Development technology for inspection and measurement software using industrial PCs

2024-04-01

Preface

This article focuses on PC software development technology in the field of factory automation (FA).

The development targets stand-alone image inspection machines that operate continuously in factories and

It is difficult to achieve this with just a general-purpose inspection machine or general-purpose program, and several development factors are required.

We assume a system that includes elements.

Currently, we are conducting AI research using interpreted languages (such as Python) that are mainstream in the AI and IoT fields.

If the results of the research are obtained and progress is made to the production of an in-factory inspection and measurement system,

It is common to ask a software developer or software production company to develop it, but for reasons that will be explained later,

In some cases, companies may want to develop their own systems in-house. In this case, it is necessary to use API libraries provided by hardware manufacturers.

In order to reference (link) the software, it is often necessary to use a compiled language such as C.

The difficulty of software development increases. Even if it is possible to achieve this by using Python and Raspberry Pi,

When rebuilding on a PC, there are many things to consider, such as the PC, peripherals,

Choosing the language of expression can be a challenge for those in charge.

Therefore, based on my experience in the manufacturing production technology department, I would like to introduce a factory that continues to operate as a standalone.

I would like to introduce practical software development techniques for development issues, assuming an internal inspection system.

Development and operation without an internet connection, and during regular factory inspections that occur once every few years

Maintenance work (such as updating PCs) is now considered a somewhat unusual type of work (non-routine work).

Isn't that right?

IoT-related technologies are advancing rapidly, and some of the content of this article is outdated.

These two examples demonstrate the key points of the programming techniques in this paper.

It's condensed.

We hope this article will be useful to readers working in this field.

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[1] The “present” of this article is January 2023.

The prerequisite knowledge for this article is listed below.

ÿ Information processing technology

Understanding and experience of the following terms:

requirements definition, basic design, detailed design, implementation, compilation, linking (building), unit testing, integration testing,

Operation, maintenance

ÿ C language, C++ language, integrated development environment

(IDE) Experience with C language alone is not a problem, and you do not need to delve into object-oriented programming. However, in order to use STL,

In this article, we will use Microsoft Visual Studio and

I used C++/CLI.

ÿ Basic knowledge of image

processing: Image processing libraries, bitmap files, OpenCV, rule-based, AI inspection, etc.

ÿ Optical system, etc.

Basic knowledge of lenses, line sensor cameras, area cameras, and lighting equipment.

You can acquire knowledge by referring to websites and catalogs.

The explanation on the website is helpful. 3

Common names of equipment used in factories, such as PLCs, control panels, and touch panels.

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[2] **I've been using it since 2005. With the advent of C++/WinRT, it is becoming deprecated.**

[3] **Example: Keyence Corporation https://www.keyence-soft.co.jp/group/products/**

Content

1. Development of inspection and measurement systems

1-1. Advances in imaging tests

With the advancement of the information society, the scope of "visualization" is expanding even in the factory FA field.
In recent decades, we have moved away from visual inspection of products and have moved towards automated rule-based inspection and AI.
Taking the example of AI inspection, a large number of product images are taken and the OK/NG information is analyzed by humans.
By adding information to the neural network and using machine learning to simulate the neural circuits of the brain,
Pewter can instantly make judgments equal to or better than those of a person (in this case, a veteran judge in the factory).
It will be.

A typical rule-based inspection is the defect detection inspection in sheets (pulp, nonwoven fabric, etc.).
Here is an example: [Figure 1] Product width: approx. 1m, conveying speed: 10m/min, black foreign matter (small particles) in the film sheet.
We are considering introducing an image inspection machine that can detect defects (sizes of 100 ÿm or more). First, we will
We will conduct an imaging experiment (in a stationary state) to see if we can detect foreign objects.
If the foreign object can be recognized on the image and can be detected by some image processing software,
If so, proceed to the next design stage.

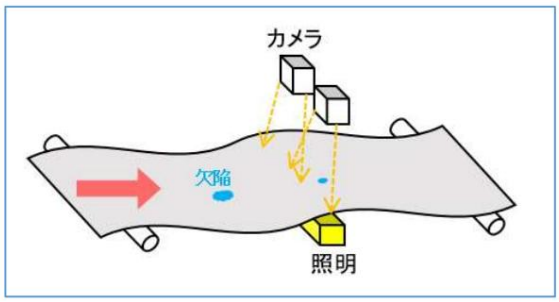

Figure 1. Typical image inspection machine

One of the key points in the inspection machine design stage is selecting an imaging system that takes into consideration blurring, dust, and light blocking during transportation.
The presence or absence of blur affects the depth of field and shutter speed of the optical system.
The number of cameras required is also determined at this stage, and the framework for the requirements definition document is created.
It will be done.

1-2. Features of the inspection and measurement app

The typical features of inspection and measurement apps can be divided into the following types A and B.

[Type A (mainly inline equipment)] The operator must be in charge of the start-up and shutdown and non-steady-state (abnormal or steady-state)
The PC is operated only during special circumstances (such as during periodic maintenance work), and only for monitoring during normal operation.

[Type B (mainly repeat measurement equipment)] The operator performs the same procedure (using a mouse, keyboard, etc.)
(frequently used) repeatedly.

Type A apps do not require high levels of UI appearance or design, and are similar to video games.
In most cases, 3D graphics processing, such as
If you have an integrated development environment (IDE), you can easily create and run the UI without having to purchase specialized third-party tools.
However, takt time and robustness for continuous operation are required.

On the other hand, when targeting Type B, it is necessary to avoid operator errors and fatigue due to monotonous work.
To meet the precise requirements for quality control, it is necessary to devise a UI that meets these requirements.
A typical example is a microscope-type inspection device.

From then on, emphasis was placed on the development of equipment with characteristic type A, and the achievement of takt time and maintenance became important issues.
I will explain it in detail.

1-3. Requirements definition

The upstream process of compiling user requests and issues for inspection and measurement into a requirements specification (URS) is called requirements definition.
The following are the features of URS:

(1) The system overview is
Written technical documentation for both parties (e.g., vendors) and their managers.
It is a ment.
(2) Contains all the information necessary for potential contractors to submit rough estimates.
(3) It is a core document that can be used during operation, maintenance, and equipment renewal.

The method for creating a URS is omitted here4, but the next step after the URS is completed (the initial implementation stage) is to
This article describes the work to be done from the selection of the system configuration onwards.

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4 When defining requirements, coordination (hearings) between the client, user, and developer is important.

1-4.Determining development policy

In accordance with the requirements specification, we will create an inspection and measurement system using general-purpose products (off-the-shelf image processing terminals, etc.). We will investigate and evaluate whether the system can be integrated. We will classify the system configuration methods into three categories based on the level of complexity (method a, b, c (see Figures 2-4) will be used to explain.

Method a: The system is realized using a sequence (ladder diagram) within the PLC. 5

(Example) A safety fence system using a proximity sensor. A system for counting the number of passing objects.

Method b: Create an inspection system using a general-purpose (image) inspection machine and its development support tools.

(Example) The "typical image inspection machine" mentioned above [Figure 1] can be realized with a general-purpose image inspection machine. The image processing terminal is equipped with lighting control and GUI development functions for image processing algorithms. It is also capable of fairly complex processing.

Method c: Introduce a PC and develop an inspection system.

(Example) Using an actuator to build an imaging system with precise positioning capabilities.

(Example) Developing algorithms that are difficult to achieve using general-purpose image inspection machines alone.

(Example) Incorporating your own AI PC.

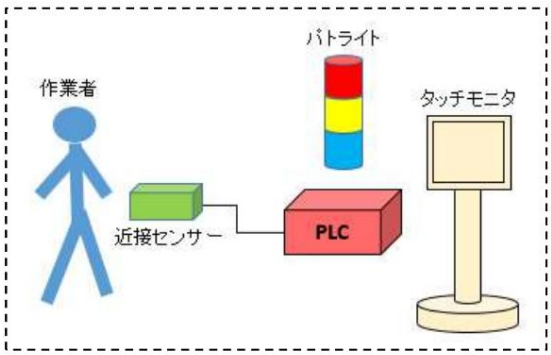

Figure 2 Method a

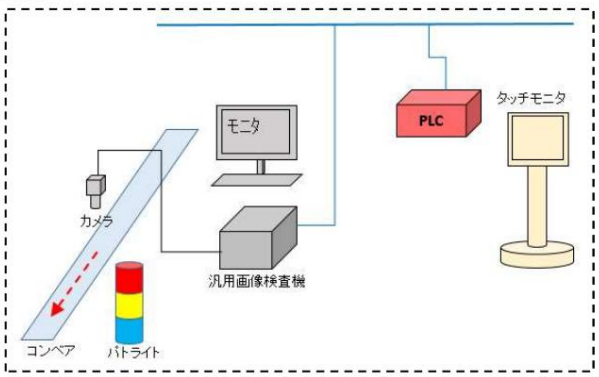

Figure 3 Method b

[5] For information on **industrial PCs and PLCs , please see https://iotnews.jp/manufacturing/176285/.** An explanation can be found at **https://iotnews.jp/manufacturing/179310/ .**

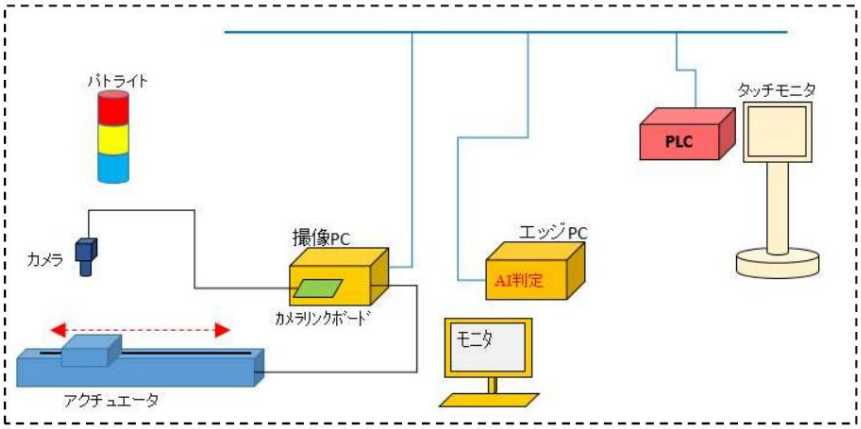

Figure 4 Method c

The order of difficulty in implementing the system and ease of maintenance is a ÿ b ÿ c.

The probability of failure of the HDD and power supply is higher than that of PLCs and general-purpose image inspection machines, so Generally, methods a and b are superior. However, if you still choose method c, the following reasons may be considered: can be done.

(1) When connection to and control of special peripheral devices is required.

(2) When the algorithm to be installed is complex and updates after operation are expected.

(3) When you want to maintain inspection and measurement technology as a core technology within your company for the long term

(4) Cost (general-purpose inspection machines can be expensive) (5) When you want to store a large amount of image data for capturing learning images for AI image inspection6

The following pages explain practical techniques for adopting method c.

6 Conventional image processing (rule-based inspection) requires humans to be able to explain the basis of judgment theoretically and develop judgment algorithms. The number of OK/NG learning images required for development was small, which was a good thing.

2. Selection of peripheral devices, OS, and development environment

Based on the development policy, we select peripheral devices and development environment (software).
In factories with high expectations, the selection of equipment and machinery is conservative.
For example, the Camera Link method, which was standardized in 2000,
This is because there is a strong demand for this type of product.

The following are industrial PCs, cameras, PLCs, expansion cards, etc., and operating systems and development environments.

We will explain the selection points from the perspective of operation and maintenance in the following order.

2-1.Industrial PC

Industrial PCs are available in a variety of sizes, including CPU type, tower/rack mount type, expansion board slot type, and number of boards.
You can customize the number of units, memory, HDD capacity, etc. [Figure 5] The OS (Windows) is installed immediately after shipping .
In most cases, only the software is installed, and other software (such as Excel) is installed by the user.
Please also be aware of the repair warranty period (free/paid) before purchasing.

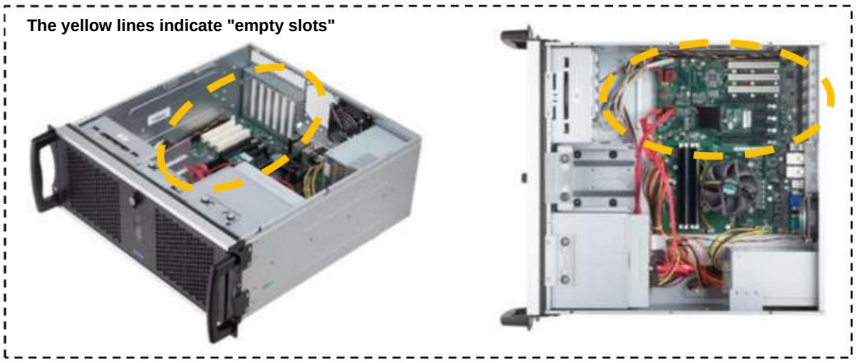

Figure 5: Inside an industrial PC (from the Contec website)

2-2. HDD, SSD

From around 2020, industrial PCs began to be equipped with SSDs instead of HDDs.
We have experience using 1-2T external storage media.
It is now possible to save all captured images, which was previously difficult8, and this is extremely useful for accumulating learning data for AI.

7Industrial PCs can generally be repaired for about seven years after they are no longer on the market.

8 Performance is sometimes very slow. Fragmentation may be a factor.

In recent years, the performance of personal computers, especially the computing power of CPUs, has increased due to the increase in the number of cores[9].
The emphasis has been placed on the SSD, and the overall performance has improved considerably.
You can.

2-3. OS Selection

Approximately 70% of desktop PCs are equipped with Windows as their operating system, and it is currently the first choice.
[10] In this paper, we will use general-purpose PCs and operating systems (industrial PCs and Windows).
You can customize the memory, CPU type, SSD expansion, etc.

Windows is not a real-time OS (in the strict sense), so the processing time is not constant.
In the critical case where the takt time can be achieved in average time, multi-threading and multi-
It may be possible to realize this system by using techniques such as PCization. These techniques will be described later.

2-4. Selecting a software development environment

We will explain using Visual Studio as the integrated development environment (IDE) and C++/CLI as the development language.
The version is VS2022. It is generally upwardly compatible with VS2005 and later.

C++/CLI has been around for over 15 years since the release of VC2005, and Microsoft has deprecated it.
We recommend C# or C++/WinRT. (In Visual Studio 2022, after the default setup,
However, before C++/CLI was supported (i.e.
Visual Studio 2003 and earlier)'s mainstay[11] compared to MFC, the user interface (hereinafter referred to as

[9] To fully utilize performance, the multi-threading techniques described below are required.

[10] When choosing Linux, consider whether or not there is driver software for peripheral devices (generally, Windows OS has more drivers). After the operation, maintenance work (when requesting remote file updates from factory workers, Linux training is also required in advance) necessary) etc. must be taken into consideration.

[11] Templates for new development (as provided in previous versions) are no longer provided.

It is easy to create a UI (abbreviated as UI) and build multi-threading, and it is also possible to use C for peripheral devices and image processing libraries.
Considering the ability to link to language-compatible APIs, it is still a popular language at present. 12

In addition, the author adopted C++Builder (Borland ÿ now Embarcadero) around 2004 and has been using it for
I have experience developing an image inspection machine. The target PC is Linux, and I have a cross-comparison environment (Linux
In terms of functionality, both (C++/CLI and C++Builder) are inspection and measurement applications.
This was achieved without any problems.

Advantages of C++

(1) They are good at handling hardware. They can efficiently allocate and delete memory areas.

(2) Standard C++ functions allow handling of STL and multi-threading.

Advantages of C++/CLI

(3) It is easy to create a Windows GUI (compared to Win32 programming or MFC).

(4) Ability to handle legacy assets (C language, MFC source code, Windows API).

When choosing other languages (C++/WinRT or C++Builder), the following two points are important to consider:
there is.

(1) Can multi-threading be realized? In inspection and measurement systems, high-speed image display on a GUI screen is required.
Is it possible to make the display thread-safe?

(2) Can you control the allocation and release of memory space (rather than garbage collection)?

2-5. Connecting the camera

The camera connection method is as follows:

ÿ Install an expansion card in an empty slot (e.g. Camera Link) ÿ Via a LAN
cable

The sample source code of the API (library) of the hardware provider such as the 12DIO board is available in Visual Studio.
There are many things that were tested around Studio 2013. On the other hand, there are many things that are not related to hardware control in C++/WinRT.
The level of support is unclear. I hope Microsoft will extend the support period for C++/CLI.

ÿ Via USB port. Depending

on the system requirements (number of pixels, transfer speed, cable length, etc.) and

The optimum configuration is selected from the list. Wiring for synchronizing exposure and lighting (e.g., strobe imaging) is also available.

I'll consider it at this point.

Even if the cable length meets the standard requirements, noise may be mixed into the image depending on the factory conditions.

In such cases, you may be able to solve the problem by using an extension booster or shielding the cable.

can be done.

2-6. Expansion cards

Expansion cards that are inserted into empty slots in industrial PCs include Camera Link compatible boards,

There are many types available, including DIO boards 13, optical communication boards, graphics boards, and A/D conversion boards.

The mainstream PCI standards are PCI, PCI Express x1, PCI Express x4, and PCI

PCI Express x8 and PCI Express x16 are classified as PCI Express xN, where "N" represents the number of lanes.

The larger N, the faster the transfer speed.

Points to note when selecting:

ÿ Number of bits Depending on the number of bits on the board, the cable and terminal block types will also differ.

ÿ Number of lanes Check the available slots on your PC.

ÿ Supply voltage (if necessary)

ÿ When installing multiple boards, consider the total power capacity and physical size (thickness, distance from adjacent boards)

You also need to check that there is no interference.

ÿ Expansion cards are often made to order, so please be careful about delivery times.

If there are many peripheral devices to be connected, draw an accurate system configuration diagram to avoid incorrect selection (mainly slot

When selecting a graphics board for AI applications, it is important to note that

(GPU) As power increases, there are issues with PC power supply capacity and interference (or contact) with adjacent slots.

I would like to point this out.

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13 More precisely, this refers to a DI board, a DO board, or a DIO board that has both functions.

14Due to the impact of COVID-19 and the semiconductor shortage, there were times when delivery times were longer than six months.

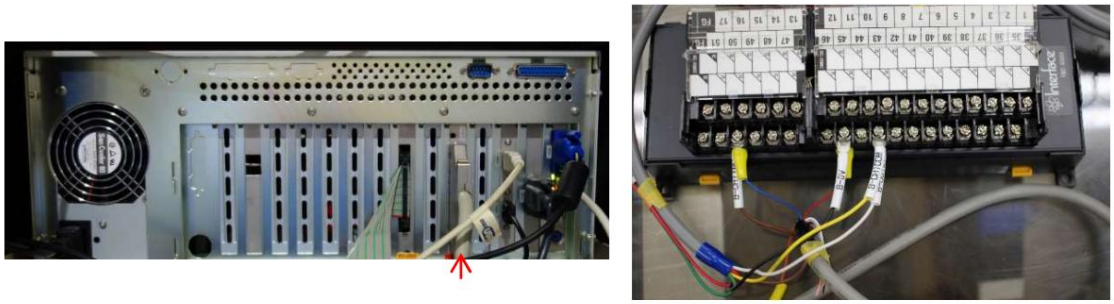

Figure 6 (Left) DIO boards installed in a PC (Right) Terminal block

The response speed of the DIO board is faster than that of LAN, so it is ideal for communication between PLC and PC when tact time is tight.

This provides a choice of means (peripheral device control and data I/O).

The optical communication board provides high-speed image data transfer between multiple PCs.

Insert the optical communication board into the slot and connect it with an optical fiber cable.

The master and slave software processes15 are written using a dedicated API .

It can be extended up to 100m and has fast access to shared optical memory.

This technology should be considered as an option, especially for AI image inspection systems (photography).

It is suitable for building a PC for image processing, an AI edge PC for judgment, and a PC for storing learning data.

PLC

Below are some examples of applications that combine industrial PCs and PLCs.

Example 1. The encoder signal is received via a PLC and can be used as measurement data in a PC.

Example 2. When entering data (selecting the brand to be produced, starting signal, etc.), the mouse and keyboard

You can use a touch panel connected to the PLC instead of the keyboard.

Example 3. It can be used as a means of communication between multiple PCs. 16

In many cases, the manufacturer and model of the PLC are specified by the factory. For communication between a PC and a PLC,

LAN connections are common, but the access time for each data transfer can take approximately 50 msec.

Therefore, careful consideration is required to adapt it to processes with strict tact times.

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15 The API of Aval Data's product controls multiple PCs on the ring with a "doorbell." The author uses three PCs.

We have experience in building a system that connects cameras in a loop to capture images, perform AI judgment, and save images.

16 It's easier to use than writing socket code.

The PLC and PC connected via LAN can share the development by accessing the shared memory (device).
The following is an example of a system development division procedure:
Masu.

(1) Request the design and production of the control panel, PLC, and terminal block from an electrical and instrumentation company. (2) The person in charge of PC production will create a timing chart between the PC and PLC.
(3) Both parties (electrical and instrumentation specialist, PC side production specialist) follow the timing chart to program Produce.
(4) Both parties will conduct a connection test between the PLC and the PC.

2-8. Actuator, ROBO Cylinder

Actuators and ROBO Cylinders are controlled using the controllers and programs provided by the manufacturer.
It is common to learn ("teaching") the range of motion and the course of motion in advance before using it.
However, if necessary, you can connect it directly to a PC (using a USB cable, LAN cable, or serial cable).
You can also use the algorithm to control servo ON/OFF, movement, stopping, etc.
Developing a low-level COM port communication software (described later) as an API for direct connection
However, caution is required to avoid physical interference (collisions) during debugging and adjustment.
In particular, programs that operate motors with large output require risk assessment and safety measures (safety fences).
It is necessary to consider these issues and proceed with development with advice from mechanical and safety personnel.
This is the most difficult of the three to develop, and the involvement of mechanical and electrical engineers will be essential.

2-9. Uninterruptible power supply (UPS)

Uninterruptible power supplies (UPS) are also common items for factory operation systems.
In addition to its original purpose of supplying power for a certain period of time, it also functions as an automatic shutdown for multiple PCs connected to a LAN.
It can be connected via USB, LAN or COM port.

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17 Reference (IAI) https://www.iai-robot.co.jp/download/tashakiki/pdf/SERIAL-COMMUNICATION_MODBUS(MJ0162-3B).pdf

18 The author has previously developed a system that operates a camera on a 2- to 3-axis stage while the target sample is fixed.
The new challenges include waiting time while the stage is moving and avoiding interference.

3. Basic techniques

3-1. About the C language (including C++ and VC++)

The C language was originally a UNIX development language and has long been used as a development language for inspection and measurement systems.

The C++ language is an extension that adds the concepts of classes and object-orientation.

VC++ (Visual C++) is a multi-variant C++ library for Windows with added API and graphics functions.

A general term for (Windows programming, MFC, CLI, etc.).

C or C++ makes it easier to reuse legacy assets (hardware drivers, libraries) (details

It is still the first choice in the inspection and measurement fields.

Of course, you can use C# to create the UI and call legacy libraries,

It is technically more difficult than writing everything in C/C++.

By the way, I have a textbook knowledge of C and C++ languages (mainly grammar explanations) and a program with a UI on Windows.

I think there is a gap in the knowledge required to realize the system. For example,

The automatically generated source code (MFC and CLI) is incomprehensible to beginners.

In addition, the actual function is written in the C++/CLI header file (extension h), and the source file

The situation where the (*.cop) is empty is quite different from the C or C++ language textbook.

vinegar.

3-2. Development environment version

For the following products, you must select the version (version, revision) that corresponds to your OS and IDE.

It is important to understand this accurately as it will not be supported by the vendor.

- •Image library (OpenCV, Halcon, etc.)
- - PLC and PC communication API (e.g. Mitsubishi Electric MX Component)
- - Image processing terminal driver software
- •Interface drivers for camera boards, DIO boards, etc.

The above programs are available in 32-bit or 64-bit versions19.

The OS support life is about 10 years, and the maintenance period for industrial PCs is about 7 years at most.

For systems with a usage period of more than 10 years, we will investigate the old and new technical content and balance the development environment itself.

19Particular care must be taken when dealing with multiple products that only support one of the two.

Regarding Visual Studio C language (MFC, CLI) 20, the version

There is no 100% upward compatibility between versions, and in rare cases, compilation may not pass or an error may occur at runtime.

This can cause problems.

Well, if the peripheral device driver is not compatible with the latest OS or IDE, it is intentionally

Sometimes we use previous versions.

3-3. Variable scope and naming rules

Variable scope is an important concept, but it is based on textbook knowledge of C and C++ languages and practical use of IDE-based languages.

There is a small gap between the general usage and where in the auto-generated source code

Once you define variables (especially CLI-specific managed variables), they can be used as static global variables.

It may be difficult to understand how this works.

To write a practical program, you need static variables (those that are only instantiated after the program has started).

It is necessary to be able to use global variables (which are generated when a program starts and exist until the program finishes).

When the application starts, the initialization function is called and the handle (API

The hardware pointer for use in the program is stored in a global variable, allowing you to call the API function at any time.

But you can also use it.

There are static member variables of C++ classes as global variables, and STL containers

(std::vector, std::map, etc.) can be used as global variables. In the two examples,

It is often used for storing data and test results.

In the days when multiple people collaborated on programming in an environment where IDEs and the internet were not yet developed,

Understanding and managing naming conventions for variables (especially global variables) and module coupling strength (order of naming conventions)

However, nowadays, a huge amount of memory space can be used within a single program, so

This reduces the need to split modules carefully based on bond strength.

Just by placing a file, variable definitions are displayed in real time, which helps to cover loose naming rules.

21 If you need to make changes, you can quickly do so by replacing strings in your project.

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[20] **Over the past 20 years, VS2003, VS2005, VS2008, VS2010, VS2013, VS2015, VS2019, VS2022**

21In my source code, global variables are prefixed with "g."

```
// Form1.h
//

//For OpenCV
#include <opencv2/opencv.hpp>

#include <stdio.h>
#include <windows.h>

//STL preparation
#include <string>
#include <vector>
#include <queue>

//Image size
#define IMG_W 2500
#define IMG_H 2000

//tmp folder (images, logs) folder
#define TMP_FOLDER "c:/tmp_PFD"

////////////////////////////// //
Normal common variables go here

//1 image worth of work
unsigned char pImgBuf_[IMG_W * IMG_H * 3]; unsigned
char pImgBuf2[IMG_W * IMG_H * 3];

//Image capture area (ring buffer)
unsigned char pImgLingBuf[IMG_W * IMG_H * 3                * IMG_NUM_MAX];

//Structure for the queue
struct ImgInQue { int
                No; int        // 0,1,2,... //
                pt;             Pointer to the ring buffer
};

std::queue<ImgInQue> _queImg; //empty

//Image counter
int gCnt = 0;

static CRITICAL_SECTION gCS;

int func_PFD_(long long N, std::vector<long long >& vecPFD) { ...omitted...

                return(0);
}
```

Example of variable scope: Image buffer and STL queue defined at the outermost layer (blue text)

```
int func_PFD_(long long N, std::vector<long long >& vecPFD) {
        ⋯omission⋯
        return(0);
}

namespace CLR_Form {

        using namespace System;
                (omitted)
        using namespace System::IO;

        public ref class Form1 : public System::Windows::Forms::Form {


                Scope Caution
                Since you want to use it globally, put it outside
            ////////////////////////////////////////////// // //////////////////////////////////////////////
                Bitmap^ bmpG1;
                Bitmap^ bmpG2;

                // gridDataView    Tables that work with
                System::Data::DataTable^ _dataTable1;

        public:
                Form1(void) {
                        InitializeComponent(); //

                        //TODO: Add constructor code here
                        //
                }
                        //

        private: System::Void Form1_Load(System::Object^ sender, System::EventArgs^ e) {

...The following is omitted...
```

Example of variable scope Managed variables defined outside the form (written in red)

3-4.STL (C++ Standard Library)

STL, the C++ standard library, provides a set of general-purpose algorithms.

It is essential for programming. Beginners should first learn how to use std::string, then learn how to use structures and classes.

Define it and write a small program that combines it with vectors, maps, etc. to learn it as a tool.

There was a time when search algorithms were created by hand, but now it is possible to register them in a map and find them.

That would be great, it would be a lot easier.

In the two examples below, we will use queues and maps (map, multimap) for exclusive control (critical

We use it as a separate section.

3-5. Measuring processing time

Early evaluation of the feasibility of takt time is an important issue in system design.

To achieve this, it is necessary to properly measure and evaluate the execution time of functions and algorithms.

Here is the time measurement code in VC++ CLI.

```
DateTime start = DateTime::Now;
... (time-consuming process, repeat N times if necessary)
DateTime end = DateTime::Now;
TimeSpan t = end.Subtract(start);
MessageBox::Show((t.Seconds * 1000 + t.Milliseconds).ToString("########"));
// Display in milliseconds
```

Generally, the measurement variation of the time measurement function is several tens of milliseconds (or more), so the average value and

The evaluation is based on the maximum value. In particular, the measurement time immediately after launching the app may be extremely slow.

Due to the nature of the OS and program, it is not easy to resolve this issue.

A good technique is to run an empty check immediately after launching the app.

The time depends on the debug mode or release mode and the external storage medium (SSD or HDD), so

Also be aware of the shortest to longest conditions.

3-6.CSV file

It is convenient to use the CSV format for parameter files, result data files, and various log files.

Beginners should try to create their own functions to read and write comma-separated files (at least once).

Inspection machines have a tree structure for each brand, so you can select an XML file, but programming is also required.

The difficulty of the game increases.

```
2024/01/29 9:01:46, Glide_Path started
2024/01/29 9:33:12, Glide_Path started
2024/01/29 9:33:36, odd number of intersections
2024/01/29 9:41:30,disappear:ANA642
2024/01/29 9:41:56,disappear:ANA293
2024/01/29 9:42:22,disappear:SKY706
                ...
```

Once the inspection machine is in operation, the factory operator can remotely request changes to the "parameters."

When making changes, prepare a UI that uses VC++ dataGridView.

22 (Example 2 has an implementation example)

Figure 7. UI for modifying CSV files

3-7. Use of Japanese in files and GUI

Using Japanese (kanji) in Windows folder and file names for business purposes

Although it is common, in inspection and measurement systems,

It is best to avoid using characters up to 23 half-width alphanumeric characters.

Use of Japanese (double-byte characters)

ÿDescription in the parameter file

ÿText of GUI components (e.g. button names) ÿDescriptions in

log files (it is safe to limit it to infrequent error messages)

ÿ It is best to limit it to pop-up error

messages.

To avoid mistakes, it is best to avoid editing the CSV file directly in a text editor.

An application that displays text in a label on the GUI every time the watchdog polls (every few hundred milliseconds).
When developing this app, we encountered a rare issue where the app would hang up if Japanese text was mixed in.

3-8. Memory allocation and memory leaks

When allocating continuous memory for a large number of images, the malloc function is used in C++.
If you forget to do so, a memory leak will occur.
Even if memory leaks occur for a short period of time, it rarely causes hang-ups, but it is absolutely not recommended for continuous operation.
This should be avoided. The memory usage in the Task Manager's Performance Monitor should be recorded on a daily basis.
By recording the signal, you can check for leaks.

When using "garbage collection", be careful that the memory is not released as intended by the programmer.
This may not occur at the time of writing, making it difficult to test for memory leaks.
If you need to allocate and free memory, consider using the malloc and free functions as a pair.

3-9. How to use various APIs (specify at compile time and build time)

To control peripheral devices (such as cameras), use the API provided by the device manufacturer.
The first thing you need to know is the supported OS, supported language (version), and build bit number (32/64bit).
This is the response status (whether or not support is provided).

Generally, OS and IDE are updated once every few years, and the API (including the driver) of the device is updated accordingly.
It is often difficult to keep up with updates. In this case, there is a high possibility that the higher version will work, so
It is worth testing when selecting a model. However, the number of bits at the time of building must be the same in order for it to work.
(For example, a certain manufacturer's PLC only supports 32-bit, and some image libraries support 64-bit.
If only one of the following is supported, the PLC and the image library cannot be controlled at the same time within the same program.
yeah.)

The setting location for using the API DLL is on the project properties screen in the IDE, as shown below.
Set ÿ to ÿ.

ÿSpecifying include files when compiling

ÿ Specifying the LIB file when linking ÿ

Specifying the location of the DLL file when running

In Visual Studio, you specify this in the properties in the Solution Explorer, but here you can
Regarding ÿ, if you store it in the same folder as the EXE format, you can specify
No setting is required.

There is also a special API called the Windows API (a set of system call functions for Windows).
For C and C++ source code, you can add a few lines of include statements to use it.

Even when it is difficult to achieve something using only closed-world functions, it can be achieved by using the Windows API.

There are many. (See the section on saving enlarged images in the large-size viewer in the appendix.)

3-10. Cooperation with PLC

For example, to implement the timing chart in Figure 8, you need to use the API provided by the PLC manufacturer.

24. It is necessary to code a program for periodic monitoring of the device (PLC shared memory).

After that, during the integration test, the developer in charge of the PLC on the mechanical (machine) side (e.g., electrical/instrumentation person)

I will work with you to debug the issue. I would like to offer the following advice:

1) To install a PLC, an IP address must be assigned.

Prior confirmation with the system manager is required.

ÿ Each PLC manufacturer has different terms, initial setting methods, and device (shared memory) monitoring methods.

If you are using a model that you have no experience with, try to rent it early.

Generally, the API (software) of a PLC is different from the OS and development environment.

In comparison, updates are less frequent, and you may be forced to use a version that has not been confirmed to work.

3) The PLC has a backup system (on an SD card or a PC USB memory key) to protect against malfunctions.

This operation and its contents will be passed on to the next generation.

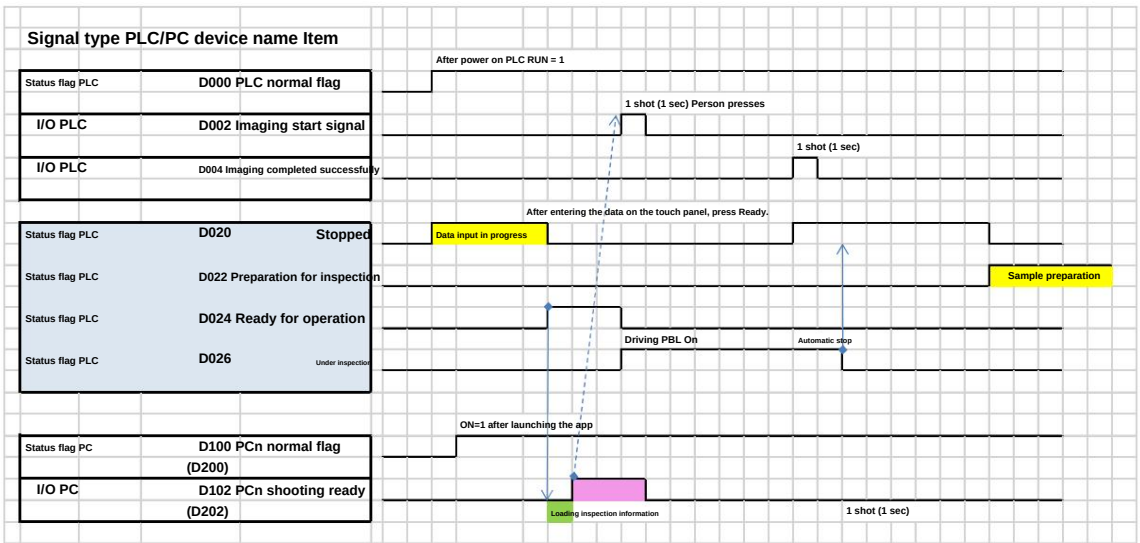


Figure 8 Example of timing chart between PLC and PC

The API for software development varies from company to company. Note that "sequencer" is a product name of Mitsubishi Electric, and the general name is PLC.

3-11. Using the DIO board

The basic techniques for using the DIO board are listed below.

1. Link and build the API provided by the board manufacturer. 2. When opening and closing the board (usually when starting the app), the handle (or address) and handle it as a global variable. 3. Become proficient in bit manipulation and calculations

Below is the source code for an example of using the Read function of the DIO board.

```
HANDLE hDIOHandle;          // DIO board handle
      ...
// Open the DIO board
hDIOHandle = DioOpen("FBIDIO1",0); // Interface GPC2000 compatible board
          ...
// Load
int nBuffer[8];
int nRet = DioInputPoint(hDIOHandle, &nBuffer[0], 1, 2 ); // 2 bits from the first
In1=nBuffer[0];
In2=nBuffer[1];
          ...
// Close the DIO board
DioClose(DIO_Control::hDIOHandle);
```

Figure 9. Example of using a DIO board (Interface product)

3-12. Linking multiple PCs

If the tact condition is not met even after splitting the thread (using the multi-threading technique described below)
In cases where it is easier to develop by dividing the system into multiple parts, a method of operating multiple PCs in cooperation is recommended.
there is.

This is a simple method that can be achieved by accessing files from each PC on a shared HDD on a LAN.
PC1 creates file A in the shared folder. PC2 monitors the shared folder.
If file A is created, then take action B.
It can be used without problems on systems with few constraints on the interface.

If you need a faster response time, you can program the socket communication in each PC.
25 PCs can be equipped with PLCs, and communication can also be performed via the PLC.

If you want faster transfer speeds and access times, there is an optical communication board option.
In this case, the PC needs to have a slot for the optical communication board.

3-13.Basic form of GUI screen

Double-click the icon on your PC (or have it start automatically when you start your PC) to launch the GUI screen.
The following items will be displayed on that screen as needed.

- ÿ Stock selection
- ÿ Start (/pause/stop) inspection button
- ÿ Parameter change
- ÿ Display of data/judgment results during inspection and measurement ÿ Various maintenance functions

In a system that operates continuously in a factory, ÿ and ÿ are input on a touch panel and transmitted via a PLC.
It seems that this is often communicated to the PC.

Regarding ÿ, if there is a possibility that an operator who is unfamiliar with PC operations will use the system,
There should be a GUI screen.

ÿ processes the captured images and acquired data (e.g., rule-based judgment or AI judgment) and outputs the judgment result.
It is visualized and displayed using graphs, maps, etc.

There are other methods, but I have not used them. For example, MFC has a Shared Memory function.

ÿ Install an app that can check the individual functions of peripheral devices. For example, a DIO board.

Other functions include the ability to turn all contacts on/off, and in the case of a camera, the ability to capture and display a single image.

The EXE format of the created application and the IDE itself are basically run in administrator mode.

The development of PLC communication applications has stagnated based on the OS prior to Windows 7, and the management of the latest OS is difficult.

This resulted in the security level of the PC itself being lowered.

In some cases, the program would not operate normally unless the executable was set to administrator privileges.

Multi-threaded programming

Multi-threading techniques are necessary when creating a production-ready inspection and measurement system.

It is a programming technique.

The advantages are:

ÿ Accepts the interrupt button (without delay) during time-consuming processing. ÿ Divides control processing for multiple peripheral devices and data I/O and operates asynchronously.

This increases processing efficiency.

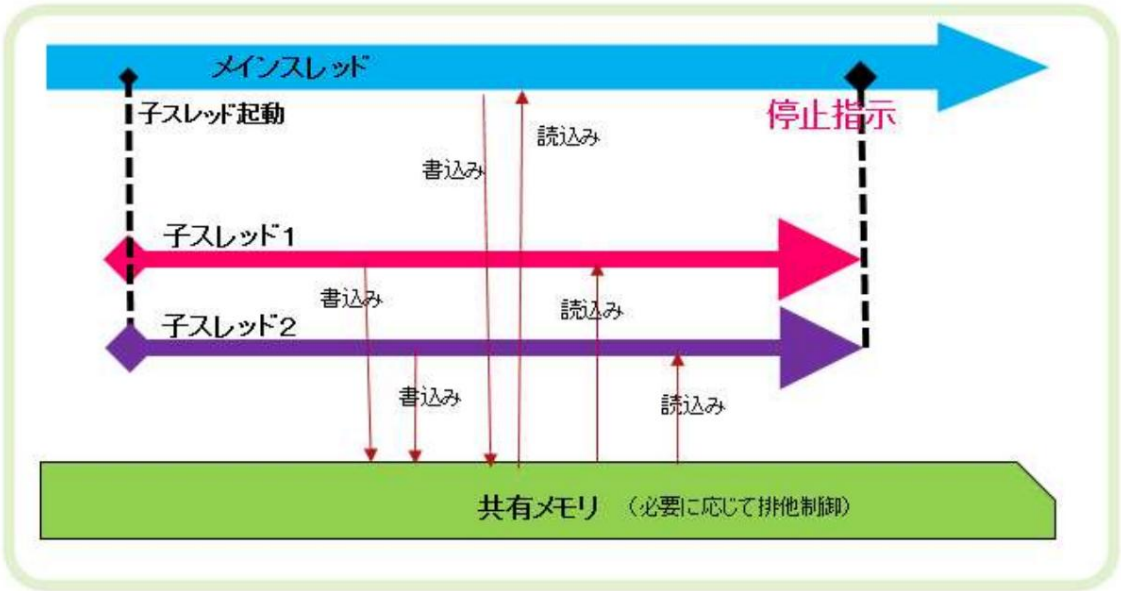


Figure 10. Multithreading concept

The more threads there are, the more difficult it becomes to develop software.
By mobilizing a wide range of knowledge, including understanding the behavior of peripheral devices (PLC, etc.),
A red-enabled continuous operation system will be developed.

The prime factorization application in Example 1 described below can vary the number of threads (number of calculation threads 1 to 5).
More threads will increase CPU usage and improve PC performance.

vinegar.

3-15. Thread safety (exclusive control of variables)

Each thread must take care to avoid contention when simultaneously reading or writing to the same variable.
This consideration is called "thread safety."

In particular, adding and deleting SLT containers such as vectors and maps that store test data
Conflicts must be strictly avoided. There are several methods to avoid conflicts, but first,
We recommend using the Windows API critical section.
If you code the target variable between the lines of LeaveCriticalSection, the
This avoids conflicts in the same place (between the lines EnterCriticalSection and LeaveCriticalSection).
(One of them will be in a waiting state.) In the two examples below, a shared STL Queue
It uses critical sections around any additions, references and deletions to variables.

In addition, even without the exclusive control code, it appears to operate normally in a short test.
However, this may cause serious bugs (such as ring counter misalignment), so
You should never slack off.

Thread Safety (for GUI Components27)

(The same problem exists in C# and VB, but) conflicts in multithreading are not limited to shared variables.
This can happen not only to GUI components, but also to C++/CLI worker threads that call the GUI control.
There are many questions and instructions online about how to access (=operate) thread-safely the progress bar.
This is a topic that has received a lot of inquiries. Below is one method of countermeasures.

---

[26] For example, https://atmarkit.itmedia.co.jp/ait/articles/0503/12/news025.html The author
The most common was creating a print.

27Picture boxes, text boxes, and other components that make up the GUI

In C++/CLI, you can "directly" call GUI components (e.g.
It is prohibited to rewrite the text boxes, picture boxes, etc.
In the theory, when updating the progress bar from a child thread (worker thread), ReportProgress
This function is not specific to progress bars, but also to monitor the progress of asynchronous operations.
Text (instead of updating a progress bar) as a way to report status to the user
It can also be used in boxes and picture boxes.
Arguments used when issuing the ReportProgress function and triggering the ProgressChanged function in the parent thread
(e->ProgressPercentage) is used as a pointer to access the shared variable, and text information and images are stored.
In this case, ProgressChanged may not be called immediately, so the display
The rhythm of the presentation may appear slightly disrupted.

3-17. Image acquisition by camera

The image capture trigger (= shutter) of the application that connects the camera to the PC and captures images is an external trigger.
Signals (e.g., encoder synchronization signals, cargo presence sensor signals, etc.), internal software signals (e.g.,
There are two ways to do this: take a picture by clicking the mouse, or take a picture by clicking the mouse.
Assume the receiving imaging system.

When an external trigger signal is received by the Camera Link compatible board, a callback function is executed when image acquisition is completed.
The programmer can write image processing algorithms in the function.
Yes, you can. Monitor the image acquisition completion flag using the watchdog method without using a callback function.
You can do this.

Input data from the camera is transferred to a buffer (memory on the camera board).
When this is not possible, a method is available to avoid loss of data due to overwriting by using a ring buffer structure in the image storage area.
(See Example 1)

When shooting with a strobe light using an area camera or when shooting with a line sensor camera synchronized with the encoder
This can also be achieved by setting the parameters of the Camera Link compatible board.

28Compile and build are possible, but errors occur or unexpected behavior occurs when running VC++
The behavior may vary depending on the version.
29 Similar behavior can be seen in timer1_Tick and fileSystemWatcher1_Changed.
It seems that you can control the components.

[30] https://www.avaldata.co.jp/solution_imaging/cameralink_tips/aiptool_encoder.html

3-18. Image processing library

There are many image processing libraries to choose from (e.g. Halcon, OpenCV (free)), and for simple image processing
You can also create your own by referring to a textbook. If you use a library, first check the build bit number.
(32/64). The image data area when using the API has special characteristics that are different from the BYTE array in C language.
It may take on a special form (object), so you will need to learn how to convert between BYTE arrays and special areas.
There are 31

The following code fragment in Example 1 is an example:

```
cv::Mat img(H, W, CV_8UC3); //OpenCV image area allocation
std::memcpy(img.ptr(), &pImgLingBuf[ip], WH3); // Copy from pImgLingBuf to img in C
```

For paid libraries, it is also important to be aware of and manage runtime licenses (e.g. OS
When updating, can the image processing library keep up?

3-19. Image drawing

In an imaging system, it is basic to draw an image on a monitor and save the image on a HDD or SSD.
"Drawing" can be achieved by copying image data to a picture box on the GUI screen.
However, in the case of C++/CLI, large size images (e.g. line sensor images 4096x4096 or more)
Since the processing speed is slower when using the Image::FromFile function, we will use a different method.
See also:

31I once had a difficult experience because there was surprisingly little information available.

```
 (1) Procedure for displaying data in the image memory area on the screen
(pictureBox) //Lock bmp in memory with bmp.LockBits(...) and put it into BitmapData. //
After processing is complete, you will not be able to draw unless you release the lock.

 Bitmap^ bmpG2; //Define in outermost scope
  if (bmpG2)
     { delete bmpG2;

 } bmpG2 = gcnew Bitmap(W, H, System::Drawing::Imaging::PixelFormat::Format24bppRgb);
 Drawing::Rectangle rect = Drawing::Rectangle(0, 0, W, H);
 System::Drawing::Imaging::BitmapData^ bitmapData =
   bmpG2->LockBits(rect,
       System::Drawing::Imaging::ImageLockMode::ReadWrite,
       System::Drawing::Imaging::PixelFormat::Format24bppRgb );


 // Get bitmapData pointer Byte*
 pBuf = (Byte*)bitmapData->Scan0.ToPointer();
 std::memcpy(pBuf,(source image area), W*H*3);

 // Unlock bitmap
 bmpG2->UnlockBits(bitmapData);

 pictureBox1->Image = bmpG2;
 this->pictureBox1->Refresh(); //required
```

```
 (2) How to display image files on the HDD in pictureBox1
System::IO::FileStream^ fs1 = gcnew System::IO::FileStream(StrViewFile1,
  System::IO::FileMode::Open);
this->pictureBox1->Image = System::Drawing::Image::FromStream(fs1); fs1-
>Close();

 (cf Image->FromFile(S1) is slow or causes an error.)
```

Figure 11. Example of image rendering

3-20. Saving images

Image storage in image inspection systems is mainly limited by tact time, making it difficult to store all images.
Recently, SSDs are being used to store a lot of data for AI images.
It seems that it is now possible to save all of the images in large quantities.

As a rough guideline, it takes about 100msec to save a 2500x2000 color JPG image to a HDD.
If the takt time is tight, it is recommended to use SSDs (e.g., replace multiple external SSDs).
Consideration will also be given to partial saving by clipping and changing the data.

In a system that continuously saves images, a large number of files (approximately 5,000 or more) are generated in one folder.
Be careful not to create this error. This will cause a sudden drop in Explorer performance.
In such cases, it is a good idea to automatically create time-stamped folders and sort them.

There are several image saving functions to choose from (IDE provided, image processing library provided, camera board driver provided).
When saving lossy images (e.g. JPEG images), you can specify the compression rate.
However, even with the same compression ratio, there are subtle differences (file sizes vary slightly) depending on the function used.
Masu.

3-21. Obtaining pixel values of an image

In the development of image processing software, it is necessary to extract pixel values at specific coordinates from image data (usually continuous areas).
The calculation to get the pixel value is frequently used. In the beginner's guide for C++/CLI, Bitmap.GetPixel (when setting,
However, this function is slow and not practical.
As a workaround, we need to understand the BITMAP file structure and use the (trivial) buffer addressing technique.
Please learn the technique.

(Example) For monochrome image data (size WxH 1 pixel 8 bits), the pixel with coordinate values (ix, iy)
The value can be obtained by:

```
char cbuf[N] Image buffer for N=WxH
int ip = ix + W*iy;              (0ÿixÿW-1, 0ÿiyÿH-1)
        (ÿ 0ÿipÿ(W-1)+W(H-1)=W-1+WH-W=WH-1)
int pixVal = cbuf[ip];
```

To get pixel values of a region of interest (ROI), simply loop through the above formula.

3-22. Simple Image Viewer

In the inspection and measurement fields, handling large size images (approximately over 4,000 images wide)
(Example: Imaging using a line sensor camera, Continuous imaging using a microscope, and images)
Linking function) If you want to enlarge a specific part of an image, draw it, or save the image (with location information),
It is a natural program and a good exercise for writing your own programs.

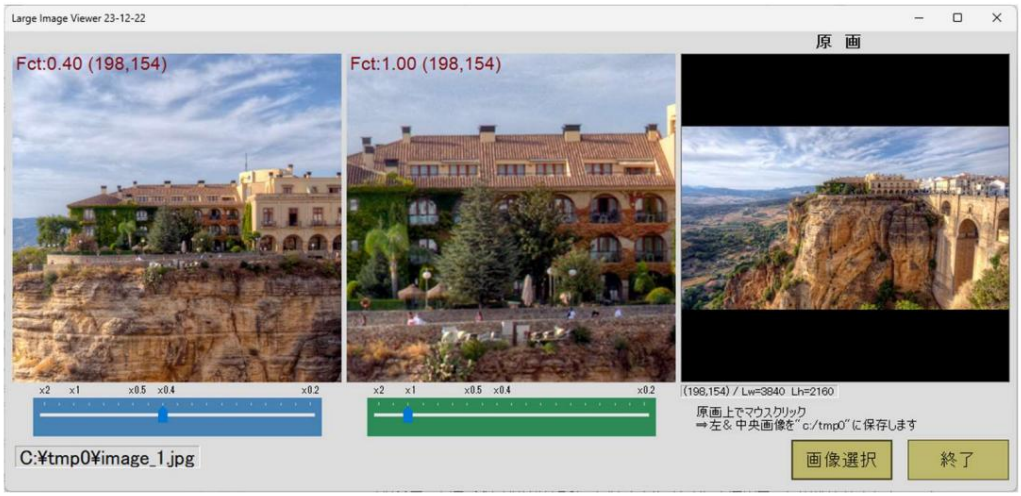


Figure 12 Simple image viewer

3-23. COM port, serial communication

COM port is a serial communication port (connection port) that has been around since the MS-DOS era.
Even laptops without serial ports can have a serial port in the USB port.
You can use a real port conversion connector. It is slower than a LAN connection and is used for short-distance communication.
Use.

If you are using a Camera Link compatible camera, use serial communication software (e.g. Tera Term) to connect to the camera.
By sending commands to the main unit, you can change and check settings (color balance adjustment and gain adjustment).
You can check the port status in the Ports (COM and LPT) section of Device Manager.

vinegar.

---

[32] See the LIV_Form.exe source code in the appendix.

[33] The names "COM1" to "COM9" are reserved words, and folders with these names cannot be created.

Furthermore, by coding the master-slave communication procedure as a legacy technology, "RS-232C non-protocol communication" is also available. 34

Figure 13 COM ports (four ports on the top left)

3-24. Batch files and pipes

A batch file (or the enhanced version, PowerShell) is an extended executable that contains a sequence of commands you want to execute. It is a "bat" text file and is a useful tool from the MS-DOS era.

Roughly speaking, it is a simplified version of the UNIX shell and is used on the command prompt. Pipes and redirections are also available. In the inspection and measurement system, the application can be automatically started. You can set the waiting time (in seconds) when connecting to a LAN, or issue a ping command to check if the LAN environment is properly connected. You can do this.

Using a pipe to the auxiliary application (Stdin_Apl1.exe ADS radio wave reception program) of the example Glide_Path dump1090.exe is a console program provided by the ADS antenna manufacturer that outputs the standard Stdin_Apl1.exe is an application that simply outputs the coordinates of aircraft. It has the function of receiving the coordinate information via a pipe and saving it in text format.

Description in dump1090_with_StdinAPL1.bat

dump1090.exe --aggressive (omitted) --mlat |Stdin_Apl1.exe

---

34 The author performed non-protocol communication with a Keyence general-purpose image processing terminal and an IAI actuator.

3-25. Automatic system startup

To start the app automatically after starting the PC, add it to the Windows settings (the "Startup" folder).
(Copy the shortcut) to wait for a certain period of time for DB or PLC application startup and preparation.
In this case, you can use the Sleep function in MS-DOS batch files (or PowerShell).
vinegar.

When multiple PCs are connected to form a system, the order in which the PCs and applications are started may be different.
Some communication software is divided into the roles of master PC and slave PC, and
Since the master PC needs to check whether the communication path is open, the master PC program
In this case, it is better to start the master PC later.

Regarding shutdown, when using a UPS, you can shut down multiple PCs on the LAN (for a certain period of time).
Power outages can be used as a trigger to shut down all devices at once.
You can also shut down an individual PC using the ExitWindowsEx function.

Virus detection software

Security software is one of the applications that affect takt time and performance.
In order to avoid system load, the in-factory inspection and measurement system prohibits connection to the Internet.
Disable online virus checking and Windows Defender.
There are times when this happens.

On the other hand, external storage media (e.g. USB) are used for updating programs and transferring stored data.
In such cases, offline storage devices (memory keys) may be used, which may pose a risk of virus contamination.
Use virus checking software in your online environment (Microsoft Safety Scanner).

3-27.Further developments

If the system receives positive feedback during the trial operation, the following developments can be expected:

- Horizontal expansion (repeat production on other production lines)
- Linkage with production management systems
- Expansion to AI testing

New challenges beyond the scope of this paper (establishing reproducibility of optical systems, security measures, machine learning, etc.)
) will be the main characters.

4. Testing and debugging techniques

Test environment

When testing and debugging on a factory line, you may be subject to the following restrictions:

- The period, time and manpower available for using the target equipment are limited.
- Safety and health environments unsuitable for software development (dangerous areas, radio wave conditions, temperature, noise, etc.)
- Standalone environment isolated from the internet for information security

Under these circumstances, we must improve the log file design to make the most of the limited testing period.
You need to use it.

Working outdoors, in a noisy environment, or in a clean room is less efficient than working in an office environment.
Depending on the noise level or signal quality, you may not be able to contact your coworkers by phone.
For this reason, it is recommended to incorporate a process that simulates the response of the other side of the integration test[35].
It is recommended that you go through the basic operation flow while you are on the development site.

When conducting connection tests with a PLC or DIO board, the other party (e.g., the equipment manager for the mechanical PLC ladder development)
[36] Nevertheless, the actual implementation of the integration test
When doing so, you may encounter unexpected situations due to subtle misunderstandings between the parties.

Log files

On-site testing involves running tests according to a prepared task list and saving the log file.
It is best to analyze the results in a quiet place.

When debugging multi-threaded code, the debugger has limited functionality, so the log file
It is important to have a good output function. The log file should contain the time, minute, and second on each line.
Use CSV format, set generation levels (e.g. none, minimum, detailed), and switch between them using system variables.

---

[35] If you expect to update your PC in the future, it is a good idea to take the time to update it here.
Using the writing function of the chair monitor, it is possible to simulate the other person's operations to a certain extent.

[36] There were some experienced people who were prepared to do development on-site, but this left the other party's staff feeling bored.

It is a good idea to enable this.

By following it, you can see the chronological flow.

4-3. Debugging tools

Generally, industrial PCs are initially installed with only the minimum number of programs.

Therefore, you will need a PDF reader or a spreadsheet software (such as Excel) to handle log files output in CSV format.

Also, learn a file content comparison tool (application) to compare the contents of the files before and after the work.

It is necessary to accurately manage the differences between the software and the parameters.

In this case, the basic rule is to return it to the state it was in before the modification.

During development, especially during continuous operation testing, we used task managers and resource monitors.

Monitoring (especially detecting memory leaks) is

performed. It is also a good idea to learn how to set up remote desktop work. Due to the constraints of the work site, monitors and

If you cannot find a place to set up a keyboard, connect a LAN cable and set it up a little further away.

You can secure a working environment in place.

4-4. Supplementary information regarding debugging

In my experience, debugging during integration testing and integration testing is done in a different place than usual.

This was often done in a remote environment (e.g., in a factory in another prefecture that required business trips).

The travel preparation list and test plan are important tools for on-site work process management.

If you forget, the test may be cancelled.

I'll check the delivery.

In addition, during system testing, we take photographs for operation manuals and equipment adjustment procedures, and also prepare finished drawings.

We often also collect basic data for the project at the same time, so we include this in our plans.

---

[37] **Please make sure that the license is recognized and the software works even when you are not connected to the Internet (offline).**

[38] **For example, WinMerge.**

5. Maintenance

Hardware failure is inevitable, so when a problem occurs in the system, it is important to act quickly.
Advance preparations are necessary to ensure a speedy recovery.

5-1. Preparing a spare PC and HDD

First, it is important to plan for spare PCs and spare HDDs from the budget stage.[39] Many industrial PCs
So, you can order a spare HDD when you buy it. We will make a copy of the entire HDD and keep it for you. [40]

To replace the HDD on-site, the power to the control panel must be turned off and the cables to the mounting rack must be disconnected.
The process of removing the drive, taking out the PC, and replacing the HDD is quite tedious.
If possible, we recommend a PC that allows you to replace the HDD from the front panel.

5-2. Preparation for breakdowns

When a problem occurs, it is possible to accurately determine whether the system hardware is the cause or whether there is another factor.
In the case of hardware failure, the basic approach is to replace it with a spare part.
These are items that system developers can carry out in advance.

ÿ Eliminate initial defects. In rare
cases, there has been a lack of compatibility between industrial PCs and DIO boards, causing concerns about startup.
In such a case, remove the HDD and leave the board installed, and ask the PC manufacturer to perform a performance test.
If you want to be cautious, you can borrow a PC or board for evaluation and testing during the design phase.

41

ÿ When the system starts up, various hardware checks are performed and the normal/abnormal operation is displayed. For
example, a green light will be lit on the monitor screen when normal, and a red light will be lit when abnormal.
At this point, you should also be able to determine if there are any gaps.

ÿ When calling a command (function) for hardware, if the return value is an error, it will be written to the log file.
Please state this.

ÿ Document maintenance information.

---

39 The author has only practical experience with external SSDs, so he does not have experience maintaining a PC that uses an SSD for the system disk.
I can't comment on that.

40 There are also devices that can connect two bare HDDs and copy data (without going through a PC).

41 We recommend that you regularly exchange information with the manufacturer's sales representative.

After the system is installed, the factory maintenance staff will handle the initial response.
It's easy to forget about terry replacements, as they occur after four years.

5-3.PC update

Industrial PCs have a repair warranty period of about seven years. If a PC breaks down after that period,
In this case, you will need to update your system with a successor PC.

It is important to make the app work on the latest OS and the next generation PC.
Are the drivers for peripheral devices compatible with the latest OS? Can they be compiled and built?
It is especially important to select the 32-bit or 64-bit platform.
The API of device A does not support 64-bit, and the API of device B only supports 64-bit (32-bit support has been discontinued).
It exists in reality.

The source code of a system that has been in operation for many years is old (with no history of function extensions or debugging).
In my experience, if the source code remains, 42% of the time,
Even outsiders can modify and improve the algorithm. On the other hand, the hardware environment (including driver software)
Reconstruction is not possible without the appropriate materials and physical items (CDs, etc.).
A manual that describes the installation procedures for peripheral devices, their drivers, IDEs, and image processing libraries.
Creating this is a must for developers.

5-4. Camera and lighting adjustment

After changing the hardware, it is often necessary to recheck and readjust the cameras and lighting.
You need to create a procedure.

When adjusting industrial cameras, manual adjustment is the norm to ensure repeatability.
43When making manual adjustments, it is necessary to adjust the lighting brightness and white balance at the same time.
Therefore, it is necessary to determine a "standard reflector" suitable for the imaging system and quantify the adjustment.

---

[42] Of course, it's always better to have specifications and design documents.

[43] Therefore, I do not use the AUTO shooting mode.

[44] There was no definitive way to quantify the lens focus adjustment, so we had to adjust it visually.

To adjust a camera compatible with Camera Link, you need to: 1) set up the Camera Link board; 2) set up the camera itself. There are two settings, and they are often confused. White balance and color adjustments are done in ÿ. Usually, this adjustment is done via a COM port using a program prepared by the camera manufacturer ((for updating the ROM).

5-5. Maintenance of peripheral devices

Prepare for repairs and updates of hardware connected to PCs (e.g. cameras, PLCs, image processing terminals) Many hardware devices store their configurations on an SD card, USB memory, or It has a function to save (back up) the file in a PC folder. A replacement manual will also be provided.

6.Example

It is good to learn about systems in operation, but in companies, design documents, source code, are confidential documents and cannot be viewed by outsiders.
However, copying it to a personal computer has become a violation of compliance.

To present two examples created for the purpose of explaining this paper, and demonstrate high-speed display techniques for images and self-made maps. to.

In Example 1, we prioritized incorporating many basic technologies (image processing and prime factorization). Example 2 is an application that uses software radio (SDR) to control aircraft.
Each example takes in data every few hundred milliseconds or less,

They have in common the fact that they perform calculations and visualize the results. If you master the techniques here, you will be able to use the previously mentioned [Figure 1] inspection system can be constructed.

6-1. Prime factorization + image display

Overview

Images captured at regular intervals (in the example, an image of 2500x2000 is set as an alternative to interrupt capture). (generated dynamically) ÿ Draw the original image ÿ Display the processed image ÿ Save the processed image as JPG, It's Puri.

The processing time for each image is intentionally varied, and the accumulated data is processed (using a "queue"). (This is handled by FIFO.) OpenCV is used for simple image processing.

Calculate the counter value No (initial value = 0) as No%50 (the remainder when divided by 50) and add 5 to it. Calculate the power of 2 for the number you have obtained, add No to it, and let the result be NN.

The formula is NN = 2No%50 + 5 + No

Factorize the NN. By increasing the number of digits, the time required for factorization will vary. This is a device to make it more interesting, and the coefficients in the formula
are set appropriately. Prime factorization uses an elementary algorithm.

Techniques: multithreading, ring buffer, prime factorization, OpenCV, bitmap display

6-1-2. Input/Output Data

(Input parameter) The image capture interval (here, the generation interval) is approximately equal to the counter-up interval.

Minimum value = 10 msec

(Output) The original image is color-inverted to visually display the prime factorization results.

Overwrite the file so that only one copy is saved.

A log file containing a list of discovered prime numbers.

This application creates result image files and log files under C:\tmp_PFD.

6-1-3. Screen layout

As shown in the figure below.

Figure 14. Continuous image display (prime factorization)

6-1-4.Using the Image Library

Use opencv3_1_0 for VS2013 (copy C:\opencv3_1_0\build directly under the C drive)

45 The API functions that are actually used are file saving and image flipping.

To pass the check, you need to add a few things to the project file.

You can check this by launching CLR_Form.sln.

---

[45] **The site is here: https://opencv.org/releases/**

6-1-5. Correlation diagram of threads, memory, and UI components

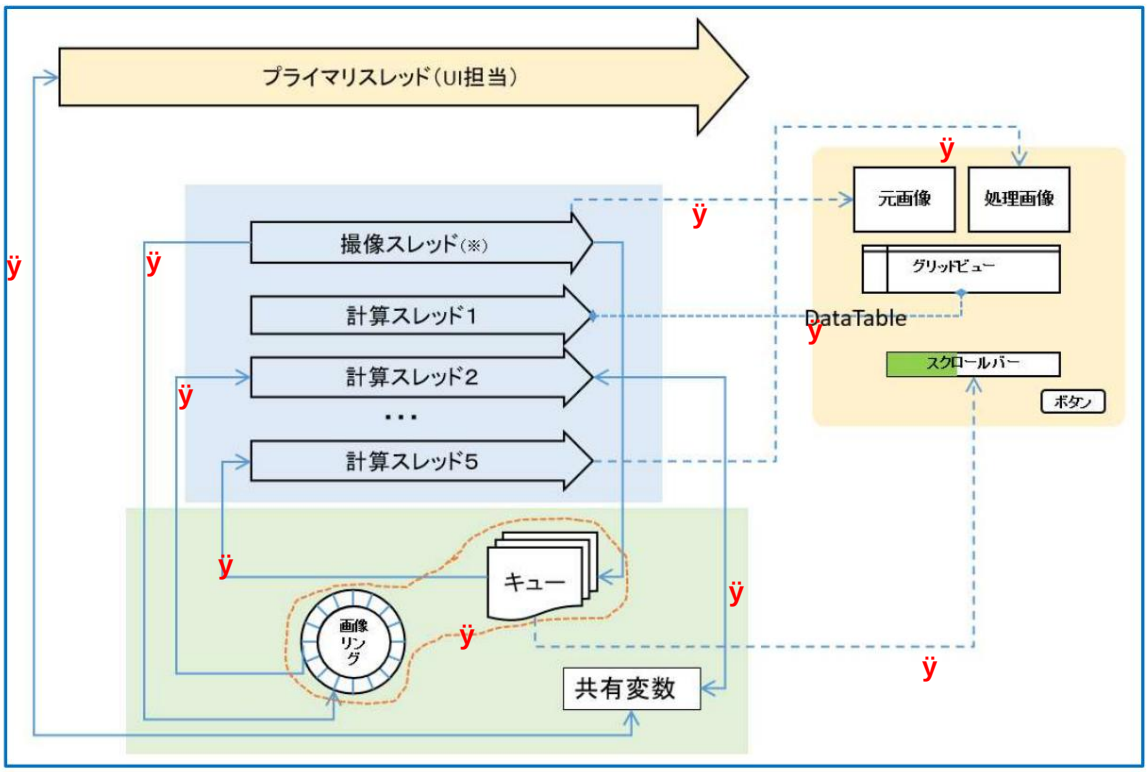


Figure 15 Relationship between threads and shared variables

ÿ Display the image in a picture box. (ÿ) Generates an image instead of capturing an image with the camera. ÿ The capture thread copies the image to the image ring buffer and adds it to the queue at the same time. ÿ When adding to the queue, exclusive control is performed (Critical Section). // Queue structure

```
struct ImgInQue
        { int No; // 0,1,2,…
        int pt; // pointer to the ring buffer

};  std::queue<ImgInQue> _queImg; //empty
```

ÿ The calculation threads (maximum of 5) monitor the queue size and receive data if available. ÿ The calculation thread copies the image data at the same time as receiving the data in ÿ above. ÿ Each calculation thread and imaging thread can access the shared variables. ÿ The primary thread (main thread) can access the shared variables. ÿ The grid view is updated (by associating the data table with the grid view). ÿ In parallel with the prime factorization, the processed image is sent via ReportProgress&Pr

ÿ The number of items stored in the queue is displayed in a progress bar.

6-1-6. Effects of multithreading

The target numbers are natural numbers within the range of 25 to 254 (32 to approximately 2 quadrillion).

On **a Core i7 laptop, it takes about 1 second for a quintillionth (1017) natural number. The**

minimum image generation interval that does not increase the queue is 180 msec with one thread and 180 msec with five threads.

It took about 40 msec. Also, we confirmed that increasing the number of threads resulted in an increase in CPU usage. 46

スレッド数	1	5	5	5
画像生成間隔 [msec]	200	200	100	50
CPU使用率	**20**	**35**	**50**	**75**

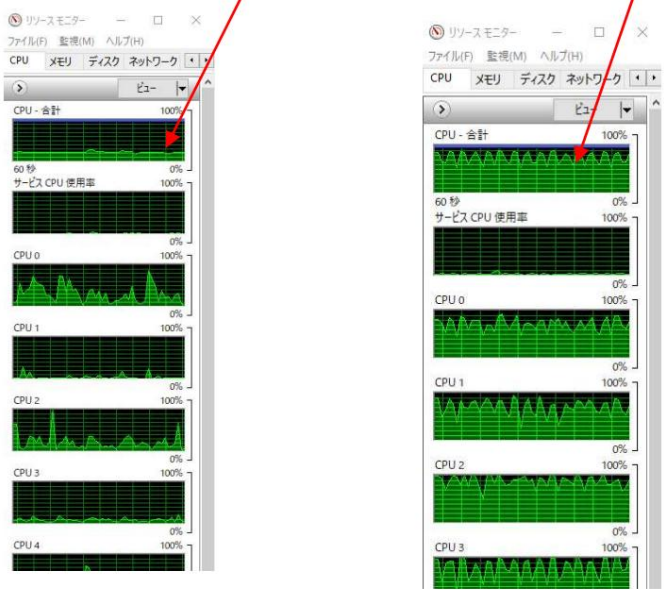


Figure 16 Number of threads and CPU usage

6-2.ADS-B Flight Monitoring System

Overview

This is a simplified version of an aircraft tracking app. Connect an ADS-B antenna to your PC via USB and you can track real-time aircraft.

The system obtains the position information of nearby aircraft using a time signal and plots it on a map.

It has a GUI for parameter change files.

---

[46] **A 16-core PC purchased in 2023 could reduce the interval to 20msec.**

[47] **The GPS location information transmitted by each aircraft is imported into a PC using SDR (software radio) technology.**

There are two runtime modes.

Mode 1: The input data is the aircraft position coordinates from the ADS-B antenna in real time.

Mode 2 Demo mode. The data set (text file) obtained in Case 1 is used as input data.

The input data and output data are the same file, but in different folder locations.

Techniques: Multimap (STL), classes for geometric calculations, reading CSV files, fileSystemWatcher

6-2-2. Input/Output Data

The decoded data for the ADS-B signal (example of one unit: tmp_ADS_B-00009012.txt) is shown below. [48]

It receives about 4 files per second. In particular, the following yellow data is used. (Flight number, degrees, speed, direction, latitude, longitude)

```
Hex      Mode Sqwk Flight Alt      Spd Hdg   Lat      Long Sig Msgs Ti -
--------------------------------------------------------------------------------

86D2CC S      3316 ANA18      6175 203 335 35.160 140.203 10 2336          1
841B6A S      0442 SFJ43     27050 350 265 35.463 138.885       6 1473     0
8422F9 S      2212 JAL184     4275 181 300 35.268 140.026 34 3781          0
84B772 S      3361 ANA396     3125 186 330 35.417 139.892 15 8432          1
8511CA S                     13250 346 042                    4     2 49
```

Figure 17. Example of ADS-B decoded data

[48] **I used dump1090. Reference site: RTL-SDR.COM Also, Stdin_Apl1 (my own work) Split and split the file using the pipe function.**

6-2-3. Screen display

example In the author's reception environment49, ADS-B signals were received at a frequency of about 4 times per second. The reception range depends on the installation height of the antenna.

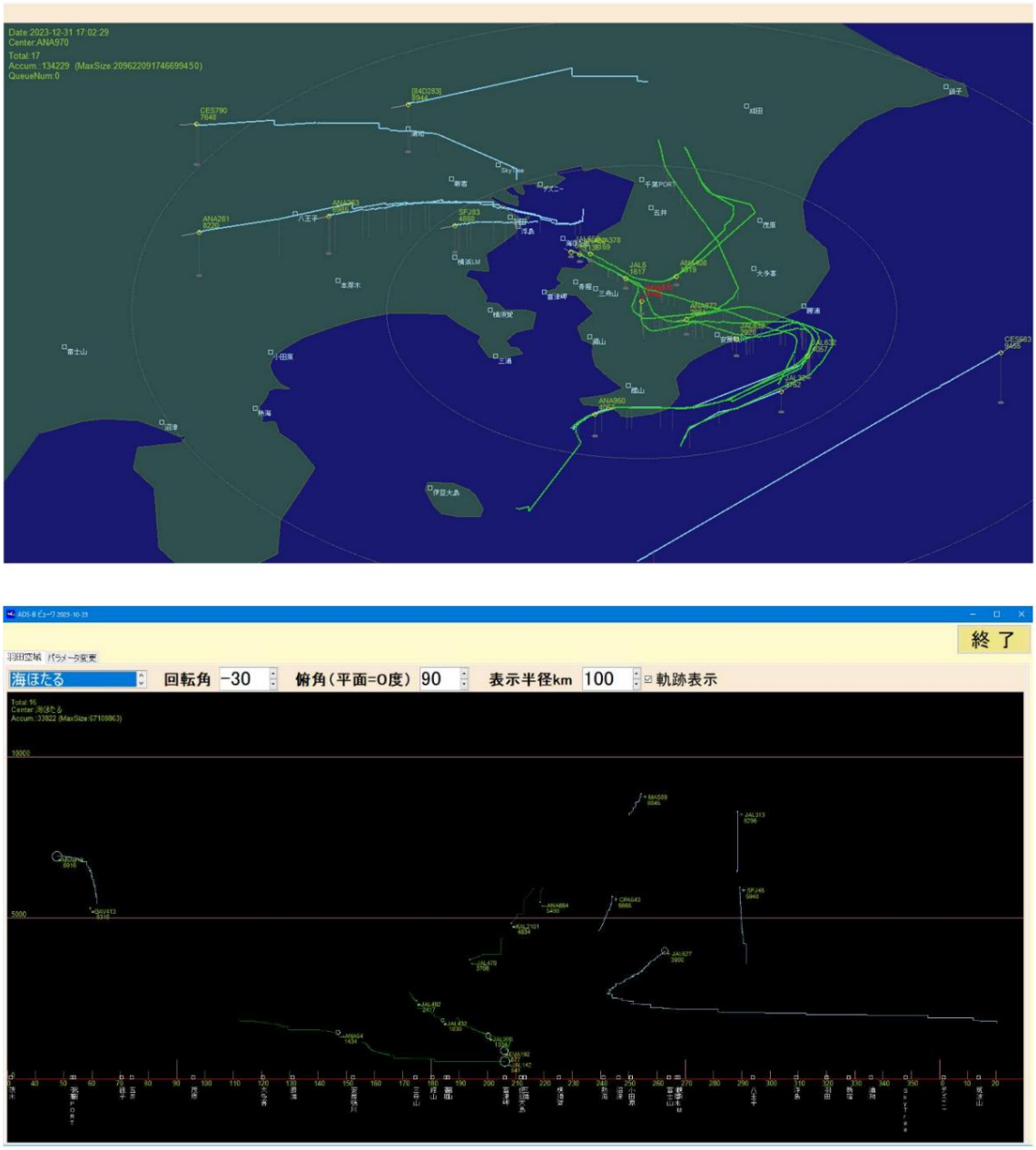


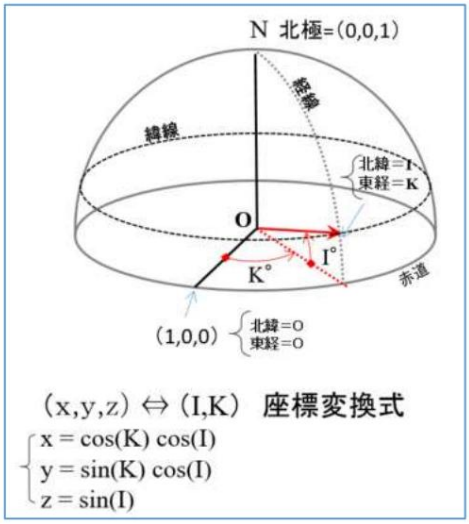
Figure 18 Display screen (top: perspective view, bottom: elevation view)

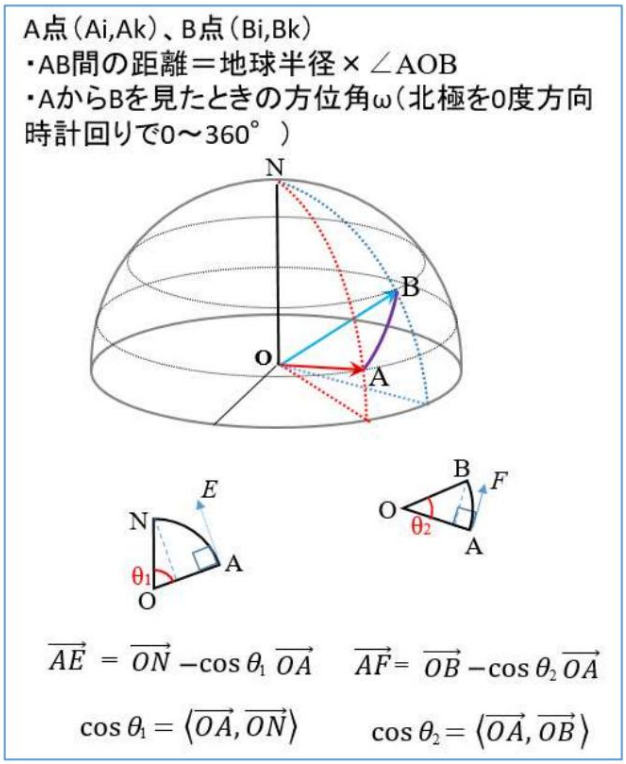
[49] **From Mt. Mifune (Kimitsu City), which is 130 meters above sea level, it was possible to see the aircraft parked at Haneda Airport. You can see aircraft about 100km away.**

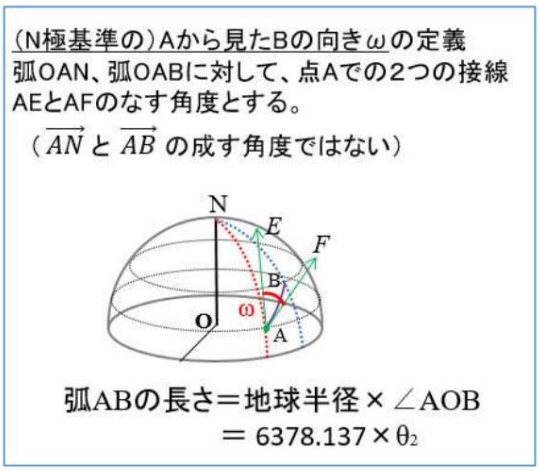
6-2-4. Coordinate Systems and Geometric

Calculations By classifying 2D and 3D vectors and matrices, you can write source code in an easy-to-understand manner.

The figure below shows the coordinate transformation formula on a sphere ((latitude, longitude) ÿ (x, y, z)).








```
Vct3 vON(0, 0, 1);
Vct3 vOA,vOB; //3-dimensional vector D2R is degÿrad conversion
coefficient vOA.x = cos(keidoA * D2R) * cos(idoA
* D2R); vOA.y = sin(keidoA * D2R) * cos(idoA *
D2R); vOA.z = sin(idoA *
D2R); vOB.x = cos(keidoB * D2R) * cos(idoB *
D2R); vOB.y = sin(keidoB * D2R) * cos(idoB * D2R);
vOB.z = sin(idoB * D2R);

double cosW = (vOA | vOB); //vector dot product
distABkm = Rkm * (acos(cosW)); //arc distance

//When A is not the N pole
Vct3 vAF = vOB - (vOA | vOB) * vOA;
Vct3 vAE = vON - (vOA | vON) * vOA;
double cosT = (vAF | vAE) / (vAF.length() * vAE.length()); //vector dot product (After this,
  with some ingenuity, you can determine ÿ between 0 and 360 degrees)
```


Figure 19 Geometric calculation

6-2-5. Simple Map and Clipping Processing The simple

map (coastline and landmark points) consists of SeaLine.csv and LocationList.csv.

The author defines continents and islands as counterclockwise closed curves50, and the latter includes airport names, city names, etc.

To distinguish between the continents and oceans, we use the image processing function to fill in the gaps by treating the continents as closed curves.

However, the map in question is an equidistant map that needs to be recalculated and redrawn every time the center position is changed.

Therefore, (rather than image processing) rectangular clipping of the closed curve is performed.

The clipping process of a closed curve is implemented in the function (sub_Clipping).

Convex decomposition and hidden point processing are important techniques for projecting a 3D model into a 2D image.

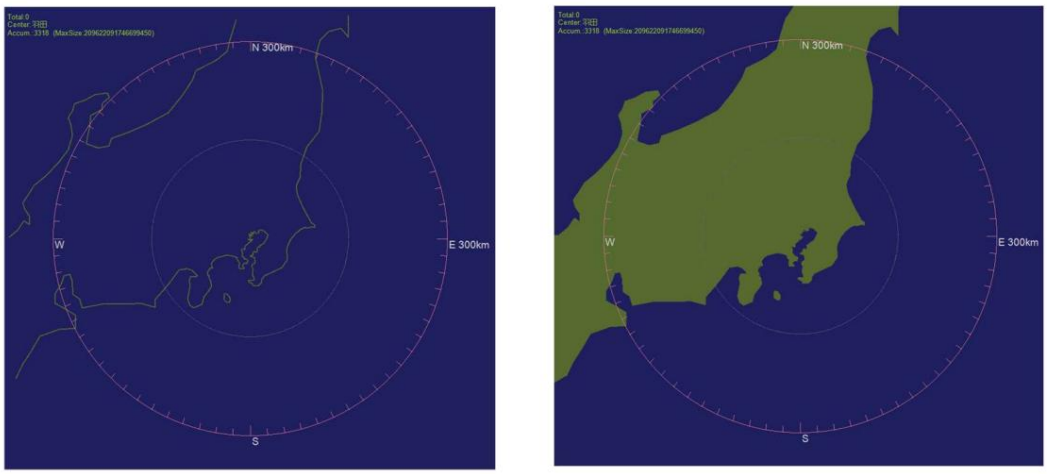


Figure 20. Line drawing and filling of a simple map

The conceptual diagram of clipping processing is shown below. 52

As a point,

ÿ When defining closed areas (islands and windows), always keep the direction constant (e.g., clockwise).

---

50 **Approximately 1,700 points were used for coastlines around the world. The coastlines other than those near Haneda are rough.**

51 **The Visual Studio .NET library provides a function called "FillPolygon" to fill a closed curve, but it does not support clipping.**

There are limitations to processing complex closed curves (e.g., Honshu Island) that extend beyond the boundary of the map area.

52 **Known Bugs: ÿ Filling in the far side continent when in a bipolar positional relationship ÿ Closed curve (continent) clipping**

Filling error when touching (not intersecting) a window.

ÿ Once the orientation mentioned above is determined, the connection between the red dotted line and the blue dotted line will be determined naturally.

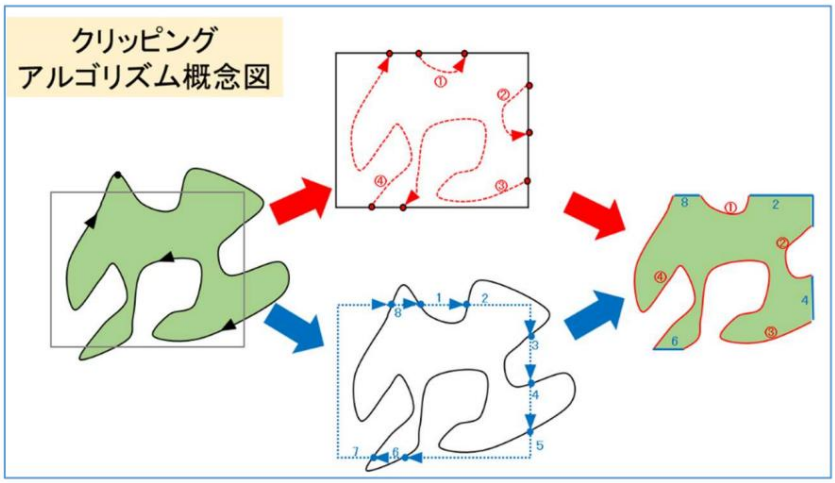


Figure 21. Clipping process concept

6-2-6. Continuous operation example

The following are actual values for continuous operation.

January 16, 2024, 4:00 AM to 11:00 PM (approximately 19 hours) During this period, 1,785 aircraft were captured near Tokyo Bay.

This app has a function to turn on/off the display of aircraft trajectories, but it does not have a database.

Multimap is used to store track data. Therefore, data on aircraft that have disappeared from the map is not available.

If you don't discard unnecessary data, performance will decrease, so delete unnecessary data at the appropriate time.

The corresponding code in the source code is "CGPCommon::_mltMapTrail.erase(strKey.c_str())".

Similar issues arise with continuously operating image inspection machines (e.g., when defect information is continuously stored in a vector).

In this case, you should decide on a course of action based on the frequency of occurrence and the duration of continuous operation.

If the limit is exceeded, one option is to display a warning on the screen or with a patrol light.

7. Afterword

Based on the author's development experience, the software development process for in-house development of small-scale inspection and measurement systems
I introduced the development technology. I asked my former colleague, YK, to read the original manuscript of this article and
Thank you for pointing out the clear points.

During the heyday of minicomputers and engineering workstations in the 1980s (before Windows),
Many Japanese manufacturers (automotive, electrical, construction, steel, etc.) have their own CAD systems and analysis programs.
There was a time when the company was developing and selling programs, and it was around that time that I started learning programming.

"Software Production Technology" (Institute of Electronics, Information and Communication Engineers, 1985) covers everything from requirements definition and design to maintenance management.
It is a textbook that compactly describes the contents of the book, and is the author's favorite book.
The chapter on "Solar Launch Ground Support System" is notable for its explanation of Petri net diagrams that take takt time into consideration.
Example 2, Glide_Path, is an original program created with this in mind.

Since the spread of the Internet, various information such as programming and image processing has been freely available from both within Japan and overseas.
I have benefited from the wealth of information available and have used it in my work.
I would be happy if I could give back even a part of my knowledge and experience to those involved in this field in the future.

End

Reference list (in no particular order)

[1] Shunji Hinata, Quick Solution! Reverse Reference Handbook for Visual C++ (Technical Tips Series), Soshimsha, 2007

[2] Yoshikazu Fujino and Shuetsu Hanada, Software Production Technology, Institute of Electronics, Information and Communication Engineers, 1985

[3] Hiroyuki Kitayama, Win32/64 API System Programming - Coexistence of 32/64 bits, Cut System, 2011

[4] Makio Katori, Junichi Tatsuta, Easy to Understand! Embedded Technology Textbook: The Basics of Embedded Technology and Development Understanding from the Basics of Embedded Technology (CQ Publishing Co., Ltd. 2008)

[5] Image processing explanation site Imaging Solution https://imagingsolution.net/

[6] Herbert Schild, STL Standard Course: C++ Programming with the Standard Template Library Ma Software 1999

Sites referenced in the text have been omitted.

About the example

The original example in this article is a project (source code) due to restrictions on uploading EXE or ZIP files.) are in a folder on a separate service (GitHub) from the blog.

https://github.com/mt2967/mt2967_REPOSITORY