Development and Evaluation of a Manufacturer-Independent Synchronization Framework for GenICam Industrial Cameras

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Introduction

High-precision machine vision tasks, such as object recognition, often rely on stereoscopic or multi-view vision systems[1]. These systems use multiple cameras to capture images from different angles, enabling accurate depth perception and 3D model creation. For optimal performance, the reconstruction of multiple frames must be perfectly synchronized to eliminate artifacts caused by motion, lighting variations, or other environmental changes. This synchronization is particularly critical in time-sensitive applications, such as industrial inspection and robotic guidance, where real-time processing and decision-making are essential to maintain efficiency and accuracy.

Camera settings, synchronization, and control are typically managed through manufacturer-specific software tools, such as graphical user interfaces (GUIs) that offer configuration and calibration options. Although many GenICam-compliant cameras support standardized synchronization protocols such as Precision Time Protocol (PTP[2]), which allows precise time alignment between devices, achieving seamless cross-manufacturer camera synchronization is often challenging. This difficulty arises from proprietary implementations and incompatibilities in vendor software, limiting the ability to create a unified, multi-camera setup with devices from different manufacturers.

The aim of this thesis is to provide practical solutions for integrating various cameras into cohesive, high-performance setups. This will be achieved by evaluating hardware and software solutions for synchronizing cameras and integrating them into a unified framework, enabling users to easily set up and trigger synchronous recordings from up to six heterogeneous cameras.

1 Project Goals

The primary objective of this project is to develop a universal synchronization method for industrial cameras to ensure compatibility between different manufacturers. The project seeks to overcome current limitations by leveraging the advantages of the GenICam[3] standard with the insights from existing synchronization technologies. In addition to developing a robust synchronization method, the focus will be on delivering a seamless user experience through an intuitive graphical user interface (GUI). This GUI will be designed to simplify the configuration and operation of the synchronization system, allowing users to easily control the setup. By combining an effective synchronization solution with a user-friendly interface, the project aims to provide a practical tool that meets the needs of diverse industrial applications while also promoting ease of use and operational efficiency.
These expected outcomes can be summarized as follows:

- **Comprehensive evaluation of existing camera synchronization methods,** focusing on their effectiveness and limitations.
- **Detailed requirements specification for the synchronization system,** covering both hardware and software components.
- **Practical implementation of a synchronization system** capable of coordinating industrial cameras of different brands.
- **Development of an intuitive graphical user interface (GUI)** to facilitate easy management and operation of the synchronization system.

2 Methodology and Work Packages

To achieve the objectives of the project, the work will be divided into 3 main phases. The initial phase will focus on **defining the system** to be implemented by researching and evaluating existing software and hardware solutions for camera synchronization in industrial settings. This will include a comprehensive review of current literature to understand different synchronization methods, as this is not a recent challenge, and their requirements, along with an assessment of solutions provided by various manufacturers for their specific cameras. Following this, key hardware and software requirements will be defined, including camera types, brands, communication protocols, frame rates, and operating systems. With the requirements defined, the next phase will involve the **design and implementation** of the system, followed by testing to evaluate its performance and precision. Any issues identified during the tests will be addressed and refinements made to optimize the solution. The final step in this phase will be to integrate the most effective solutions into a user-friendly graphical interface, ensuring that the system is both functional and easy to use. Integration testing and validation will then be carried out to ensure that all predefined requirements are met. Finally, the **Validation and Refinement** phase begins, during which all results and findings are reviewed, compiled, and documented in the final thesis report. A detailed breakdown of the work involved in each phase is outlined in the following work packages:

WP 1: Research

1.1 Perform a detailed literature review on camera synchronization techniques.
1.2 Evaluate manufacturer-specific synchronization methods and their effectiveness.

WP 2: Requirements Definition

2.1 Specify hardware requirements for different types of cameras and brands.
2.2 Specify software requirements as communication protocols, frame rates, and operating systems.
2.3 Review and validate requirements.
2.4 Document the outcomes into a requirement table.

WP 3: Design and Implementation

3.1 Design and implement the synchronization solution according to the design specifications.
3.2 Design and implement the GUI layout and functionality.
3.3 Refine the Framework based on feedback and testing results.

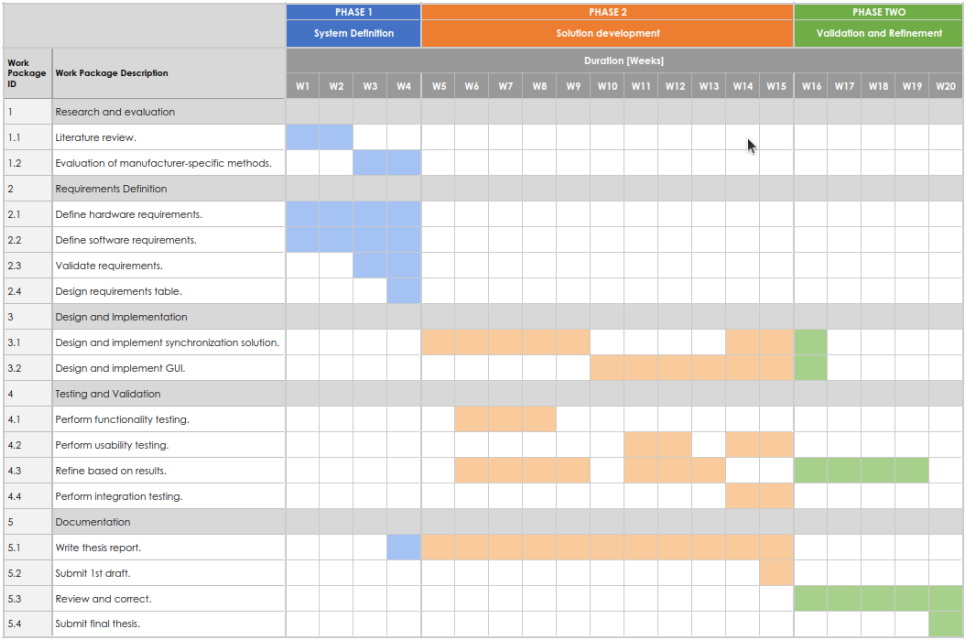
WP 4: Testing and Validation

4.1 Conduct initial testing to ensure basic functionality and performance.
4.2 Conduct usability testing to ensure the interface is intuitive and effective.
4.3 Conduct integration testing to verify that the system works seamlessly with various camera setups.
4.4 Perform validation tests to confirm that all predefined requirements are met.

WP 5: Documentation

5.1 Document work progress, including methodology, results, and conclusions.
5.2 Submit the first draft for review.
5.3 Revise the thesis and, if necessary, update the implementation based on the collected feedback.
5.4 Write the final thesis report and submit the thesis.

3 Timeline



4 Literature

References

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3. *Generic Interface for Cameras (GenICam)*. Available also from: https://www.emva.org/standards-technology/genicam/introduction-new/.