High Speed Sensor - Control Interfaces
First Workshop on Smart Sensor Interface Standard
Thomas E. Wheatley, NIST

High Speed Sensor - Control Interfaces

* Background
* Physical and Logical Requirements
* Sensors: Control, Inspection, and Hybrid
* Sensor Interfaces and Timing
* Status of Sensor Interface Modules

Background 1

* High bandwidth between sensor and controller requires a point to point connection.
* Data registration in time and space are key issues.
* User requires knowledge of machine dynamics for surface following applications.
* Sensors for inspection can range from simple LVDTs to complex vision systems, complicating physical implementations of sensor interface modules (SIMs).

Background 2

* Coordinate measuring machine (CMM) sensing is dominated by touch-trigger probes - slow; crash-prone; and unsuitable for rapid high-density data acquisition.
* CMMs are slow for production monitoring; they are a bottleneck particularly in high-volume industries.
* CMM control systems cannot handle advanced sensors.
* CMM control systems lack open architecture.
* Next Generation Inspection System (NGIS) Project was started to address these issues for CMMs and machine tools.

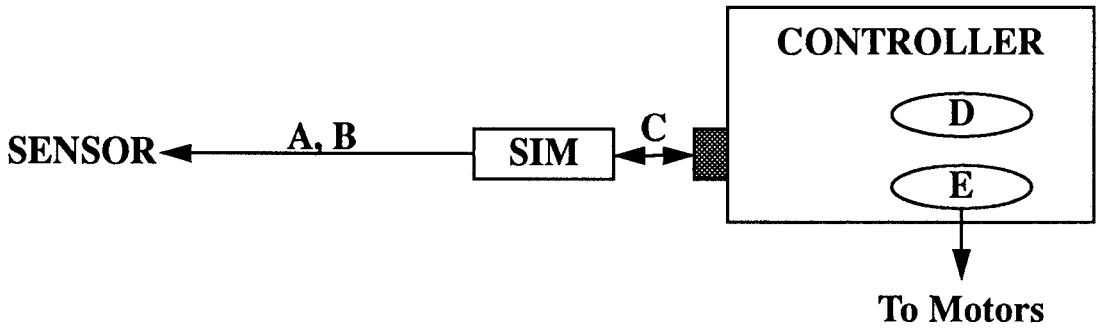
NGIS Project Objectives

* Rapid inspection of complex shapes.
* Flexibility and interchangeability of system components.
* Multi-sensor capabilities - touch; video; laser triangulation.
* Sensor-driven trajectory control.

NGIS Project Team
Coordinated by the National Center for Manufacturing Sciences (NCMS)

* End users: Ford, General Motors, UTC/Pratt & Whitney
* CMM builders: Brown & Sharpe
* Controller suppliers: Hughes Information Technology, Automation Intelligence, Wizdom Systems
* Sensor suppliers: Sensor Adaptive Machines, Inc., Extrude Hone, Automated Precision, Inc.
* Technology providers: NIST, ICAMP

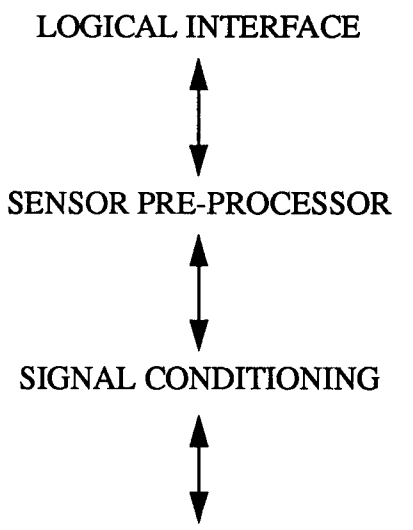
Physical and Logical Requirements 1



A - Data rates and data registration
B - Physical data transfer over long wires
C - Physical interface to controller hardware
D- Logical interface and software for high speed inspection
E - Logical interface and software for surface following

Physical and Logical Requirements 2

A Sensor interface module can span the range from a simple I/O point with no signal conditioning up to a complex sensor requiring its own processor and high bandwidth connection to the control processor.



Sensors: Control, Inspection, and Hybrid 1

Control Sensor:

Any sensor used by a servo control process to aid in closing the error between the commanded goal and the current position. Traditionally, these sensors are tightly coupled to the control process, with little or no latency in communication and are persistent in their connection. Any significant lag in sensor processing or communication to the consuming control process tends to lead to instability of the control loop. They are continually read in a temporal fashion, with the frequency determined by the machine dynamics and requirements of the control process.

Inspection Sensor:

Any sensor used by a machine for purposes of inspection. They have little or no interaction with the control loop, but are merely along for the ride. They can be used in either a temporal or spatial fashion, with the frequency or data spacing determined by the user and/or capabilities of the measurement process. They tend to be periodic in their use, i.e., whenever the sensor is over the part of interest.

Sensors: Control, Inspection, and Hybrid 2

Hybrid Sensor:

Any sensor used for both control and inspection. It can either complement the primary control sensor, or replace it for short periods of time. It shares the characteristics of both control and inspection sensors. In other words, the type of sensors we are dealing with in the NGIS project. What do we need to do this?

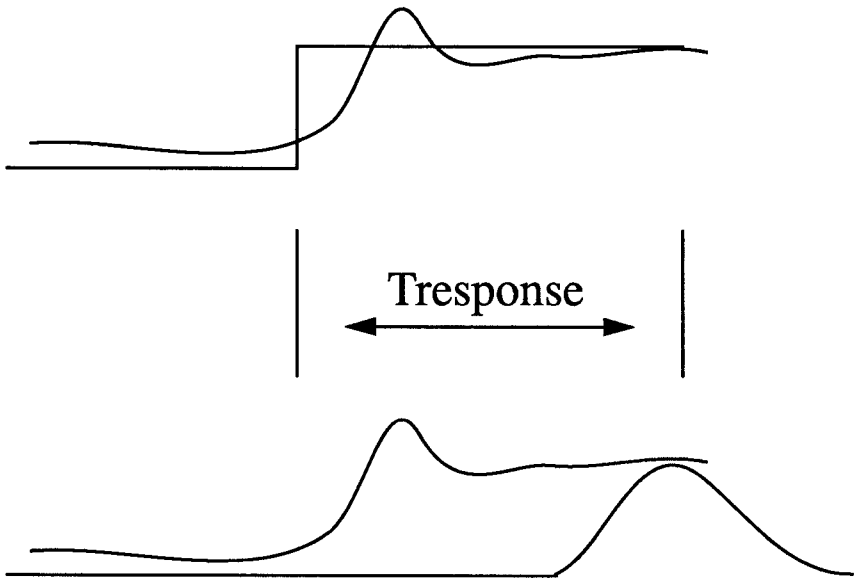
1. Sensor data needs to be available to the control process in time to avoid control instability.
2. Sensor data needs to be aligned in time with the primary control sensor data; in other words, data registration.

A traditional solution to both problems is to embed the new sensor within the controller, retaining the full bandwidth of communication and reading it at the same time as the primary control sensor for data registration. We don't want to be forced into this solution, so let's examine the problem closer.

Sensor Interfaces and Timing 1

Step Response Analysis:

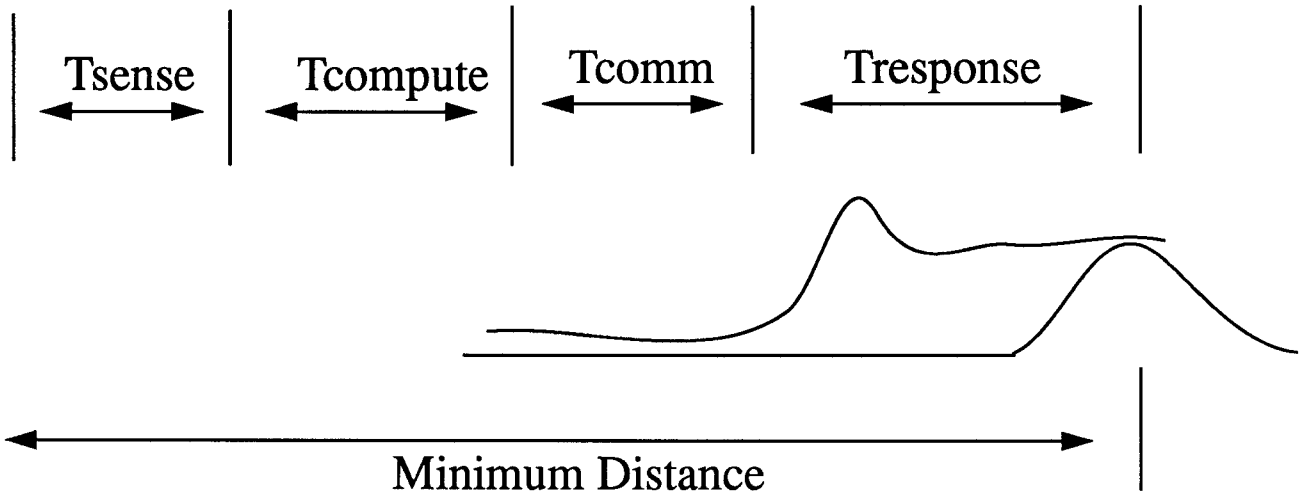
If a step response is thought of as an obstacle to be cleared, we can determine the minimum time at which the control process needs the hybrid sensor's data in order to clear the obstacle. Call this time Tresponse.



Sensor Interfaces and Timing 2

Data Acquisition and Communication

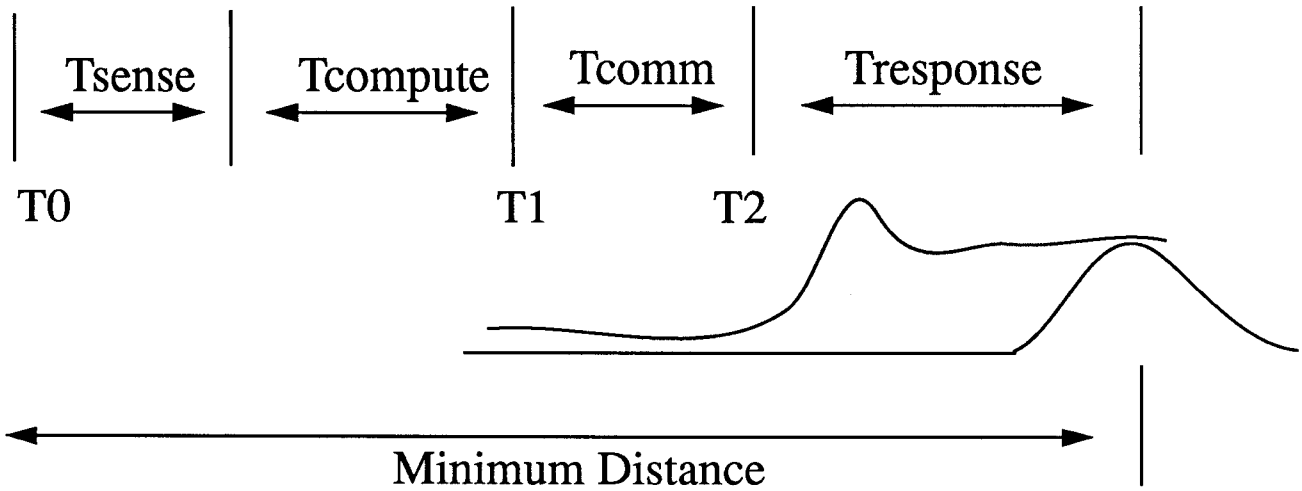
The hybrid sensor needs to sense the obstacle, compute its value, and communicate it to the control process. Call these times Tsense, Tcompute, and Tcomm. The net sum of these times, coupled with the current speed over the surface, determines a minimum distance that the hybrid sensor needs to "see" the obstacle if the control process is to have any hope of clearing it or stopping in time.



Sensor Interfaces and Timing 3

Data Acquisition and Communication

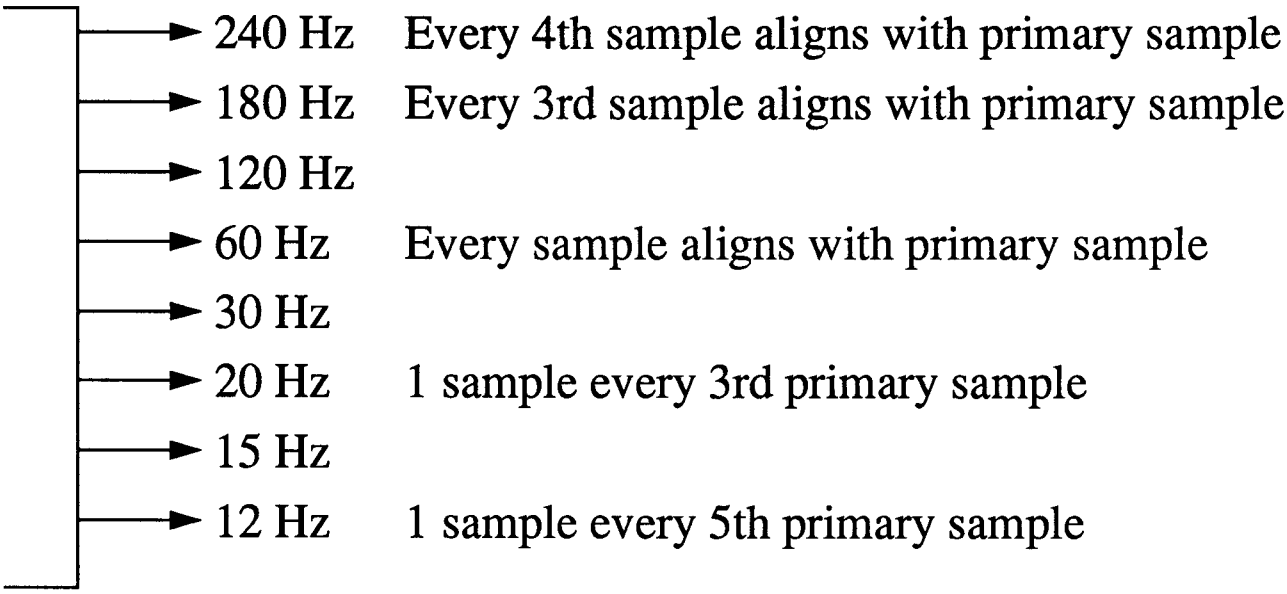
The minimum distance tells us what sensor is suitable for the expected obstacles, (i.e., what working range), and something about our original two problems: control instability and data registration. If we establish the timing relationship between the hybrid sensor and the primary control sensor at T0, we can take a (somewhat) arbitrary amount of time before T2, when the data must be in easily consumable form.



Sensor Interfaces and Timing 4

Timing issues, asynchronous and synchronous

Really a precision issue. If T0 is synchronous with our primary sensor clock, we have exact knowledge of the relationship. Otherwise, some interpolation is required, which also adds some time delay to the hybrid sensor. My recommendation is a simple clock module with harmonics and sub-harmonics about a common frequency like 60 Hz, and possibly some on / off gates available to the control processor.



Sensor Interfaces and Timing 5

Sensor manufacturer requirements

A simple genlock circuit, a timer, and a little logic for the gate handles the clock synchronization / data registration problem. The sensor manufacturer would also publish the time delay (T0 to T2) of acquisition, processing, and communication for their sensor and chosen data link.

Control system requirements

A separate task to handle the physical data link, perform a predictive algorithm on the data (knowing the timing relationship of the clocks and the time delay), and then publish the data as a homogenous transform to the control process by Tresponse.

Sensor Interfaces and Timing 6

Pros of approach

Timing relationship is well established.
User can easily determine sensor stand-off range for desired speed of scanning.
Manufacturers can create range of communication links.
Data clocking can be temporally or spatially based.

Cons of approach

Requires clock and gate signals to SIMs.
Predictive process required on control side.

Status of Sensor Interface Modules

Prototype Sensor interface modules have been defined and are being built.

Data rate:	No defined rate at present.
Data registration:	Genlock input, no defined clock values at present.
Physical wire:	As appropriate for sensor; no standard expected.
Physical interface:	ISA PC card at present.
Logical interface:	Dual-port RAM and/or register approach with sensor dependent data structure using integer, ASCII, IEEE 754 and SI units.

Problems still unresolved and/or unreconciled:

Common physical mounting or other means to create homogeneous transformations to handle different sensor lengths and machine coordinate systems.
Standard mezzanine with enough room for CPU-based SIMs.
Additional technical work to define data phase delay for hybrid sensors.