

HMI Introduction

Dr. Patrick Chan
patrickchan@scut.edu.cn

South China University of Technology

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More Powerful & Autonomous

Application: Photography

• Manual Camera

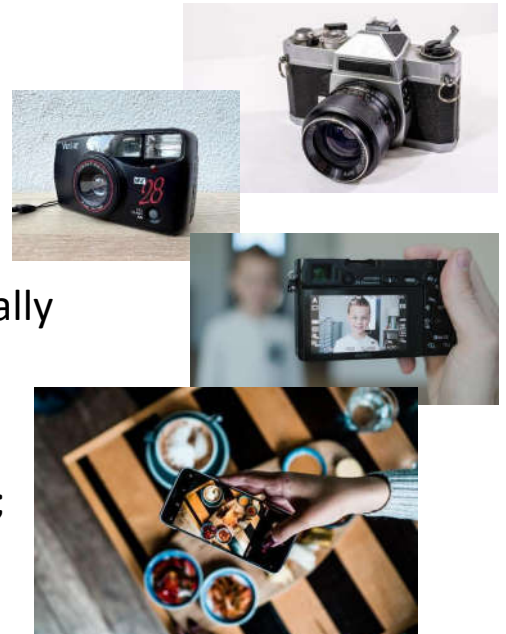
- User sets focus, exposure, shutter
- Machine only captures light

• Auto-Focus / Auto-Exposure

- Detects face; Adjusts brightness automatically
- Human: supervises and corrects

• Computational Photography

- Scene understanding (food, night, portrait);
Multi-frame AI enhancement;
Auto object removal / enhancement



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More Powerful & Autonomous

Application: Information Search

- **Library Search**

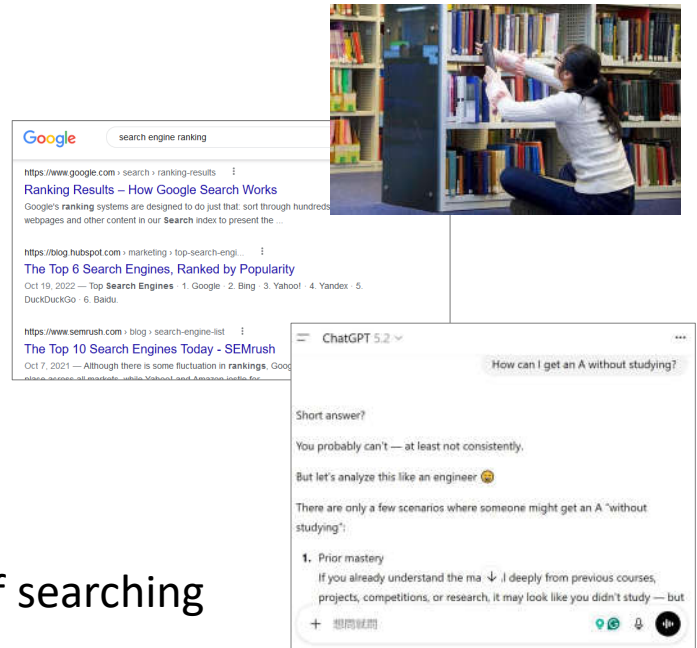
- Find books manually

- **Search Engine**

- Returns ranked results
- User filters information

- **Answer Engine / AI Assistant**

- Provides direct answers
- Summarizes sources
- User evaluates truth instead of searching



More Powerful & Autonomous

Application: Medical Diagnosis

- **Measurement Device**

- Doctor interprets data
- Machine provides data only

- **Decision Support System**

- Flags abnormal patterns; Suggests possible diagnosis
- Human evaluates suggestions

- **AI Clinical Prediction**

- Predicts deterioration risk; Recommends treatment priority
- Human supervises AI judgment



Why HMI?

More Powerful & Autonomous

- Modern machines **no longer just execute commands**
- **Sense → Decide → Act**
 - **Faster** than human reaction time
 - Operate continuously **without fatigue**
 - **Make decisions** in **complex** environments
 - **Increasing autonomy** (human supervises instead of controls)
- **Humans** are **shifting** from *operator* → *supervisor*

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Why HMI? More Powerful & Autonomous

Example: Autonomous Driving

- Understands lanes, vehicles, pedestrians
- Predicts motion of other agents
- Makes real-time driving decisions



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Why HMI? More Powerful & Autonomous

Example: Surgical Robot

- More precise than a human hand
- Removes hand shaking (tremor filtering)
- Large hand movement becomes very small tool movement
- Makes minimally invasive surgery possible



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Why HMI?

Technology Paradox



More intelligence is more safe?

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Example: Smart Infusion Pumps

- Modern hospitals use **smart infusion pumps** to automatically control medication delivery
 - Include drug libraries including dosage limits for a drug
 - Alarm triggered when violation to prevent nurses from giving wrong drug dosage



- **Look a great idea?!?**

Example: Smart Infusion Pumps

- In reality, a hospital **treats very different patients**: child, adult, elder, kidney failure, emergency cases, unusual body weight
- Doctors intentionally **prescribe doses outside the standard range**
- This **looks like an error** to the machine
 - Alarm triggered
 - Nurses have to turn off the alarm before treatment

Example: Smart Infusion Pumps

- **Pattern**
 - Nurse **selects drug** from list
 - System **alarm** triggers (limit exceeded)
 - Nurse **believes** dosage is **correct**
 - Nurse **overrides safety warning**
 - **Patient receives dangerous dose**
- **Why do nurses ignore the warning?**
 - **Because the alerts occur too frequently**

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Example: Air France Flight 447

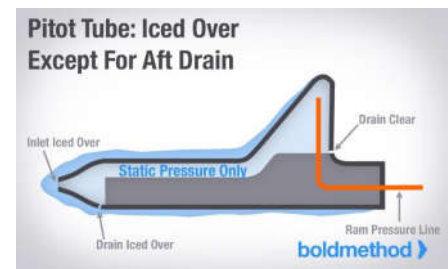
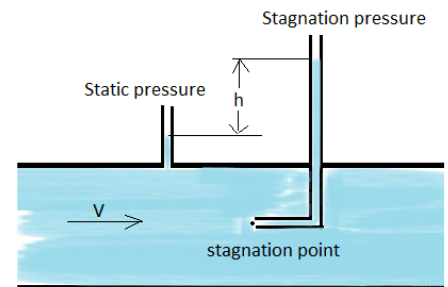
- In 2009
Aircraft: **Airbus A330**
Route: **Rio → Paris**
Weather: **High altitude thunderstorm**
- **Consequences**
 - **228 fatalities**
 - **No mechanical failure found**
 - **Highly trained professional pilots**



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Example: Air France Flight 447

- Airspeed is measured by using **pitot tubes** (pressure sensors)
- In high altitude icing, the **pitot tubes froze**
 - Speed readings became unreliable
- **Other than this the whole airplane flies normally**



Example: Air France Flight 447

- Airbus **Autopilot Logic**:
If airspeed data unreliable → autopilot disconnect
- Aircraft switched: **Normal State → Alternate State**
 - Alternate State:
 - **Pilot must manually fly**
 - **Many protections removed**

Example: Air France Flight 447

- Within **5 seconds**,
In **night storm**, **no outside visibility**,
Pilots got:
 - Speed indications disagree
 - Autopilot disconnect alarm
 - Flight control behavior changed
 - Multiple warning sounds
- **What should you do?**

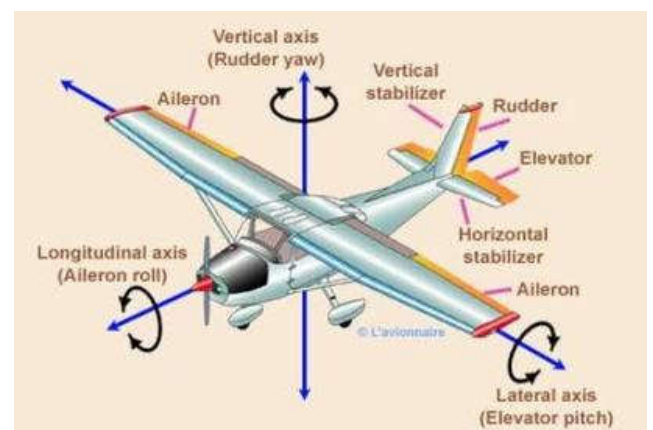


A Side Note

Captain Sully safely landed US Airways Flight 1549 on the Hudson River, saving all 155 people on board.

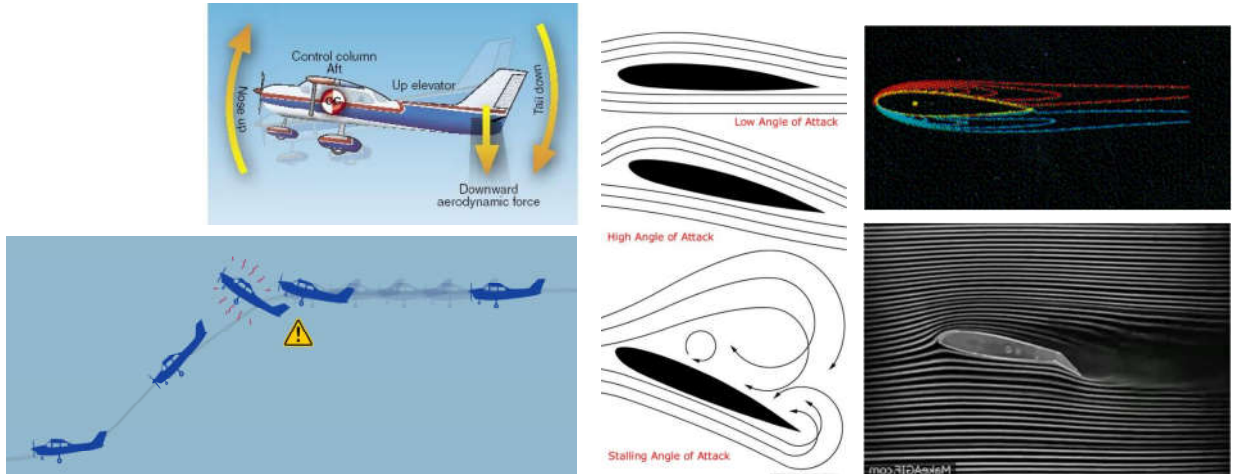
Example: Air France Flight 447

- The pilot **pulled the stick UP**
- **Nose up** → Climbing
- **Why?**
 - **Uncertain + Alarm = Danger**
 - = Climb instinct
 - = **Gain more control margin**



Example: Air France Flight 447

- Keep pulling up, What happens?
- A Stall occurs



Example: Air France Flight 447

- There is **stall warning** in the pre-stall situation
- But the stall warning **sounded**, then **stopped**, then **sounded** again, ...
- **Why? What does it mean?**
- Stall detection **depended on airspeed data**
 - Pitot tubes does not work normally
 - Stall detection **becomes unreliable**

Example: Air France Flight 447

- Pilots **did not recognize that the aircraft was actually stalled** in this complicated situations
 - Unstable warning
 - Many warnings
 - Short Decision Time
- Pilots **kept pulling up** to **avoid the aircraft descending too fast**

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Example: Air France Flight 447

- Consequence
 - Aircraft: fully stalled
 - Nose: pointed upward
 - Falling: 10,000 ft per minute
 - Nearly free fall speed
10,560 ft per minute
 - 228 fatalities



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Technology Paradox

- **Expectation:**

Better technology →
Fewer errors →
Safer systems →
Better outcomes

- **Reality:**

Better technology ≠
Better outcomes

- **Why?**

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Advanced Machines Perform badly?

- Modern **systems** are **powerful and intelligent**
- **Users** are trained **professionals**
- But **serious mistakes still occur**
- **Why?**

- Performance depends on
the human-machine system, not either alone

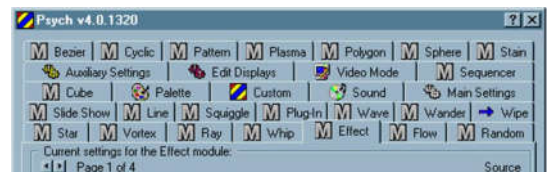
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Complexity vs Human Capacity

- Machine abilities increase exponentially
- Human abilities are fixed
 - E.g. memory, attention, reaction time
- When systems demand more cognition than humans can provide, errors occur
 - E.g. Able to ride a bicycle car ≠ Able to drive a car

Interfaces Designed for Machines

- Many interfaces mirror the system's internal implementation
 - Show how the system works
 - Not how the human thinks
- Users must translate rather than simply operate



Why HMI? Technology Paradox: Advanced Machines Perform badly?

Interfaces Designed for Machines

- Automated systems are more complex and contain **internal modes/states**
- As users cannot clearly see what the system is doing, cannot **fully understand**
- Uncertainty **leads to incorrect actions**



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Why HMI? Technology Paradox: Advanced Machines Perform badly?

Interfaces Designed for Machines

- Automation **change human roles**
 - **No longer actively controls** the system
 - Mental engagement decreases
- **Sudden Handover**
Control transfers at the worst moment
- **Over-Trust**
Believing the system even when wrong



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Technology Paradox

- Advanced and intelligent systems are often:
 - Hard to operate
 - Misunderstood by users
- Changes the nature of failures, not frequency
 - Most failures are interaction failures, not hardware failures
 - Systems become technically safer but operationally riskier

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Why HMI? Technology Paradox

Are Training/Rules Helpful?

- Can interaction failures solved by Training/Rules?
 - Humans are highly adaptable
 - Typical response after incidents:
More training, manuals, procedures



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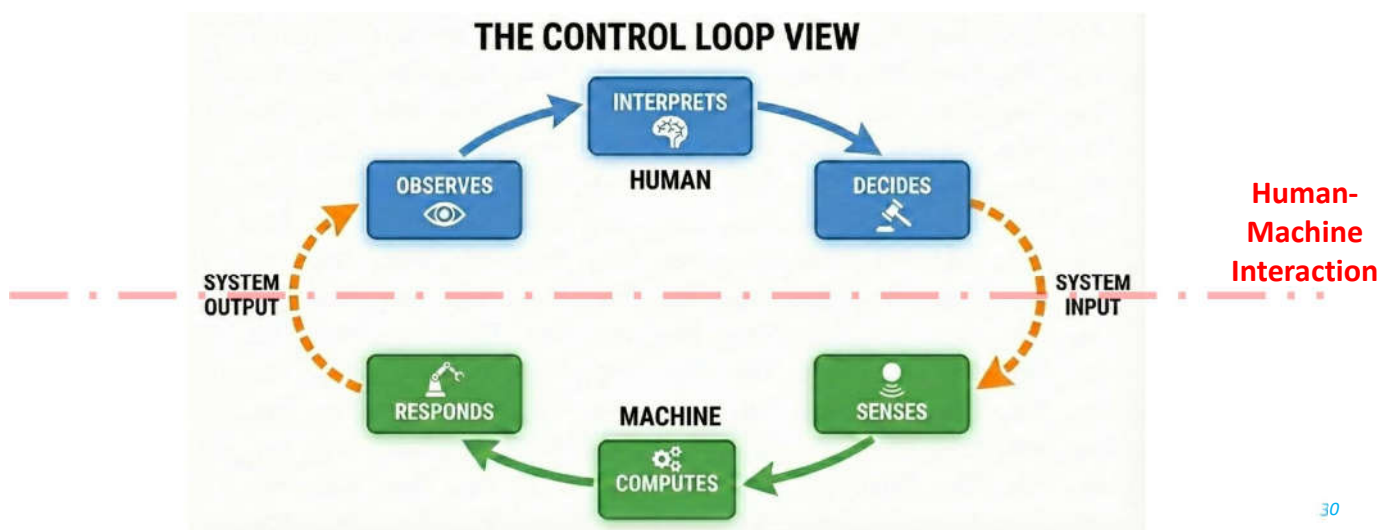
Are Training/Rules Helpful?

- **Treat Symptoms, not root causes**
 - Humans can **compensate** for poor design
 - The system **appears functional** but **safety margins still small**
- The issue is **not user competence**
 - Many accidents involve: **experts, professionals, and trained operators**

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Human-Machine Interaction

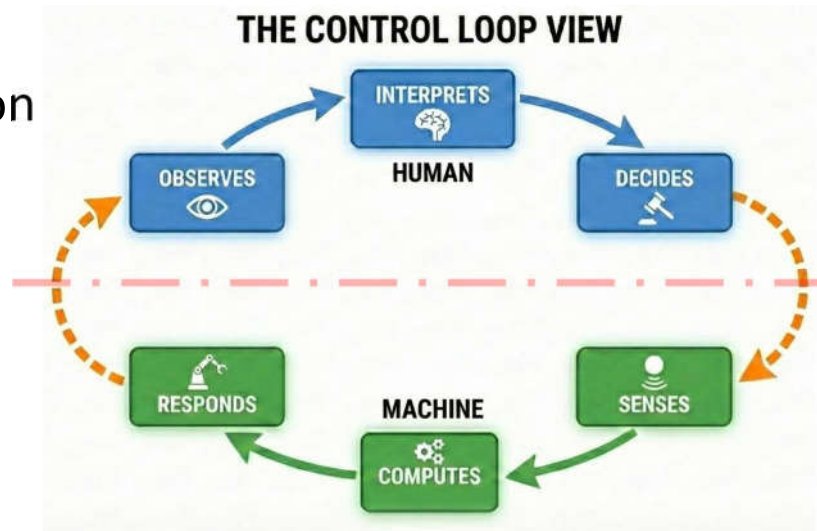
- **Traditional View**: Human **operates** the machine
- **Modern View**: Human is a component **inside the control loop**



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Human-Machine Interaction

- **Poor HMI breaks the control loop:**
 - incorrect interpretation
 - delayed response
 - unexpected system behavior
- **Failure occurs**

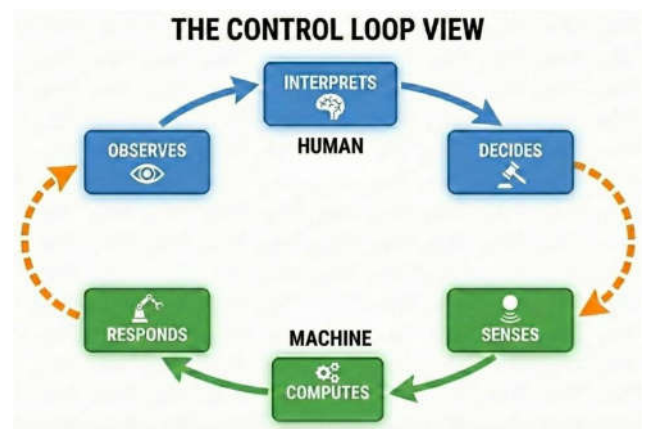


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Human-Machine Interaction

Perception, Decision, and Control

- Human interaction introduces
 - **Perception**
Sense signals
 - **Understanding**
Interpret as meaningful information
 - **Decision**
Evaluates and chooses actions
 - **Control (Action)**
Manipulates system behavior
- This process is similar to the machine



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Variable Human Behavior

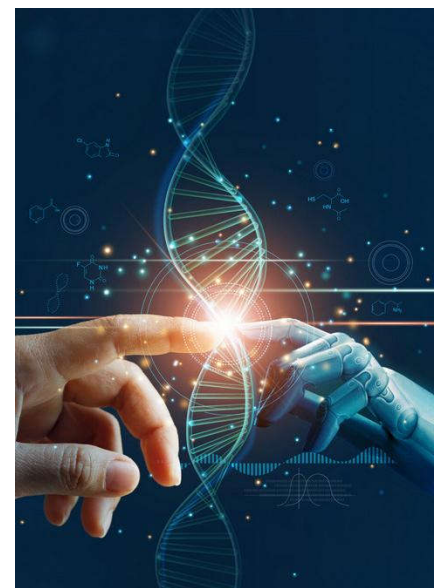
- Unlike machines,
humans are not constant controllers
- Human response gain changes over time
 - Depends on:
workload, fatigue, stress, trust, ...
 - Parameters are **dynamic**



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From Tools to Teammates

- **Modern systems** have **intelligent**
 - Sense, decide, and act
- No longer simple tools but **teammates to humans**
- Human and machine must be treated as one **integrated system**



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New Requirements

- Engineering traditionally optimizes:
 - accuracy
 - speed
 - efficiency
 - reliability
- Intelligent systems depend on:
 - understanding
 - attention
 - trust
 - interpretation

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Human-Machine Interaction

- **Traditional Engineering Focus**
Design the machine to work correctly
- **HMI Engineering Focus**
Design the human-machine system to work correctly
- **Human-Machine Interaction (HMI)**
Design a system which
humans and machines form a stable control loop

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Beyond Software Interfaces

- NOT making interfaces pretty or convenient
- NOT limited to screens and buttons
 - It involves physical systems
 - Actions have physical consequences
- HMI affects safety in the real world

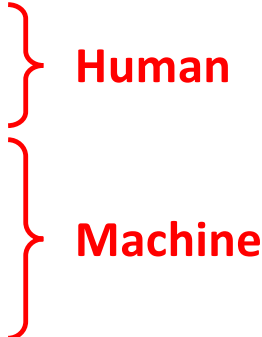
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Interface vs Interaction

- | | |
|---|---|
| <ul style="list-style-type: none">• Interface
The visible input/output elements
(buttons, screens, alarms) | <ul style="list-style-type: none">• Interaction
The dynamic behavior between human and machine over time |
|---|---|
-
- **Good interface does not guarantee good interaction**

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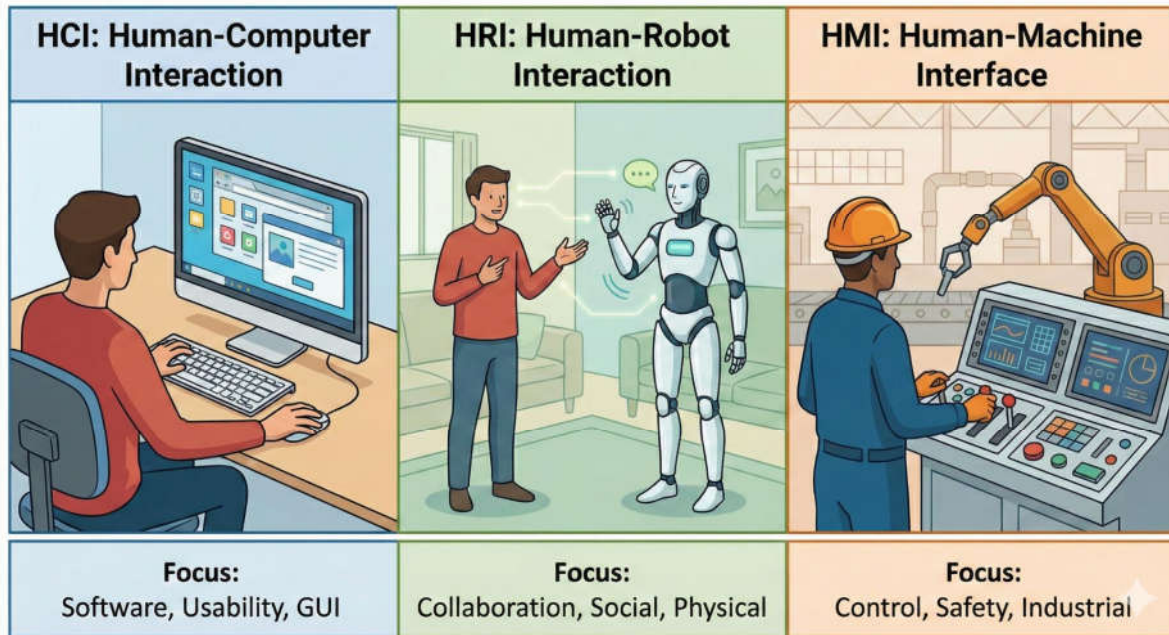
Interdisciplinary

- The goal is to design working human-machine systems
 - Not to study humans or design machine alone
 - Draws **knowledge** from:
 - **Psychology** (human cognition)
 - **Biology** (human perception)
 - **Control Theory** (feedback loops)
 - **Computer Science** (automation)
 - **Engineering** (system behavior)
- 
- The diagram shows two red curly braces on the right side of the list. The top brace groups 'Psychology' and 'Biology' under the label 'Human'. The bottom brace groups 'Control Theory', 'Computer Science', and 'Engineering' under the label 'Machine'.

HCI vs HRI vs HMI

- | | | |
|---|---|--|
| <ul style="list-style-type: none">• Human-Computer Interaction (HCI)<ul style="list-style-type: none">• Between: humans and software systems• Focus: information manipulation and usability• E.g. Navigating a mobile app | <ul style="list-style-type: none">• Human-Robot Interaction (HRI)<ul style="list-style-type: none">• Between : humans and embodied robots• Focus: behavior, motion, cooperation, safety• E.g. Interacting with a Robot Vacuum Cleaners | <ul style="list-style-type: none">• Human-Machine Interaction (HMI)<ul style="list-style-type: none">• Between : humans and engineered systems• Focus: control, feedback, and joint task execution• E.g. the control panel of a nuclear power plant |
|---|---|--|

HCI vs HRI vs HMI



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HCI vs HRI vs HMI

Key Differences

Aspect	HCI	HRI	HMI
Embodiment	Virtual	Physical robot	Any machine
Physical consequences	Usually indirect	Direct physical	Often safety-critical
Autonomy	Low–medium	Medium–high	Wide spectrum
Main problem	Usability	Cooperation	System stability & safety

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Relationship

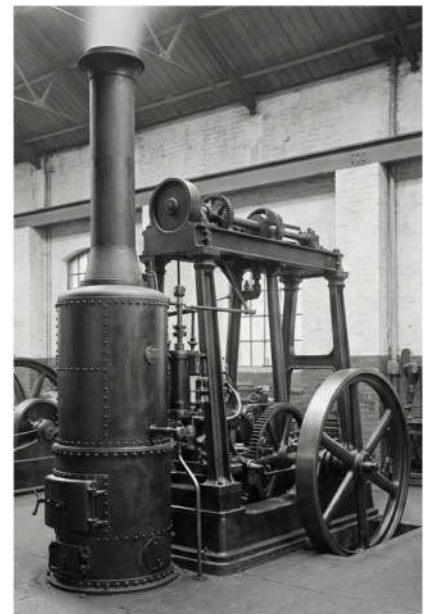
- HCI focuses on **information interaction**
HRI focuses on **embodied cooperation**
- But **modern engineered systems** include:
 - **Software** interfaces
 - **Physical** devices
 - **Automation** behavior
- **HMI studies the whole operational system**
 - $HCI \subset HMI$ and $HRI \subset HMI$

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Brief HMI History

1850-1940: Mechanical Era

- Direct **physical coupling**
 - E.g. Levers, pulleys, and gears
- Human "felt" the machine
 - Energy and Information were the same.
- **Physical strength** was a requirement
- **Feedback** was raw (heat, vibration, noise)



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1940-1970: Electromechanical Era

- Remote **control through electricity**
 - Gauges, knobs, and lightbulbs
- As machines got complex, **cockpits contains hundreds of single-purpose gauges**
 - **Cognitive Load is very High**
 - Operators had to scan dozens of indicators to understand system state



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1980-2000: Digital Era

- **Screens** (CRTs & LCDs) replaced physical gauges
- **Information became Layered**
Only see what is on the **current screen**
 - **Pros:** Reduced clutter by **showing only relevant information**
 - **Risk:** **Losing the big picture** (may not know what is going on)



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2000-Present: Automation Era

- **Machine intelligence**
the system now makes its own decisions
- Human becomes a supervisor rather than a direct operator
- Interaction moves from physical manipulation to **abstract, logic-driven control**.



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Evolution with Automation

- **Systems became automated:**
 - **Old interaction:** Muscle effort and perception
 - **Modern interaction:** Interpretation and decision-making
- **Interaction became cognitive** rather than physical
 - **Operators:** read symbols, understand modes, and predict behavior

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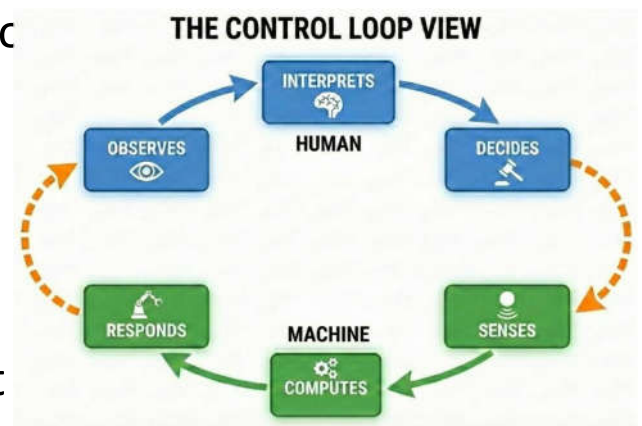
Why HMI Is More Critical Today

- Lessons Learned from History
Major incidents repeatedly showed:
 - machines worked correctly
 - operators were trained
 - **misunderstanding caused failure**
- Technology advanced faster than interaction design

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Course Syllabus

- **Ch02** Human Factor
- **Ch03** User Centered Design Methods
- **Ch04** Interaction Modalities and Technologies
- **Ch05** Human-in-the-Loop Collaboration Mechanisms
- **Ch06** Evaluation, Safety, and Trust in HMI Systems
- **Ch07** Application



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Human Factor

- Machines are precise and deterministic
Humans are adaptive but limited
- Aim to understand the **capabilities and limitations of the human operator**
 - Human Capability & Limitations
 - Human State & Workload
 - Human Failure in Intelligent Systems
 - Real Accident Case Studies

User Centered Design Method

- Engineers often design for the system
Instead of designing for the human
- Systematically translate **human needs** → **engineering decisions**
 - Understanding Users
 - From Data to Requirements
 - Modeling Users
 - Prototyping and Iteration

Interaction Modalities

- Interaction is not only through buttons and screens
- Humans communicate using multiple senses and actions
 - Visual and auditory interaction
 - Gesture and motion interaction
 - Haptic and tactile interaction
 - Physiological-signal-driven interaction

Human-in-the-Loop Collaboration

- Robots are no longer isolated machines
They now share space and tasks with humans
- Not only making robots smarter but making autonomy compatible with human safety and understanding
 - Autonomy and Human Roles
 - Shared Control
 - Human-Aware Planning
 - Collaborative Robots (Cobots)

Evaluation, Safety, and Trust

- Engineering does not end at implementation
It ends when interaction is reliable
 - Evaluating Interaction
 - Designing for Failure
 - Safety Principles
 - Trust and Responsibility

Application

- HMI principles are only valuable when they work in real environments
- Different domains create different interaction challenges
- Introduce real life applications

About This Course

What you think this course is...



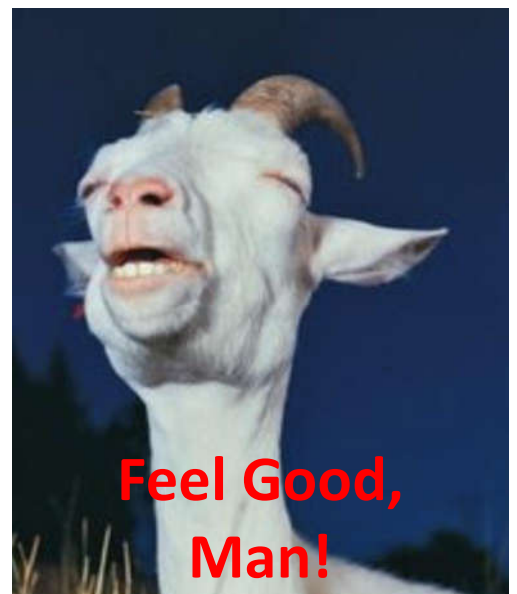
Reality is...



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About This Course

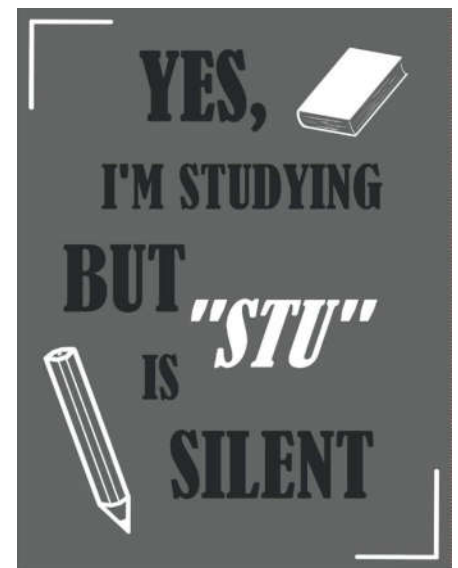
- **Traditional technical courses**
 - Explain how systems work
 - Contain complicated algorithms and complex formulas
 - **Make you feel professional**
- Unfortunately, this course is nothing similar to these



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About This Course

- This is an **engineering course**
 - **Look simple** and **easy to understand**
 - Sometimes it may even feel **obvious**
 - *like saying “your mother is a woman”*
 - Sometimes it may be **too detailed**
 - *like a boring user manual*



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About This Course

- But:
 - Real value appears when you apply it
 - Simple principles prevent serious problems in practice
 - Simple ideas, powerful engineering impact
- Work hard
Do not regret it when you lose this learning opportunity



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About This Course

- What is the problem?



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About This Course

- Why are there so many rules?



keep window shades open during takeoff and landing



do not inflate the life vest inside the cabin

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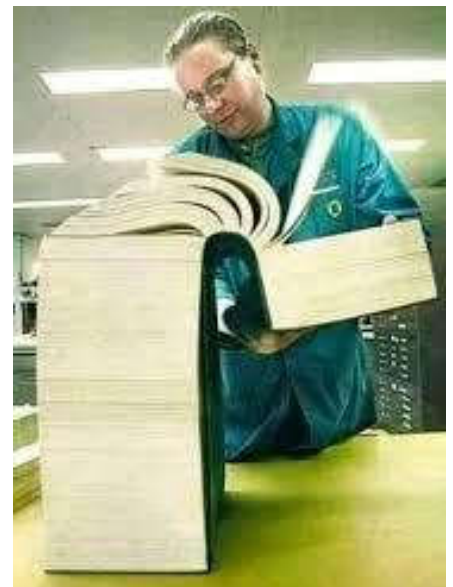
About This Course

- Those procedures / rules **come from lessons learned through painful experience**
- This is similar to what we will learn in this course
 - When you first see the rules, they may **look simple**
 - But if you do **not aware of them, your designed system may cause serious mistakes**
- **Goal: not only knowledge, but mindset**

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About This Course

- This course is about Human
- Understanding human is often a weakness of science students
 - Good at understanding machines, but not human
- You are human.
Do you think you understand humans?



Book of How to understand human
(volume 1)

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About This Course

- What does she mean?



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About This Course

- How to **communicate clearly**
 - How to **express your intent**
 - How to **listen and understand others**
- How to **collaborate effectively**
- How to **build trust**

- These are **also concerns in human–machine systems**

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About This Course

- Hope you will find a way to appreciate this course
 - May be not now, but some days when you grow up
- Its value may not appear immediately, but it will grow with experience

Me after I finally understand it...



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About This Course

- Reduce one-way passive learning
- Less lecture, more interaction.
 - Discussion
 - Short Sharing
 - Group Project
- Please speak more than I do



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