STATE-OF-THE-ART SYSTEMS FOR PREDICTIVE MAINTENANCE IN INDUSTRIAL MACHINES

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Abstract

This report is part of a group project about Systems for predictive maintenance in industrial machines, this report will talk about a simple yet very crucial and intricate part of this system. Fault Identification is the first step in a system designed for maintenance. This report will show how we can use high frame rate cameras to identify faults in machinery.

1. Problem Statement

While there are alot of IoT options to find faults in machines, sometimes it can be cost inefficient and also more labour intensive since we actually have to install those sensors. While they give alot of accurate data the investment to use them just for maintenance can be a bit pricey, specially when nothing is wrong in the machine.

2. Business need assessment

- Many factories are not equipped with sensors in all machines and maintenance technicians have to install them for testing when a machine breaks down or even just to test.
- It would be helpful if we could identify faulty areas beforehand to reduce cost and even to predict in which part of the machine the fault is occurring based on how it's vibrating.
- This will allow contactless analysis of the machine and hence help the experts to work on it more efficiently.

3. Target specification and characterization

- The target is to build a system which will take high frame rate video footage of a machinery and enhance the visibility of vibrations and point out areas with vibration over a certain threshold set by the user.
- After enhancing it, the system will provide us with various data about the machine like how much a certain part is vibrating, its frequently, FFT analysis etc.
- The user can select an ROI (Region of interest) based on a heatmap of vibrations and that area will be enhanced for further analysis.

References and Technologies which can be utilised:

1. For selecting the region
   https://github.com/facebookresearch/segment-anything
2. For enhancing video footage
   https://github.com/dangeng/flowmag/tree/main
3. For analysing vibrations
   https://vibrationresearch.com/blog/fast-fourier-transform-fft-analysis/

4. Benchmarking similar technologies

- While companies like RDI technologies are well established and provide a similar solution, they are too much hardware dependent although their proprietary hardware and live testing increases their systems robustness.
- Our Solution is a bit more software oriented, using cutting edge developments utilising deep neural network models and optical flow frame generation for targeted enhancement while having minimal noise.

5. Solution Pipeline

Our solution follows a carefully designed pipeline, offering a seamless experience for users. Here is an overview:

5.1 User Upload and Region of Interest Selection:

- Users initiate the process by uploading a video.
- They are prompted to define a region of interest (ROI) by drawing a bounding box around the specific object or area of interest in the video.

5.2 Amplification and Heatmap Generation

- The magnified video undergoes an amplification process, incorporating techniques such as a high-pass filter, Fast Fourier Transform (FFT), and inverse FFT.
- An amplification factor is applied, resulting in an amplified video.
- A grayscale overlay is then applied, generating a heatmap that vividly represents the amplified vibrations.

5.3 Mask Creation and Motion Magnification

- Utilising the defined bounding box, our system generates a mask isolating the selected object.
- The program then magnifies the motion or vibration within the masked area, providing users with a visually enhanced representation.

5.4 Vibration Analysis and Visualization

- The magnified video enters a vibration analysis phase.
- Utilising the original bounding box coordinates, the system conducts a comprehensive vibrational analysis, producing various plots and extracting frequencies from the magnified-amplified video.
- These insightful graphs and extracted frequencies are presented to the user, providing a detailed analysis of the video's vibrations.

6. Business and Financial model

6.1 Value Proposition:

Our solution offers a cost-effective, software-centric approach to predictive maintenance in industrial settings. By leveraging high frame rate cameras and advanced analysis software, we enable factories to conduct non-invasive, accurate fault identification and vibration analysis without the need for expensive IoT sensor installations. This approach significantly reduces upfront costs and labour associated with traditional sensor-based systems, while providing precise, actionable insights into machinery health.

6.2 Customer Segments:

Our primary customers are manufacturing facilities, power plants, and any industrial operations that rely heavily on machinery. Secondary markets include maintenance

service providers and equipment manufacturers interested in offering added-value services to their clients.

6.3 Channels:

The solution will be marketed directly to end-users through an online platform, offering subscriptions to our software. Additionally, partnerships with industrial equipment suppliers and maintenance service providers will serve as a secondary channel, expanding our reach and providing integrated solutions to their existing offerings.

6.4 Customer Relationships:

We will maintain customer relationships through continuous software updates, dedicated customer service, and user training programs. Feedback loops will be established to gather user input for future improvements, ensuring our solution evolves with the needs of our customers.

6.5 Revenue Streams:

The primary revenue stream will be subscription-based, with different tiers based on usage volume, features, and level of support required. Optional services, such as custom analysis or integration support, will provide additional revenue.

6.6 Cost Structure:

Initial development costs include software development, research into high frame rate camera compatibility, and initial marketing efforts. Ongoing costs involve software maintenance, customer support, and continuous improvement based on user feedback.

6.7 Revenue Projections:

Revenue will be generated through monthly or annual subscriptions. Assuming a conservative adoption rate in the first year, with a focus on small to medium-sized enterprises, we project a steady increase in subscribers as the market becomes more aware of the benefits of our solution. Revenue projections will be refined based on market response and subscription data.

6.8 Break-even Analysis:

The break-even point will be calculated based on the initial development and ongoing operational costs versus the expected subscription revenue. Our aim is to reach break-even within the first two years of operation, with scalability in mind to ensure long-term profitability.

6.9 Market Trends and Financial Equations:

Given the increasing demand for efficient maintenance solutions and the trend towards digitalization in industrial operations, we anticipate a growing market for our software-centric approach. Financial models will be developed based on linear growth projections initially, with the potential for exponential growth as adoption increases. The financial equation will take into account the pricing of our service **(m)**, total sales over time as a function of market adoption **(x(t))**, and fixed costs **(c)**, represented as **y = mx(t) + c**, where **y** represents total profit.

7. Conclusion

Our business and financial model for the state-of-the-art system for predictive maintenance in industrial machines positions us uniquely in the market, offering a software-based, cost-effective alternative to traditional sensor-based systems. By focusing on ease of use, scalability, and actionable insights, we aim to revolutionise the way industries approach maintenance, ensuring longevity and efficiency of their machinery with minimal upfront investment.