approach is effective at counting rainflows with an amplitude class and a middle value class [20].

New Counting Approach

The new approach is able to evaluate two consecutive extreme points, and the results can be used as a new approach for multiparameter classification. Therefore, three steps will be needed. First, the extreme points must be identified. This will be discussed in 3.1 Identification of extreme points. In the case of extreme points, an ongoing evaluation of the new and the previous extreme point is performed. Such an evaluation is discussed in 3.2 Evaluating the half wave. The evaluated data were subjected to multiparameter classification, as discussed in 3.3 Mapping to a new multi-parameter-classification. In addition, the occurrences are listed in 3.4 handle happenings in the classification.

Identification of Extreme Points

In the first step, the extreme points of a transient sampled signal must be identified. This is achieved in three steps [23]:

• **Reading the Sample Points:** This step does not require reading the full transient data. For the new counting process, only the current sample point and its predecessor are evaluated. This approach supports the evaluation of existing transient sampled data based on measurements or simulations. The approach also supports evaluation during an ongoing measurement or simulation process.

• **Evaluation of the Gradient/Derivative:** In the next step, the gradient between the value of the new sample point at time t and the previous sample point at time t-1 is calculated. Therefore, the difference between the actual s(t) and previous s(t-1) sample values is divided by the difference between the actual t(t) and previous t(t-1) sample times.

$$g(t) = \frac{s(t)-s(t-1)}{t(t)-t(t-1)} \qquad \textit{Equation (1)}$$

• **Evaluate the Steady Behavior:** In the case where the new sample point is an extreme point, the gradient will not behave steadily. This means that the gradient changes from increasing to decreasing or from decreasing to increasing. Thus, evaluating the sign of the actual growth rate g(t) and comparing it with the previous growth rate g(tprevious) will reveal whether the actual growth rate is steady. If the comparison shows that the values will be unequal, the growth behavior will not be steady.

$$\frac{g(t)}{|g(t)|} \neq \frac{g(t_{privious})}{|g(t_{previous})|} \qquad \textit{Equation (2)}$$

In case the new sample point is an extreme point of the sampling, go further; otherwise, restart the process with the next sample point.

Evaluating the Half Wave

The realistic behavior of a sample between two neighboring extreme points is not evaluated by the new counting method. Instead, a half wave is assumed between two neighboring extreme points. Therefore, the supposed part of the half wave grows steadily, as shown in Figure 1. Other behavior assumptions of the sampling could also be implemented.

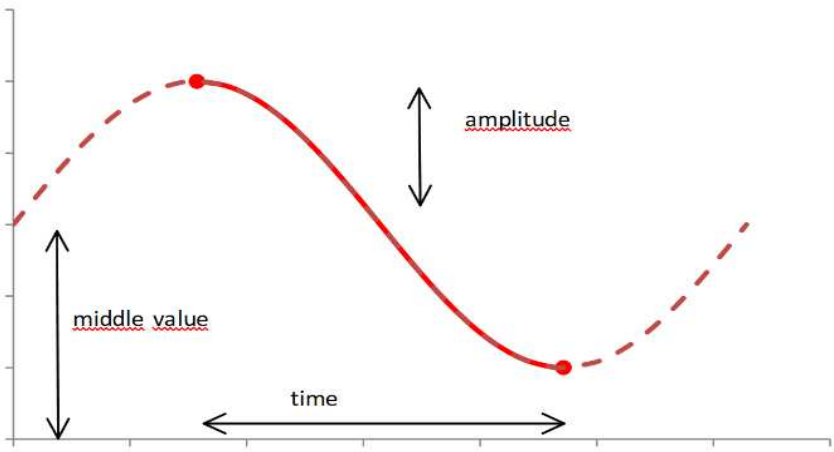

Figure 1: Half Wave Behavior

When the behavior of the sampled curve between two extreme points neighboring each other is considered to be a half wave, the middle value, amplitude and duration can be evaluated [23]. Therefore, the sample values and times of the new and previous extreme points should be accessible. A mathematical evaluation approach is presented in the following equations for time (Equation 3), amplitude (Equation 4) and the mean value (Equation 5):

$$\Delta t = t_{second\ extreme\ point} - t_{first\ extreme\ point} \qquad \text{Equation (3)}$$

$$a = \frac{\left(s\left(t_{second\ extreme\ point}\right) - s\left(t_{first\ extreme\ point}\right)\right)}{2} \qquad \text{Equation (4)}$$

$$m = s\left(t_{first\ extreme\ point}\right) + a \qquad \text{Equation (5)}$$

From a wave form that is based on harmonic behavior, we can evaluate a frequency based on the evaluated duration via Equation 6.

$$F = \frac{1}{T} = \frac{1}{2\,\Delta t} \qquad \text{Equation (6)}$$

With that, we can describe a half-wave with an amplitude a, a mean value m and a time Δt or an alternative frequency F. In the following, the mapping of previously evaluated half-wave data to a new multidimensional classification will be discussed.

Mapping to A New Multiparameter Classification System

One- and two-dimensional classification approaches are currently available [16]. A two-dimensional classification is included, for example, in rainflow counting. In the rainflow counting approach (RFCA) example, we classify hysteresis into two classes of parameters. One of the classes is the starting value of the hysteresis, and the second class is the end value of the hysteresis. The new multiparameter classification approach includes two similar parameter classes, such as the RFCA described in [22]. The new multiparameter classification maps the data in the mean value class and in the amplitude value class [23]. However, in comparison to the rainflow counting approach, the new counting approach will count half waves rather than hysteresis. Based on the mean and amplitude values, it is possible to calculate the half-wave start and end times, such as in the case of the rainflow analyses, for the hysteresis start and end values.

However, the new classification approach implemented in the new counting approach includes a class for the time duration value or frequency value. With this, the new classification steps occur in a third dimension. We can now count the occurrences by evaluating the half-wave data and mapping them into the three previously presented classes:

• Amplitude value.
• mean value.
• Time or frequency value.

As a result, all three parameters are describable by one classification container. A concrete classification container describes a concrete amplitude value class, a concrete mean value class and a concrete time or frequency value class. This could be seen as a concrete container on a container ship with columns, rows and levels. In such a classification container, the occurrences could be counted. Each time a occurrence appears able to be assigned to a concrete classification container, the counting value of the concrete classification container could increase by one. However, the classification container could be useable in the advanced approach discussed next.

Handling Occurrences in the Classification

In addition to counting for each classification container, the new classification can add a list of events. Therefore, in the case of an occurrence in a concrete classification container, the occurrence time is added to the container. An occurrence time could be, for example, the start or end time of an event. The addition of this information should be appended to the last entry of the classification container. Thus, a list of events will be stored in the classification containers. This list could be stored in addition to the number of occurrences. Alternatively, the amount stored in a concrete classification container could be counted. With this advantage, we can see the new classification approach as a 3.5-dimensional classification and counting approach. Therefore, not all classification containers must be handled via the same process.

A predefinition of how to handle each individual classification container could be implemented. Therefore, there could be a predefinition if a concrete classification container includes

• A counting number,
• A happening list,
• A counting number and an happening list or
• Nothing

Such individual predefinition of each classification container follows down to a digital filter technology.
Because each individual concrete classification container describes

- Concrete amplitude value
- Concrete mean value
- Concrete time or frequency value.

For completeness, because of the common classification, a class will have a start value and an end value. The values falling inside the range between the start and the end value are mapped to the concrete value class. The new approach can provide multiple benefits. In the following subchapters, the benefits will be discussed.

Benefits of the New Counting Approach

Provides Data Evaluation of Load Cycles

The rainflow counting method is a popular approach for evaluating load cycles. This method provides information about the appearance of hysteresis defined by the start and end values. The new approach can provide similar data with some differences. Instead of defining the load by the start and end values, the load is defined by the mean value and the amplitude. Therefore, the new approach will count halve waves with a positive amplitude or negative amplitude. Thus, the new counting approach will be similar to the well-known rainflow counting approach but based on halve waves instead of hysteresis.

With the direct accessibility of amplitude values, the data of the new approach can be more easily organized, such as block loads. Usually, and by some restrictions, block loads are evaluated using the range pair counting approach [24]. This counting approach will be used to loosen the mean values. With the new approach, the mean values will be kept and could be taken into the data analyses. A threedimensional graph was constructed to show the number of amplitude values of the halve wave appearing above the mean values shown in Figure 3. For visualization, an example of a synthetic sampled source of oscillating values is used as a base, the sampled graph is shown in Figure 2, and Table 1: shows the synthetic components. In the three-dimensional graph, the different synthetic components with their amplitude and middle value could be easily identified. As remark, we will see the values in the positive as well in the negative amplitude because halve waves will be counted.

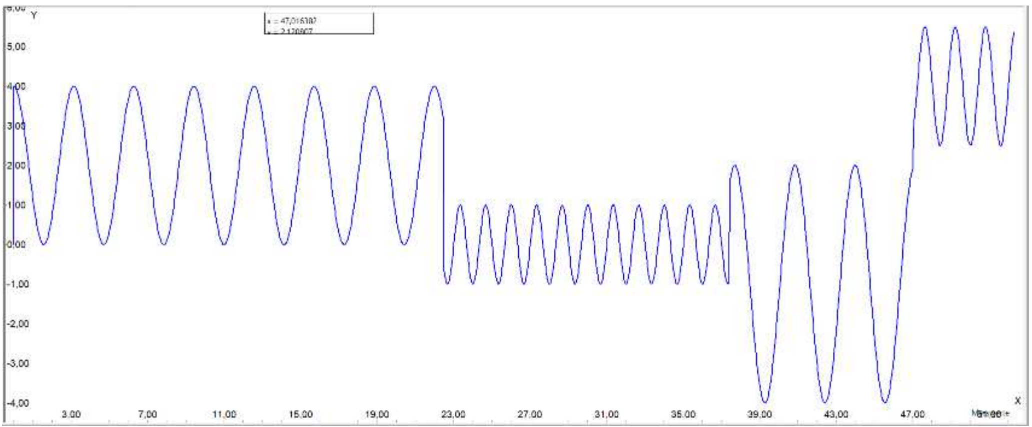

Figure 2: Synthetic Sample-Based Curve

Time	Amplitude	mean	Frequence	Gradient
0	2	2	0.3184 Hz	2.5472
22.5	-1	0	0.75	-3
37.5	3	-1	0.3184	3.8208
47	1.5	4	0.63	3.78
52.3	Last sample			
Number of Samples		1048		
		With constant time steps (even)		

Table 1: Synthetic Components of the Synthetic Sample File

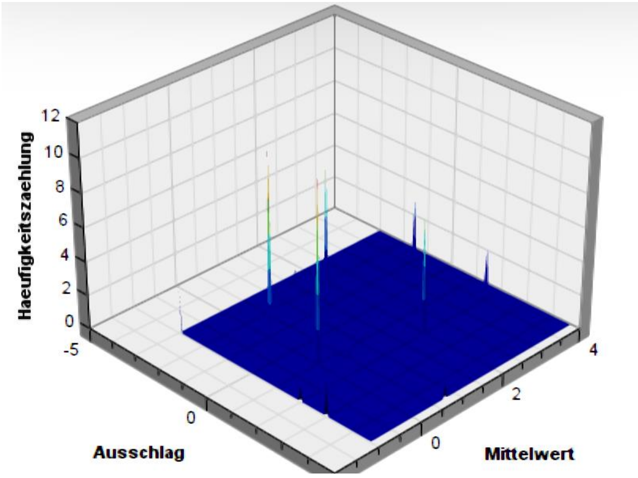

Figure 3: Graph of Amplitude (Ausschlag), Middle Value (Mittelwert) and Appearance (Haeufigkteitszaehlung)

Frequency- Or Time Dependent Data Evaluation of Load Cycles

In addition to the middle value, amplitude and appearance, the new counting method evaluates the duration of a halve wave. Independent of whether a duration or a frequency is of interest, both could be evaluated and taken care of. As discussed, a well-known approach for frequency analyses is based on the Fourier Transformation approaches.

Fourier Transformation approaches use a mathematical basis to calculate harmonic amplitudes over a frequency range that mathematically creates a sample curve similar to the input sample curve. The Fourie Transformation provides correct solutions, but sometimes, they can differ in terms of the algorithm used and the sampling rate of the signal. In addition to these possible results, in the case of the Fourier Transformation approach, only one amplitude belongs to one frequency running with harmonic behavior. In reality, there could be multiple amplitudes in a sample curve that appear at the same frequency but not with a harmonic constant behavior more than single peaks. In addition, often, a Fast Fourier Transformation shows high amplitudes at low frequencies, which could differ from reality. In Figure 4 the amplitude of each individual frequency and the amplitudes at low frequencies are shown. The base of the FFT is the curve shown in Figure 2.

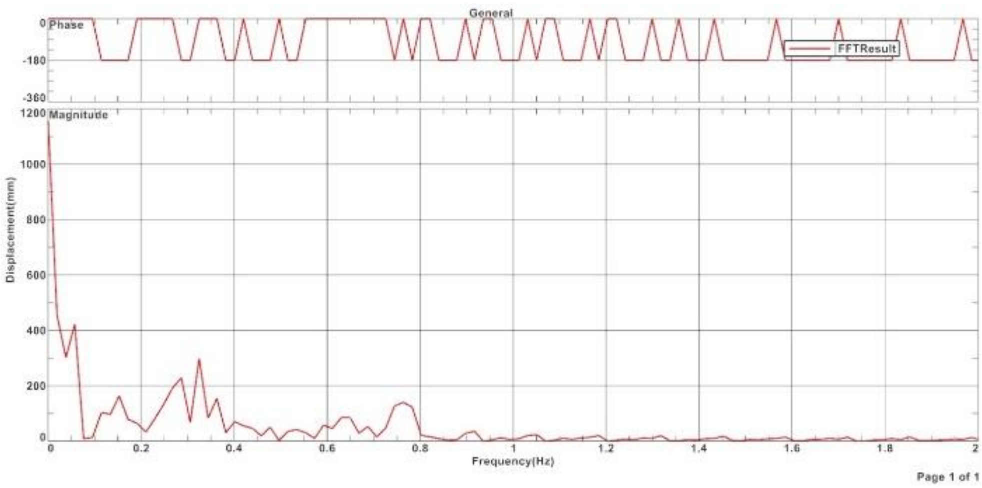

Figure 4: FFT (Performed with NX Software) of the Synthetic Sample-Based Curve

The new counting approach does not evaluate the amplitudes over a frequency range on a mathematical basis. Instead, the halve waves are evaluated in terms of duration or frequency. Amplitudes that appear with a halve wave could be ordered together in multiple amplitude ranges. As such, the amplitude ranges could be ordered according to the frequency range. Each time an amplitude with a frequency appears, the event will be counted according to these dependencies. Thus, we can obtain a much more realistic amplitude–frequency distribution from the sample curve. The granularity for determining the amplitude– frequency dependencies is much greater than that for determining the Fourier Transformation. For example, a Fourier Transformation amplitude – frequency could appear in reality with a higher or lower amplitude or both, and it represents a mathematical number. The new approach can be used to construct a three-dimensional plot

• The apparent amplitude on the first axis.
• Over the frequencies on a second axe.
• How often the amplitudes appeared on a third axis shown in Figure 5.

The evaluated three-dimensional graph was based on the previously presented synthetic sample curve. In the three-dimensional graph, the different synthetic components and their frequency and amplitude values can be easily identified. For example, Figure 5 shows two different amplitudes with positive and negative values in the case of 0.3184 Hz, as presented in Table 1, rows two and four.

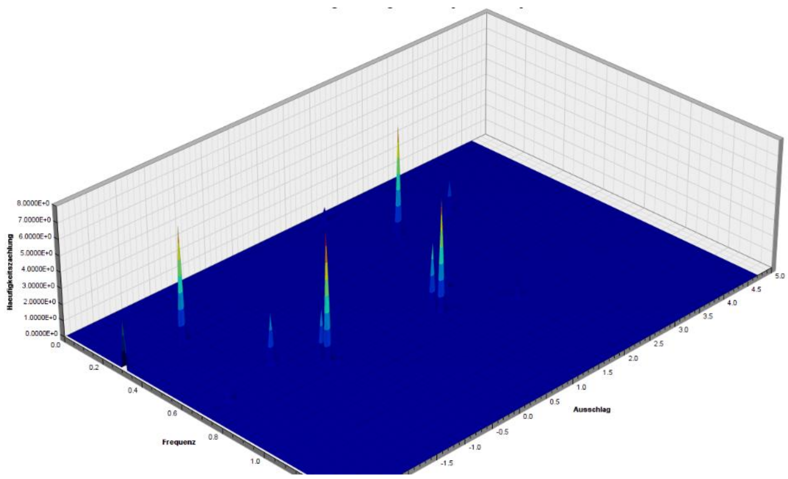

Figure 5: Graph of Frequency (Frequenz), Amplitude (Ausschlag) and Appearance (Haeufigkteitszaehlung)

The Appearances of the Load Cycles and Frequency in One Process are Counted

Evaluating the benefits of the load cycles discussed in 4.1 and the frequencies discussed in 4.2 could be performed with the new counting approach in one process. Two previous approaches were required for analysis

- The load cycle by counting,
- The frequency behavior via a Fourier Transformation approach.

The new approach includes a counting technology that is granular enough to create a counting matrix that includes information about

- Amplitude,
- mean value,
- Frequency,
- Appearances.

Compared to a Fourier Transformation or a rainflow counting approach, the new approach includes much more information and makes the two methods dependent on each other. This is shown in Table 2 Comparison.

Approach	Amplitude	mean value	Frequency	Phase	Counted appearance	Step Time
New approach	Yes	Yes	Yes	Maybe calcable	Yes	Doable
Fourier Transformation	Math number	No	Yes	Yes	No	No
Rainflow Counting	Evaluateable	Evaluateable	No	No	Yes	No

Table 2: Comparison of New and Existing Approaches

This new approach could be helpful for analyzing the data where load cycle and frequency analyses are of interest. Thus, processes involving two analyses of shoots using two different analysis approaches could often be replaced by the new counting approach.

Higher Granularity for Data Analyses

By including a greater amount of information, the new counting approach can analyze much more granular data and provide more granular information for ongoing data analyses and evaluation.

- Frequency,
- Amplitude,
- mean value data will be dependent on each other.

The dependencies of the data could be used for more granular data analyses compared to the existing popular approaches.

For example, a Fourier Transformation often will be used to create a plot showing the amplitude values over the frequency range. Plotting to picture realistic amplitude distributions over a single frequency or a frequency range is not possible with the Fourier Transformation approach. However, such data analyses could be performed with this new approach. In the prediscussion (4.1 and 4.2)

• A figure of an FFT (Fast Fourie Transformation) analyses,
• A figure of the new counting approach including amplitude, frequency and appearances,
• A figure of the input sample file was discussed.
In this discussion,
• Individual but important amplitudes of the input sample file,
• No unrealistic static frequencies (compared to the FFT analyses) can be seen in the plot of the new approach.

Thus, the new approach provides more granular data for ongoing data analyses and evaluation. Additional analyses could be performed, for example, to evaluate the amplitude in more detail, such as taking into account the middle values, in the case of a specific frequency. This will not yet be part of the prototype. Therefore, data recovery such as possible with a full FFT analysis is ideal.

Can Restore the Extreme Sample Points

The new approach could store additional data to restore and recover extreme sample points. Therefore, the new approach can add sample step time data to the evaluation matrix. Via multiclass, the counted number of occurrences could be stored, as could the time data for each multiclass. A multiclass can be combined, for example, an amplitude class, middle value class or gradient class. Reading the matrix by searching for the next time data, reading the assigned classes and evaluating the sample point value will provide extreme sample points with the sample point value and sample point time step. Thus, with this approach, the new counting approach will be able to evaluate extreme sample points after extreme sample points. The data could be plotted such that a recover uneven graph close to the original sampled graph could be generated. In the first plot, we compare the original curve and the recovered graph with the second plot. The plots were generated from the software prototype. Thereby, the software prototype is faulty yet in the ordinate representation in the case of the recovered curve. To optimize this fault, bug fixing will be needed. Nevertheless, the comparability of the results is given and presented in Figure 6.

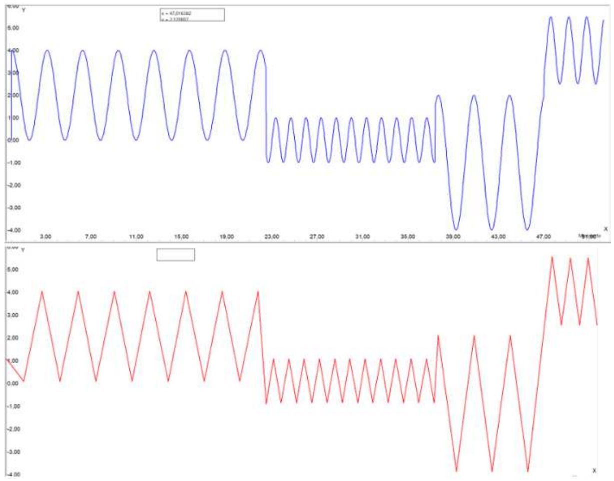

Figure 6: Original Sample Curve (Top and Blue) and Recovered Sample Plot (Bottom and Red)

A deviation between the original and the restored curve could occur because only the extreme sample points are restored, not the points between them. However, if the behavior between the extreme points is not particularly important, such as in the case of load cycle evaluations, this issue will be limited. This classification could cause deviation because of class tolerance.

There is no requirement to store the time sample data of extreme points. However, this approach is possible and required if recovery can occur later. Nevertheless, reducing the storage size of the data is desirable.

The Data Size of the Sampled Data, Including the Load Cycle and Frequency, is Reduced

Depending on the data scope that should be stored, a data reduction will be possible. In comparison to the original sampling date, where the sample value is stored for each sample step, the new counting approach will scope the storage. Without the requirement of recovery, the new counting approach can reduce the scope to the number of counted occurrences for each multiclass event. The multiclass numbers have not yet been stored because each row represents multiple classes. To predefine the class approach, in the first rows, descriptions of the classes will be provided. In the case of recovery functionalities in addition to the number of occurrences or instead of happenings, the time steps of each multiclass event could be scoped during storage.

Nevertheless, it could appear that the matrix file will be larger in the ASCII format than the original file. This could be attributed to the presence of empty rows. What will be multiple classes with zero counted happenings. In the standard format, such empty rows will require storage. In this case, the zip-technology will reduce the data size for empty rows enormously. Comparing the zipped matrix with the zipped original sampled file will show that the zipped matrix file will be smarter than the zipped original sample file. In addition to reducing the amount of data stored, a reduction in the amount of data traffic could be achieved. Focusing on multiple classes describing the amplitude, mean and frequency classes once, as well as focusing on extreme appearances and the possibility of digital filters, will greatly reduce the amount of data transfer. In the case of a separated sensor unit and storage unit (edge computing, big data, etc.), focused and smart data transfer will be realizable, especially compared to sample file transfer. Ongoing, data reduction could be performed by filtering out unnecessary data.

Implements Digital Filter Technology

The original sample data are often filtered, possibly because low amplitudes or low frequencies are not the focus of the evaluation. Other arguments for the implementation of filter technologies could also be given, such as high frequencies. The filtering of original sample data is often performed by filter technologies such as low-pass or high-pass filters, as discussed in [25]. The new counting approach provides the possibility to filter during the counting process itself as well as afterwards. Both approaches will be possible by using the same digital filter arguments. By using the multiclass approach (amplitude class, mean value class and gradient class), we can extract classes that represent a special range of amplitudes, mean values and gradients. Ignoring or deleting the content of such a multiclass will follow down in a digital filter of values belonging to the range of amplitude, mean value and gradient of the multiclass. If a special multiclass is filtered, the values belonging to the specific range of the amplitude, the mean value and the gradient are ignored or completely deleted. There will be no deleterious effects (reduction, damping, causality, etc.) of specific frequencies, such as possible in the case of common filter technologies, as discussed in [25]. Filtering of individual or multiple multiclass contents will make it possible to implement the exact required filter range. For example, low amplitudes at high middle values could be maintained during ignoring low amplitudes at a given range of middle values. An improved filter approach may be useful for evaluating durability.

Conclusion

This paper presents a new counting approach and proposes the following benefits:

- Provides data evaluation of load cycles.
- Frequency- or time-dependent data evaluation of load cycles.
- The appearances of the load cycles and frequency in one process are counted.
- Higher granularity for data analyses.
- Can restore the extreme sample points.
- The data size of the sampled data, including the load cycle and frequency, is reduced.
- Implements digital filter technology.

Therefore, the new counting approach will be implemented in a prototype. We discussed the topics via a synthetic sample file example used as a base in the prototype software. Nevertheless, the prototype can be improved on-going. However, the prototype and its benefits show the potential to optimize resources for data traffic handling and data storage. Ongoing, the new counting technology achieves a data evaluation technology that is able to combine multiple evaluation approaches. With the potential to invest in one evaluation approach instead of multiple approaches, the requirement on computing resources could be optimized. Thus, the potential to optimize computing-, data-traffic- and data-storage-resources will decrease energy consumption (green technology) and cost reduction (economy optimization), for example, in the case of big data.

Thereby, the evaluation results could be more granular and dependent on multiple parameters, such as amplitude, mean value, frequency and sample time. This approach provides further and new evaluation potential, for example, in the context of predictive maintenance and condition monitoring. Thus, the new counting approach provides multiple benefits and the potential to improve evaluation processes in multiple use cases. Invests in further and ongoing evaluations of use cases in the context of the new counting approach should be followed up to evaluate useability.

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Author contributions

Michael Mahler: Conceptualization, Methodology, Validation, Formal Analysis, Visualization, Coding, Writing, and *Kerstin Mahler:* Review, Supervision, Documentation.

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References

1. Testing, ASNT The American Society for Nondestructive. ASNT The American Society for Nondestructive Testing. *Discover Nondestructive Testing. 05* 03, 2024.
2. IKTS, Fraunhofer Institute for Ceramic Technologies and Systems. IKTS Fraunhofer. NON-DESTRUCTIVE TESTING. [Online] 05 03, 2024.
3. Forschungskuratorium Maschinenbau. Rechnerischer Festigkeitsnachweis für Maschinenbauteile. 6. s.l. : VDMAVerlag, 2012.
4. Ferguson, M., Bhinge, R., Park, J., Lee, Y. T., & Law, K. H. (2018). A data processing pipeline for prediction of milling machine tool condition from raw sensor data. *Smart and sustainable manufacturing systems, 2*(1).
5. Kolling, S. und Steinhilber, H. Skriptum zur Vorlesung. 2. Auflage Technische Schwingungslehre. Gieße : Institut für Mechanik und Materialforschung (IMM) 35390 Gießen, 2013. Technische Hochschule Mittelhessen Fachbereich Maschinenbau und Energietechnik.
6. Paech, F. (2013). Analysis-anschaulich und anwendungsorientiert. Carl Hanser Verlag GmbH Co KG.
7. Baba, T. (2012). Time-frequency analysis using short time Fourier transform. *The Open Acoustics Journal, 5*(1), 32-38.
8. Duhamel, P., & Vetterli, M. (1990). Fast Fourier transforms: a tutorial review and a state of the art. *Signal processing, 19*(4), 259-299.
9. Cooley, J. W., Lewis, P. A., & Welch, P. D. (1969). The fast Fourier transform and its applications. *IEEE Transactions on Education, 12*(1), 27-34.
10. Sharma, A., Oh, M. C., & Ahn, B. (2020). Recent advances in very high cycle fatigue behavior of metals and alloys—a review. *Metals, 10*(9), 1200.
11. Versuche über die Festigkeit der Eisenbahwagenachsen. Wöhler, A.Z. 1860, BAuwesen.
12. Bathias, C. (2013). Fatigue limit in metals. John Wiley & Sons.
13. Köhler, M., Jenne, S., Pötter, K., & Zenner, H. (2012). Zählverfahren und Lastannahme in der Betriebsfestigkeit. Springer-Verlag.
14. Köhler, Michael, et al. Comparison of the Counting Methods for Exemplary Load Time Functions. Berlin, Heidelberg : Springer-Verlag GmbH, 2017. ISBN 978-3-642-55247-2.
15. An analysis of the influence of cycle counting methods on fatigue life calculations of steel. Ligaj, Bogdan. 2011, Scientific Problems of Machines Operation and Maintenance, Vol. 46.
16. Forschungsvereinigung Antriebstechnik e. V. Zählverfahren zur Bildung von Kollektiven und Matrizen aus Zeitfunktionen. FVA-Richtlinie. s.l. : Forschungsvereinigung Antriebstechnik e. V., August 2010. FVA 131 IV.
17. Matsuishi, M., & Endo, T. (1968). Fatigue of metals subject to varying stress, Paper presented to Japan Soc. Mech. Engrs, Jukvoka, Japan.
18. Downing, S. D., & Socie, D. F. (1982). Simple rainflow counting algorithms. *International journal of fatigue, 4*(1), 31-40.
19. Fatigue life prediction based on the rainflow cycle counting method for the end beam of a freight car bogie. Baek, S. H., Cho, S. S. and Joo, W. S. s.l. : Springer Link, February 13, 2008, International Journal of Automotive Technology, Vol. 9, pp. 95-101. https://doi.org/10.1007/s12239-008-0012-y.
20. Gudehus, H., & Zenner, H. (1999). Leitfaden für eine Betriebsfestigkeitsrechnung. Verlag Stahleisen GmbH, Düsseldorf.
21. INTELLIGENT MONITORING OF A LARGE CATAMARAN FERRY. Shabani, Babak, et al. Part A1, 2023, International Journal of Maritime Engineering, Vol. 165.
22. Chen, L., & Ding, K. (2019, December). Big Data Analysis Method of Random Stress Spectrum for Crane Equipment. In 2019 International Conference on Big Data, Electronics and Communication Engineering (BDECE 2019) (pp. 8-11). Atlantis Press.
23. Mahler, Michael. Verfahren und Nivelliergerät zum relativen und lokalen Nivellieren von begehbaren Flächen, insbesondere von Außenanlagen im Garten- oder Landschaftsbau. DE102016115333B3 Germany, 2016.
24. Bäuerle-Mahler, Michael. Lastdatenaufnahme und Ermüdungsfestigkeits- und Lebensdauerberechnung: Sach- und Lehrbuch. s.l. : Books on Demand, 2008. ISBN 978-3-8370-4317-4.
25. De Cheveigné, A., & Nelken, I. (2019). Filters: when, why, and how (not) to use them. *Neuron, 102*(2), 280-293.