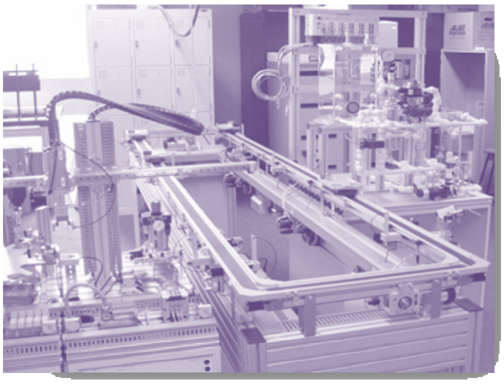
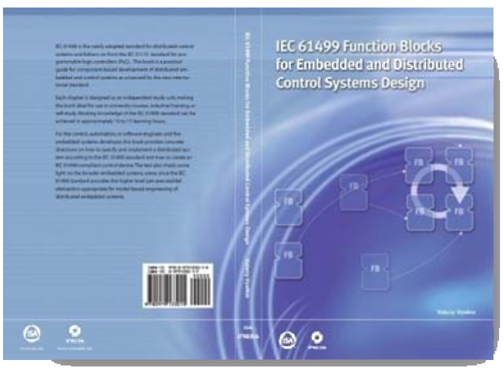
Distributed IEC 61499 Intelligent Control of Reconfigurable Manufacturing Systems

Recent experiences gained at the University of Auckland, New Zealand

The research focus of the **infoMechatronics and IndusTRial Automation** Laboratory (MITRA) at the University of Auckland is Information Technologies enabling Flexibility and Reconfigurability of Manufacturing Systems.





The research direction **Industrial Informatics and Automation** was established in the University of Auckland in 2005. Since then the MITRA laboratory has been gradually growing. It currently involves 5 academics from 3 different departments supervising 25 graduate and postgraduate students

The laboratory is equipped with a range of intelligent mechatronic models forming a model of a reconfigurable manufacturing environment, also known as Intelligent Mechatronic Testbed.

One of the focal points in the research is the new **IEC 61499** programming architecture for distributed automation systems, also known as **Function Blocks.**

Information Technologies in Industrial Automation is now a regular subject in several teaching programs. Currently about 50 students of the Computer Systems Engineering (CSE) program learn foundations of PLC programming in the Year III course "Embedded Systems" Up to 100 CSE and Software Engineering students per annum are trained in component design of automation systems with IEC 61499 using the world first textbook recently published by the group leader Dr. Valeriy Vyatkin

The students are obtaining hands-on experience in distributed systems design during tutorials, laboratories and by undertaking a challenging assignment on the design of distributed robot control with mutual exclusive access to resources.

The laboratory undertakes research projects in the following aspects of Intelligent Automation:

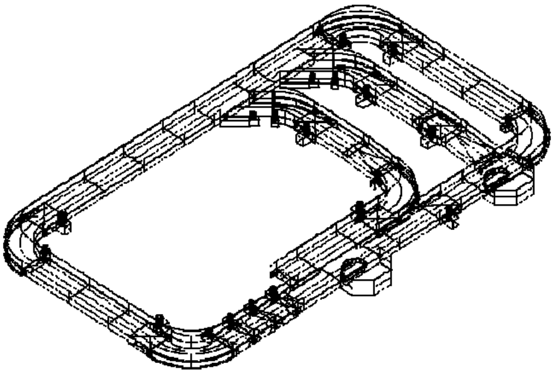
- *Design Practices, Architectures and Tools for Intelligent Automation*
- *Embedded Control Devices and Networks*
- *Intelligent Mechatronic Architectures*
- *Modelling, Simulation and Verification*

Our particular interest is in developing viable engineering methodologies for the application of distributed intelligent controls, in particular with IEC 61499.

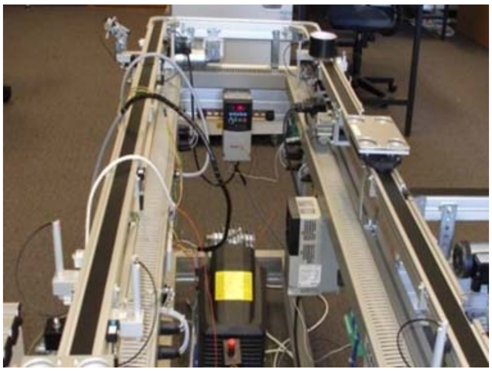
These include design patterns, development and use of software tools helping end-users to achieve such benefits as reduced engineering costs, faster and more reliable design, and better performance.

We have experience of designing complex systems implementing these ideas.

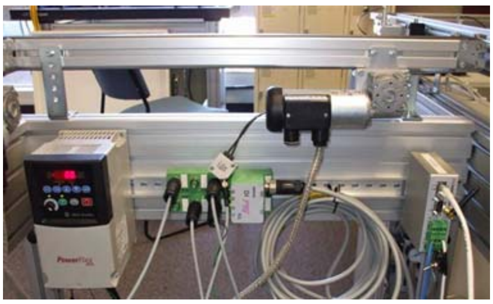
Distributed Intelligent Controls in Material Handling Systems



Section of an airport baggage handling system – a good example of modular material handling equipment



Each conveyor section is equipped with its own controller and motor drive.



The machinery used in automated material handling systems is naturally modular, making a perfect playground for distributed control.

Most of the benefits are expected in the efficiency of system engineering on account of more efficient reuse of design solutions encapsulated in components.

Intelligent control can also increase robustness of such systems. In case of any breakdowns the embedded controller can simply re-route the traffic using other available paths without operator intervention.

Performance benefits may include reduction of network traffic, since many decisions are taken locally, and simplified remote maintenance.

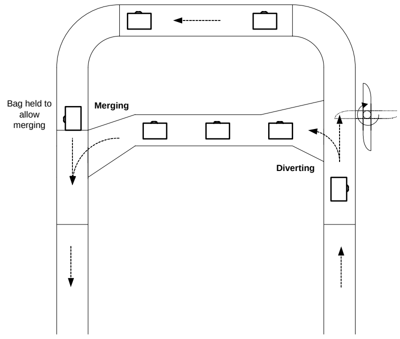
Typical examples of such systems are airport baggage handling systems (BHS). Some of the properties of a real BHS were reproduced on our mechatronic testbed.

In the testbed each conveyor section is equipped with its own control device, implementing its particular control algorithm.

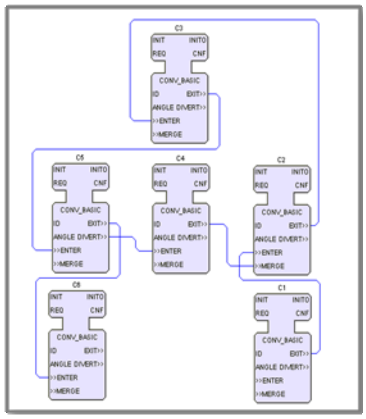
Perhaps currently such a solution may look expensive, but if adopted in mass production, the costs of the embedded controller will be negligible.

The benefits of decentralised intelligent control will easily offset the cost concerns in the longer run.

The function block "language" enables quick and easy design of controls for new physical configurations as illustrated below on an example of a BHS section that consists of 6 conveyor modules.



The corresponding controller uses 6 instances of the same function block type CONV_BASIC.

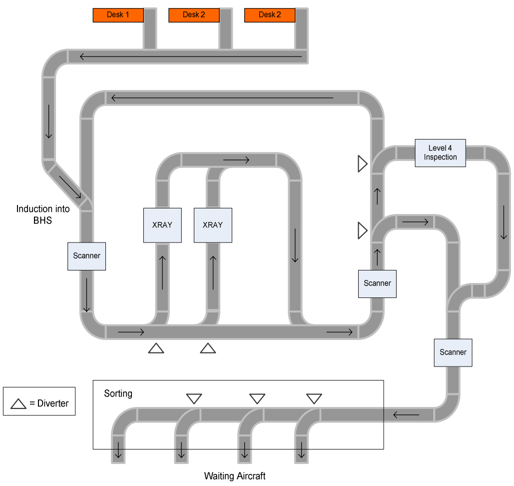


These function blocks are completely portable, i.e. the system will operate exactly the same whether all the blocks are allocated to a single control device or one block per controller embedded in each conveyor.

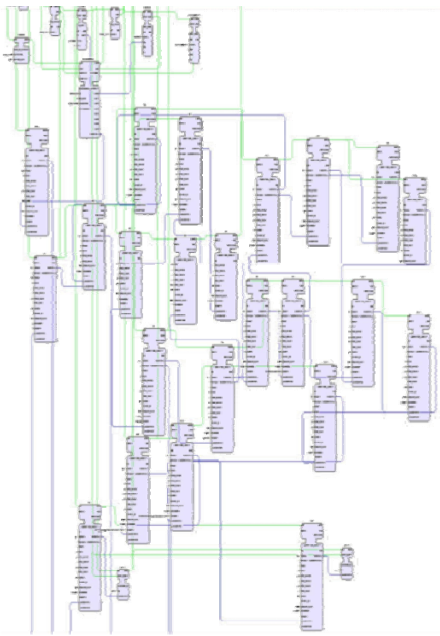
Because the path planning system incorporates processing steps in addition to movement, it is easy to express requirements for bag delivery such as bags must be scanned before reaching a destination.

The same principles could be applied to many types of material handling systems.

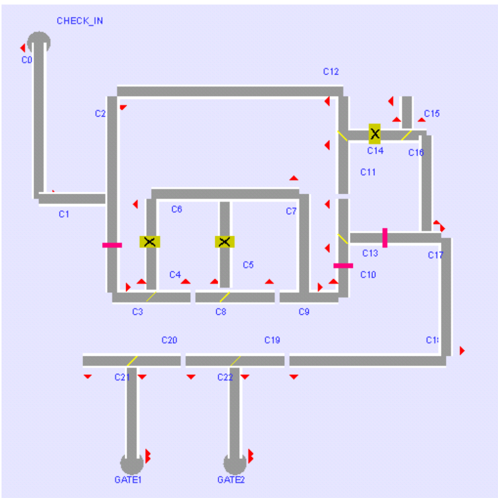
Function Blocks: IP Reuse, Flexibility and Completeness



Realistic small airport BHS layout



The function block network representing the complete control system of the BHS



Rendering of the BHS

Function-block based modelling is not restricted to trivial examples.

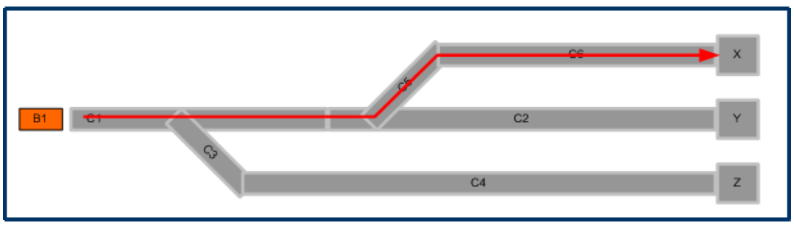
Here is an example of a realistic combination of conveyors as applied to the check-in system of a small airport. Bags are inserted into the system from check-in desks. At this point the system knows nothing about the bags. To determine the identity of a bag it must be passed through a scanner. To determine that a bag is safe to be loaded to an aircraft, it must be x-rayed. Once bags are identified and cleared, they must be sorted to particular waiting aircraft.

Again, the control of the whole BHS is achieved as a network of identical software components. But, it is not only about control!

The function blocks can encapsulate simulation models and rendering, so the whole system can be immediately simulated and visualised. The same visualisation can be used during the operation of the real BHS.

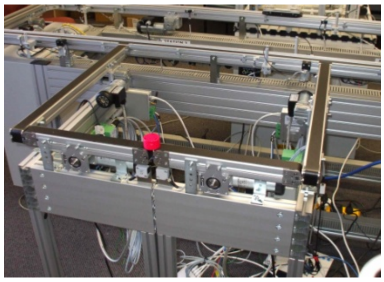
Once the correct behaviour is verified, the simulation still can be used, now in the deployed blocks. It can provide for predictive simulation, for example, supplying expected location of bags on the belt when readings of detection sensors are controversial.

In addition to the clear design facilitation, such control architecture brings other run-time benefits, such as automatic recovery from faults, re-routing of material flows dependent on the actual performance and conditions, etc.

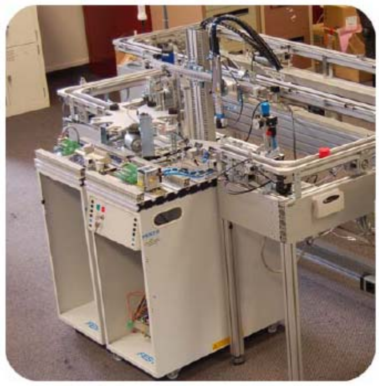


Routing of the material is done by each conveyor

The conveyor controller does not know the whole structure of the system but in collaboration they are capable of finding the optimal delivery path. Moreover, if a single conveyor section is out of order the system can reconfigure material flows on the fly.



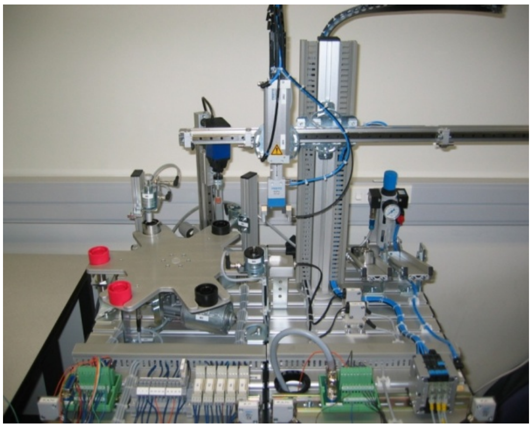
To illustrate the flexibility of this solution we have built two L-shaped conveyor belt sections which can be docked at any place of the main conveyor loop thus forming a diverting loop.



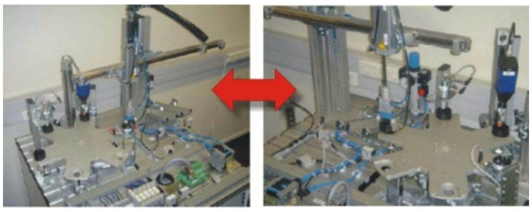
The L-shaped sections can be docked to other slots on the main loop and processing stations can be inserted in the gap. The operation can start immediately after the new physical structure is formed.

Flexible Manufacturing Processes

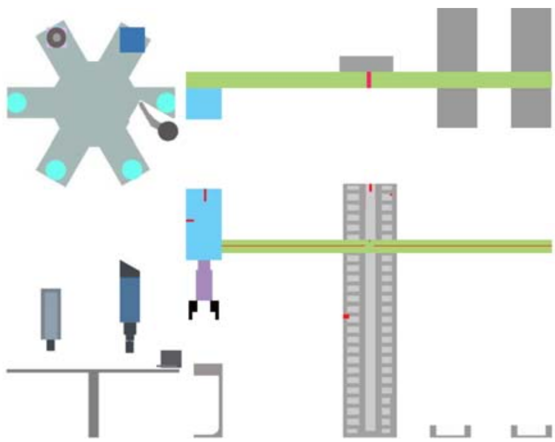
Embedded controllers of mechatronic components can be so smart that they will maintain production of support of several products simultaneously



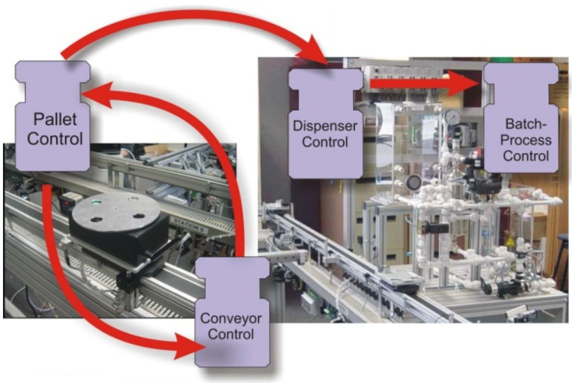
A model of automated manufacturing system



Trading places of the stations



Simulation and animation



Decentralised control enables flexibility in the logistic chain of a batch processing plant

One production line can simultaneously be producing several products and can require machines to be added or removed dynamically in order to manufacture certain features of a customised product.

The main enabler of such reconfigurability is again decentralised intelligent control.

We prototyped such approach in our testbed and experimented with several reconfiguration ideas.

The model consists of two stations: processing station (left) and sorting station (right). The processing station consists of four main components: rotating table, checker, drill and a pusher. All these components are programmed independently in separate function blocks. The sorting station consists of a pneumatic arm, two trays and an input bay where the arm can pick the work pieces.

Several reconfiguration scenarios have been tested.

One class of reconfiguration scenarios is driven by the changing orders, availability of actors (e.g. break downs) or other resources (material, energy).

Another class deals with the physical reconfigurations of the machinery. In our testbed we implemented this scenario by trading places of the stations.

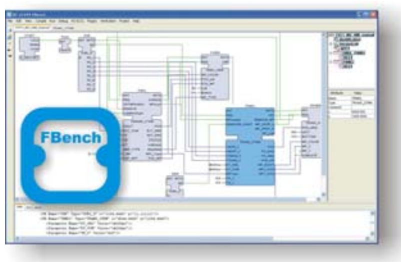
All the configurations have been simulated prior to deployment using the in-house developed simulation and animation technology, which guarantees “What You Verify is What You Run!”

Another class of interesting reconfiguration challenges is observed in the logistic chain of batch processing systems.

Implementation of an urgent product order may require a complex control re-design or substantial manual operation. However, with decentralised intelligent control in place, such an operation is routine.

To run the Function Blocks we use the new generation embedded controllers supporting various wired and wireless network protocols.

We have developed new languages, methods and tools for design and automatic validation of intelligent automation systems, such as the open source FBench.



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