iCART Acquisition Module

Software Verification

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Table of Contents

The verification of a complex software project is a difficult and time consuming procedure. The development on iCART version 1.1 started in summer 2005 with studies on a new user interface and continued 2006 with the evaluation of a new file system. During 2006 numerous test were performed to guarantee software stability, completeness and quality of the acquired data. The iCART Acquisition module integrates a software simulation to enable debugging. The simulation is placed in the same subroutine as the data acquisition procedure and is executed instead of the data acquisition procedure, if no data acquisition hardware is found. In addition to the debugging procedure iCART version 1.1 has been evaluated with some field tests. All of the above tests do only cover a part of the software. To evaluate the complete data acquisition hardware and software, a function generator utility has been built into iCART. The function generator produces all signals of a wire rope testing instrument. These signals can be fed back to the data acquisition hardware and can be used to check the functionality of the complete data acquisition system.

Introduction

The verification procedure of a complex software package like the iCART Acquisition Module (iAQM) is a time consuming and complex procedure. iAQM has been developed in a cyclic procedure in small steps: Every new feature was carefully tested before its integration into the software package.

Before starting with the verification details, it is necessary to discuss the internal structure of iAQM. The software is implemented with GOOP (Graphical Object Oriented Programming) techniques to achieve a good maintainability and a large software flexibility. The iAQM is structured as follows:

- **User interface:** The purpose of the main VI (LabVIEW virtual instrument) is to interface with the user. It starts all processes, configures them, interacts with the user and displays the results. The main VI does not contain any testing technologies.

  The main VI runs four threads that communicate with each other (user interface, result display, function generator and data acquisition).

- **iCART Acquisition Class:** This GOOP Class contains the full functionality of iAQM. It interacts with the data acquisition hardware through National Instruments (NI) DAQmx technology. The raw data accessed from the AD converter is sent to a ring buffer. A scaled and speed compensated instance of the raw data is sent to the main VI and another scaled and speed compensated instance

is sent to the analysis object. Test results are retrieved from the Analysis object and also sent to the main VI. The ring buffer is sent periodically to the "Save"-tread, which runs parallel to the data acquisition thread.

It is important to realize that preview and the raw data storage operate on the same integer array. If the preview is complete, the raw data is complete as well and vice versa.

The Acquisition Class is highly configurable through an XML preference file.

- **Data communication:** The data communication between the different threads is realized with queues. All queues are sized and are permanently supervised to determine a possible overflow. An overflow in one of the queues or the buffers is reported as an error and the data acquisition is stopped immediately. All data before the occurrence of an error is written to disk and the user is asked to choose the desired storage (database or trash).
- **Data analysis.** The data analysis of iAQM version 1.1 is a re-implementation of the identical analysis of the iCART version 1.0 software. The version 1.1 of these methods have a much better performance. The improvement was necessary to achieve a satisfactory overall performance of the iAQM software package. The analysis methods are now fully configurable through preferences.
- **Database access:** All database access is done through the XML Class object. This GOOP object has been developed for general use within the iCART software package. XML Class library can read extremely large files and is specialized to access LabVIEW data objects. iAQM uses this object to read system preferences and to manage its database. iAQM does not access raw data files with XML class library.

Verification of critical Software Parts

The iAQM software package has been developed during a time period of more than one year. All of the software components have been carefully tested and bugs have been removed consequently during the development procedure. The software is now almost bug free. Beside this "normal" procedure we have carried out verification procedures for some critical software parts or functions. The critical parts of iAQM are all methods involved in raw data handling. These are:

- The complete path from the AD converter to the stream data file;
- The internal ring buffer (as the most critical part of the data path);
- Data file quality;
- Preview quality (as part of the data file quality);
- Handling and user interface.

Ring buffer

The ring buffer serves as a temporary internal storage to optimize disk access and preview generation. The size of the ring buffer determines the length of the preview pictures and the size of the data blocks. The data from the AD converter must be read in smaller pieces to prevent "hangs" or waiting times in the case of slow movement. The ring buffer collects data from the data acquisition until it is full and then sends its data to the data storage thread.

The ring buffer functionality can only be tested in a debugging environment. The internal simulation produces an U32 (unsigned 4 byte word) that increments by 1 with each data sample. This number is splitted into two I16 (signed 2 byte word) numbers and stored in tracks 4 and 5 of the data block.

The tracks 4 and 5 of have been recombined to a U32 word and its value has been carefully observed for various combinations of data block size and number of samples from AD converter. The ring buffer works correctly under all tested circumstances.

The ring buffer test can be reproduced any time by forcing iAQM to simulate data instead of acquiring data.

Complete data acquisition path

The complete path of data acquisition has been tested using iCART's internal function generator with special values. The function generator simulates a piece of a stranded rope with a length of exactly 4 times pitch, with one wire break in the middle. The wire break pattern can be chosen via preferences. For the performance test a 35 mm Seale 6x19 stranded rope with a pitch of 250 mm was simulated. Under the test conditions, iAQM could acquire data with a speed of 5 m/s over a length of 12000 m without loosing any data[1]. The relative position of the wire break pattern with respect to the data block did not change during this time.

The complete data acquisition test can be reproduced any time with the help of a special connector.

Data file quality

iAQM writes bug free, well structured and validated XML code under most circumstances. Tests have shown that data files do not meet XML standards only in the case of a power failure or in case of disk errors. All raw data files generated during the test period have been validated with the help of professional XML validating software.

Preview quality

The preview GOOP object of iCART has been debugged carefully and many thousands of preview pictures have been generated in labor and field tests. iCART generates well scaled, clean diagrams under all tested configurations. The resolution of the pictures depend on program settings. IWM uses pictures with a resolution of approx. 180 samples per m in x-direction and 0.1 V using 10 V Range in y-direction. The resolution in x-direction is better than most paper registrations, the resolution in y-direction does not reach the quality of paper registrations, but a high resolution in y-direction is not required to detect wire breaks. More critical is the resolution in x-direction, because it is necessary to distinguish wire breaks with a distance of 10 to 15 mm.

The iAQM software allows much higher resolutions in x and y-direction, but the previews need to be kept as small as possible (less than 4k) to maintain compatibility with all XML enabled web browsers.

The preview pictures generated up to now allow a manual analysis of the testing data without any restrictions compared to "old style" paper registrations.

User interface and handling

iAQM's main advantage compared to competing products is its ease of use. The user interface has been revised several times and its functionality has been tested under field conditions. The user interface is now elegant, efficient and bug free.

Conclusions

The iCART Acquisition Module (iAQM) version 1.1 is the result of 3 years of computer aided rope testing experience and more then one year of coding and debugging. Compared to is predecessor, iAQM has a much more efficient user interface and uses state-of-the-art XML files for storing raw data. iAQM is now a fully configurable, flexible and professional quality data acquisition software.

iAQM has been tested and verified during a time period of almost one year. Several field tests have been performed during this period. All critical procedures, especially the data acquisition and storing have been supervised carefully during tests. iAQM writes now bug free, well structured and validated

[1] Depending on system performance. In case of a failure, the the data up to the occurence of the error is complete.

XML raw data files under field conditions. The preview pictures contained within the stream files are clean and well scaled. They allow a manual "old style" analysis of the test data without any restrictions.