Smart machine and process control

in chocolate mass production

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BÜHLER

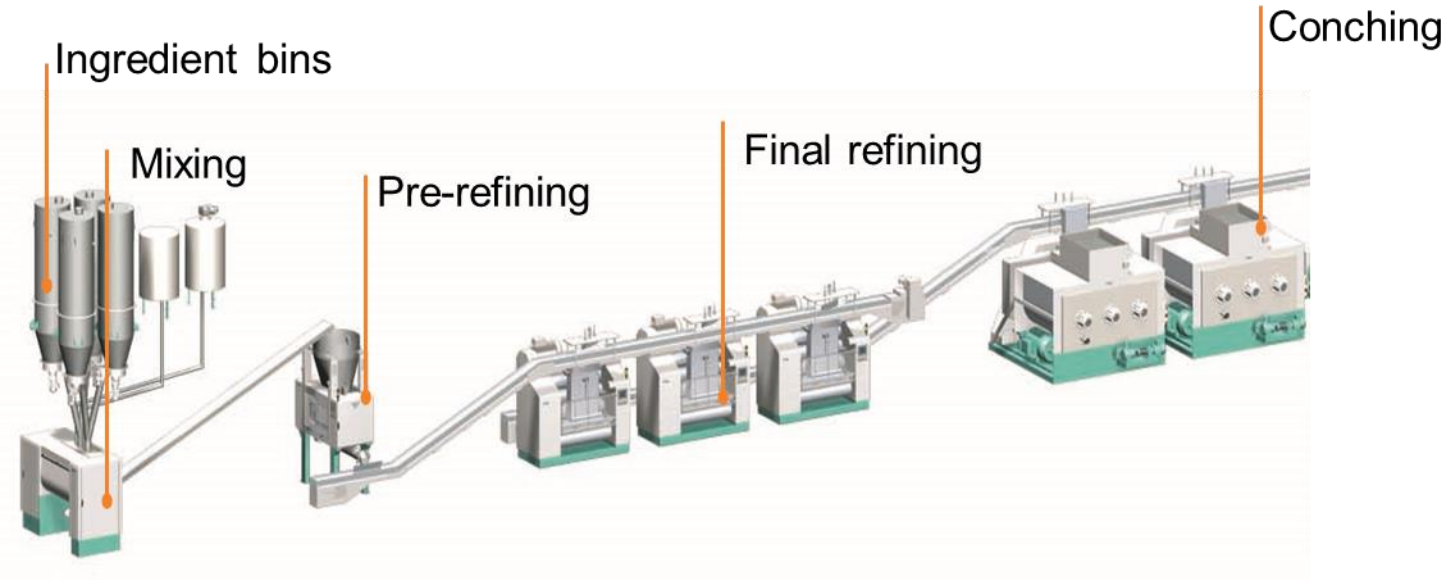
Agenda.

Smart machine and process control.

1	Process line introduction
2	Vision, goal and tasks
3	Advantages and disadvantage of optical sensors in production lines
4	Implemented solutions
5	Further developments
6	Conclusion and outlook

Introduction Chocolate Mass Production.

Smart machine and process control.



Dosing

- precision
- fat content

Mixing

- homogenizing
- coating

Pre refining

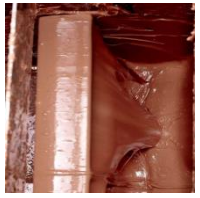
- fineness
- plasticity

Final refining

- fineness

Conching



- rheology
- flavor

Vision, goal and tasks.

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Vision

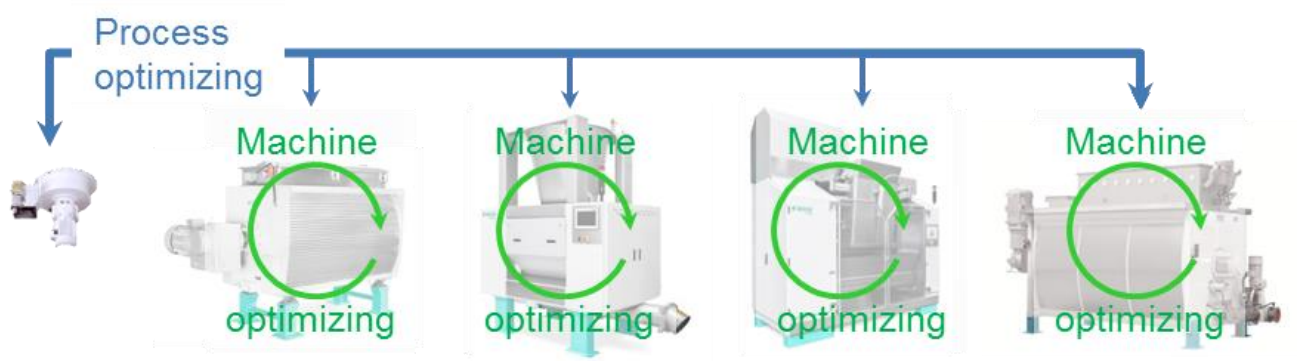
Each machine optimize automatically its throughput / quality. With a M2M connection the whole line could be optimized

Goal

- elimination human factor → constant quality
- increased machine / line efficiency → minimize line cost (TCO)
- use expert knowledge → implement know how and multiply with sensors

Tasks

Optical monitoring points:



- *Product structure change*
- *Through level*
- Product fineness
- *Roll coverage*
- Dry run rolls
- *Product structure change*
- *Filling weight*

Advantages and disadvantage of optical sensors.

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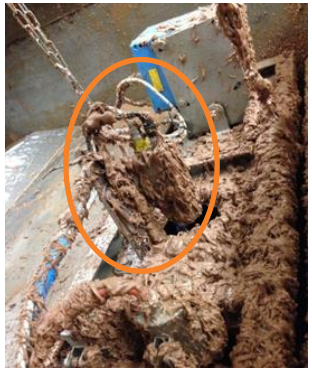
Why we use optical sensors?

Pros

- Contactless
- Wear-free
- Visual impression, close to human experience
- 3D information
- more opportunities (IR, NIR etc.)

Cons

- Distance to the object
- Free view to the object
- Resolution
- Reflections
- Visible range
  - Illumination → heat
  - incidence of extraneous light
  - depth of focus



Customers aspects

- Machine can be closed → hygienic design / process visualization in control room

- Danger of lens contamination → cleaning
- Glass not usable in food process → lens
- Safety issues → laser class
- Reliability → algorithm

Implemented solutions I

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Roll dry run protection on final refiner

Method:	CMOS image sensor b/w LED infrared illumination
Requirement:	Free view to the object

Function:

- Remission of IR signal is an indicator of the roll coverage level
- Threshold levels according to intensity

Implemented solutions II

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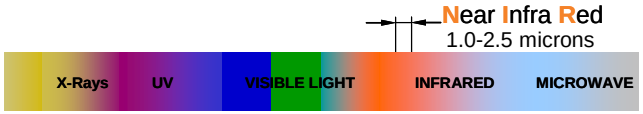
Online particle size measurement on final refiner

Method: Discrete NIR spectrometer
Relative measurement → calibration

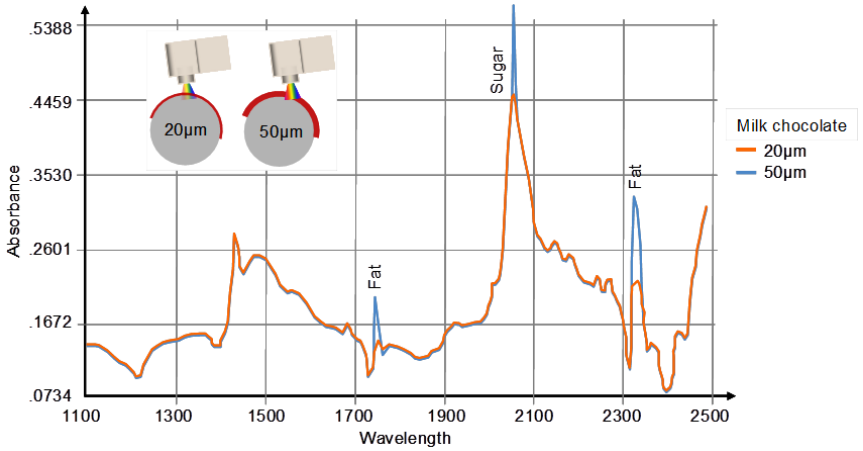
Requirement: Chocolate powder is IR active



Function:

- Product ingredients absorb NIR-radiation (energy)
- The wave length depends on the substance and is determinable
- The peak height correlates with the amount of substance, based on the calibration substance

→ After calibration, the film thickness can be calculated

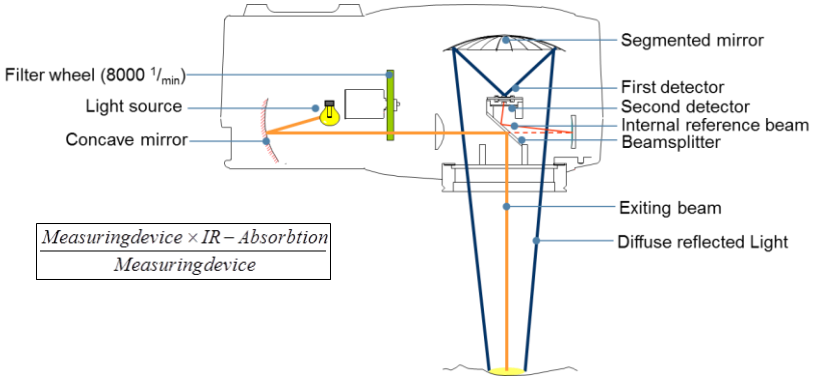


Implemented solutions III

Smart machine and process control.

Sensor composition

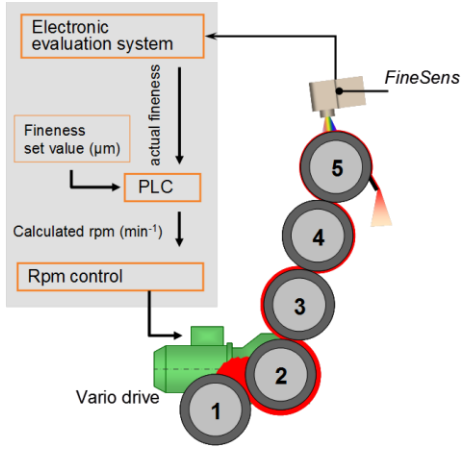
The lamp characteristic is continuously assessed by the secondary detector and by rationing this against the primary detector, wavelength by wavelength, the influence of the sensor is eliminated



$$\frac{Measuringdevice \times IR - Absorbtion}{Measuringdevice}$$

Calibration process

- A single particle size measurement at three different roll speeds (R2) has to be taken for every single recipe
- Particle size readings are adjusted by a calibration equation of a straight line



$$Fineness \approx f(product\ intake, shear)$$

Implemented solutions IV

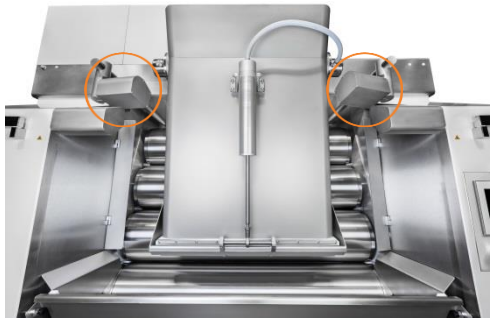
Smart machine and process control.

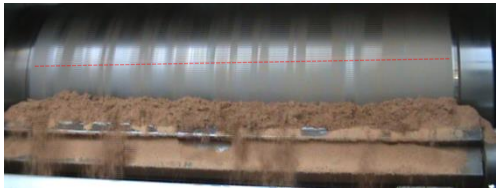
Roll coverage control on final refiner

Collaboration with n|w Fachhochschule Nordwestschweiz

Method: 2 Laser-Scanner (l/r)
Remission and distance

Requirement: Free view to the object

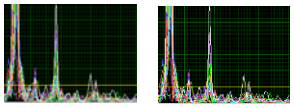




Function:

- Normalization of the remission data's
  rotating mirror with six surfaces → differences in the reflection and intensities
- Preprocessing
  Binary (max./min filter) in black and white
  Data filtering
  Analysis of the pattern in combination with dynamic information (power spectrum)
- Add left and right scan
- Condition evaluation

pattern morphology



Examples of implemented solutions V

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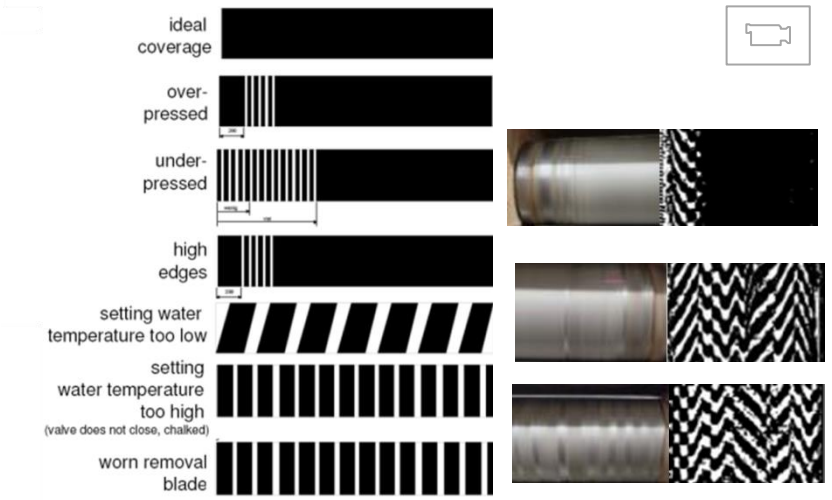
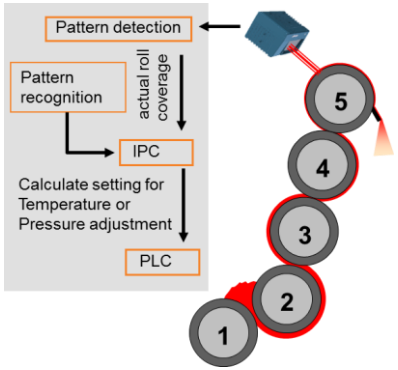
Pattern

- Different types of «coverage failures» and their corresponding machine setting failure



Control

- Algorithm calculates most probably process failure
- Patterns compared with actual settings
- Calculation of corrections
  - Roll temperature window
  - pressure setting left and right
  - etc.
- Automatic update of machine parameters



Further developments VI

Smart machine and process control.

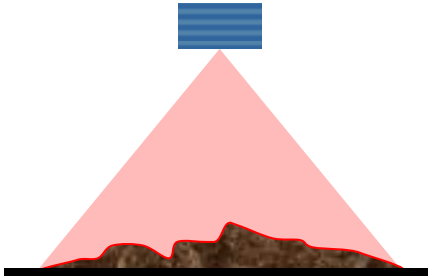
Optical belt scale

Method:	Laser-Scanner
	2D distance
Requirement:	Free view to the object
	Bulk density product
	Speed of the belt

Function:

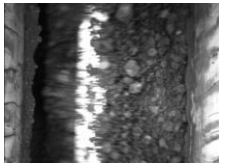
- Scanner measures the product topology (Area)
- Calculation of the product volume (topology over time)
- Weight calculation with bulk density

$$\dot{m}\left[\frac{kg}{h}\right] = 3600 * A[cm^2] * v\left[\frac{cm}{s}\right] * \rho[\frac{kg}{cm^3}]$$



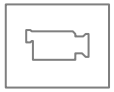
Further developments VII
Smart machine and process control.

Online monitoring of structure change I


Method: Laser-Scanner
2D distance

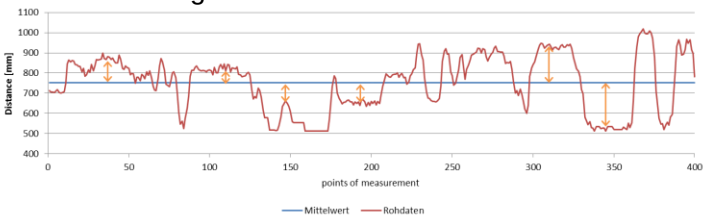
Requirement: Free view to the object



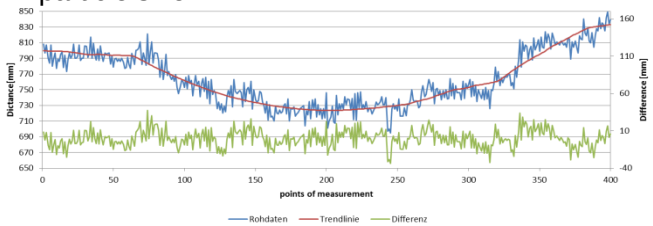
Function:

- Determination of the surface roughness
  - average → filling height
  - standard deviation → roughness
- Determination of particle size (detrend principle)
  - difference between trend and real signal

surface roughness



particle size



Further developments VIII
Smart machine and process control.

Online monitoring of structure change II

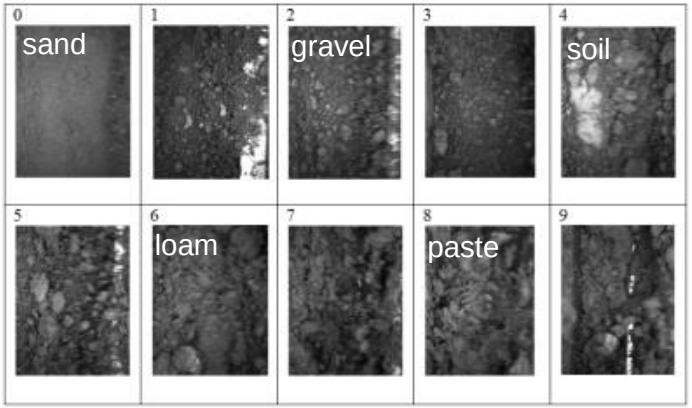
Method: Camera
gray scale image

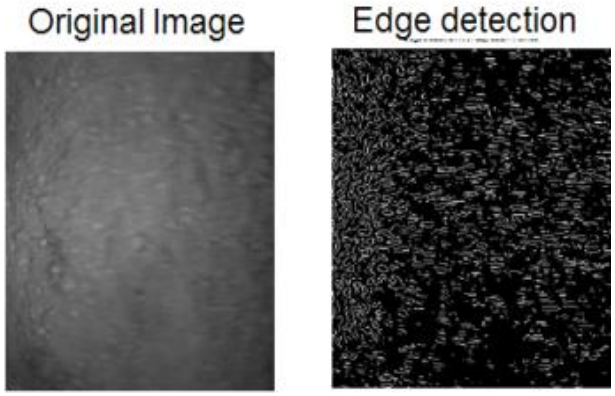
Requirement: Free view to the object

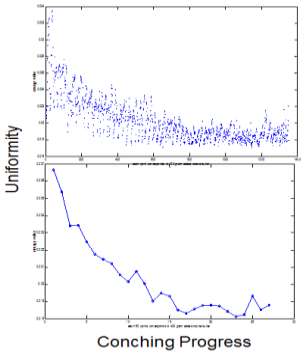
Function:

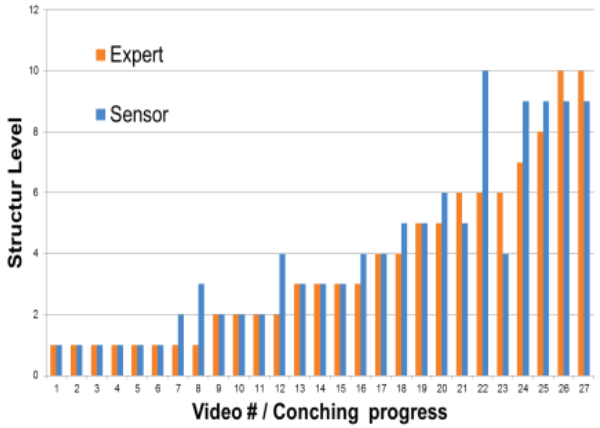
- Detect edges
- Tracking edge pixels
- Calculating area
- Analysis uniformity and edge pixels

Definition of 10 representative structures







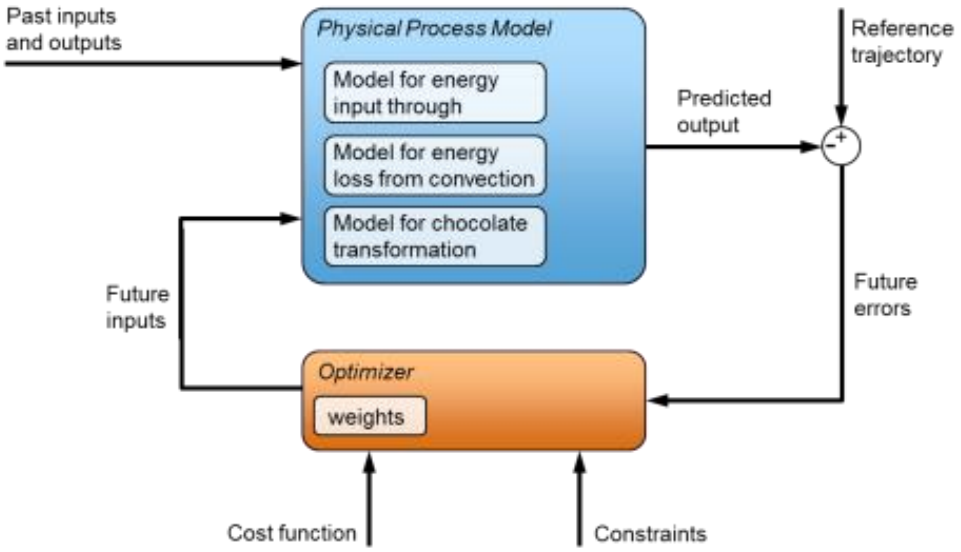


Further developments IX

Smart machine and process control.

Control

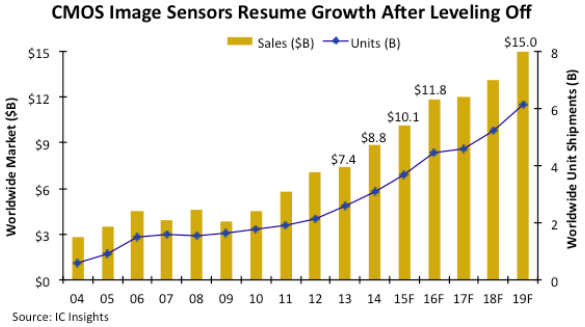
- Use of SI for model predictive control



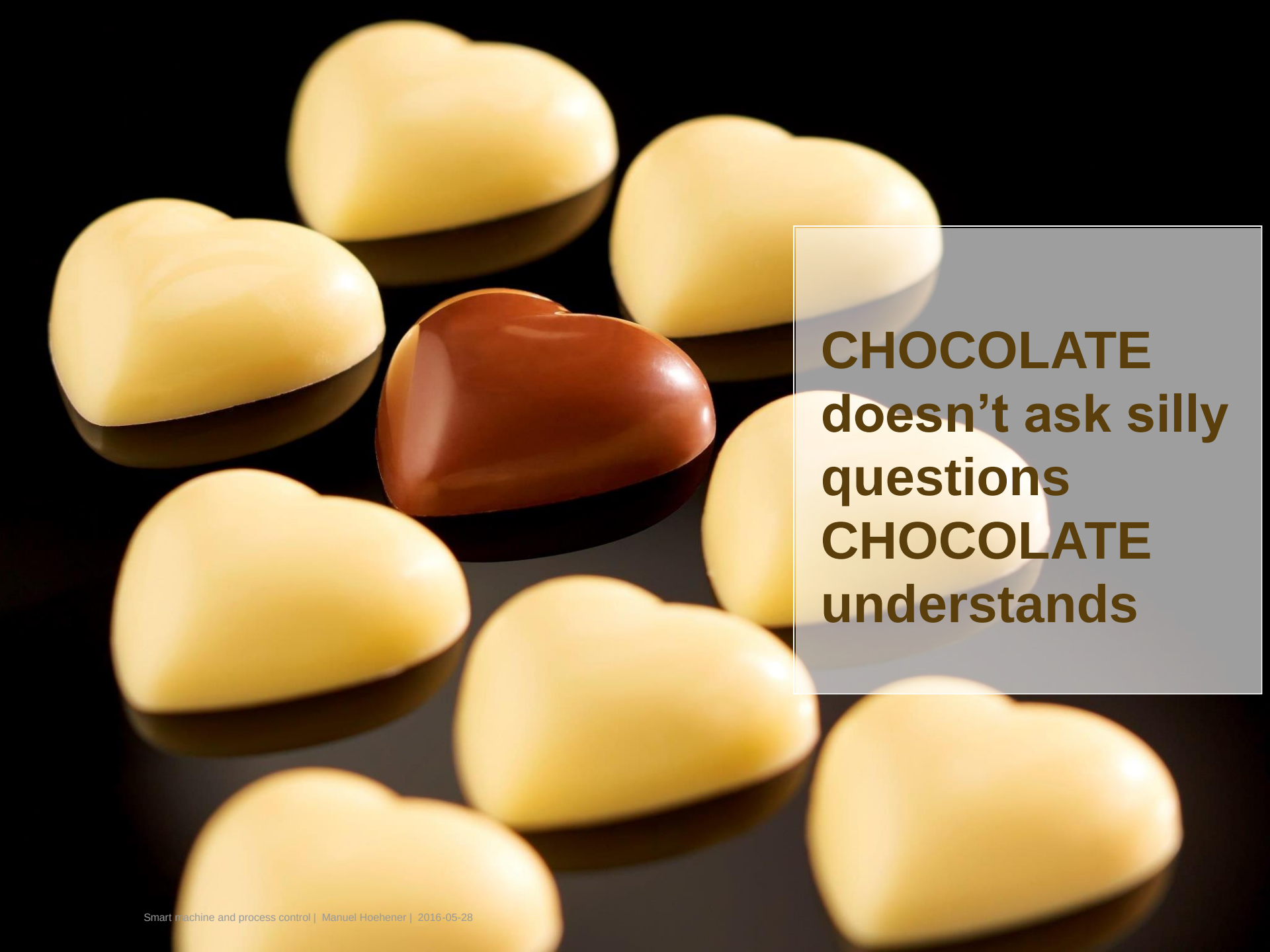
Conclusion and outlook

Smart machine and process control.

- Diversity and development of sensors fast growing
- Analytical methodology as highly improved
- Calculation power has increased dramatically



- More complex as it seems to be
- Environment is very important


CHOCOLATE
doesn’t ask silly
questions
CHOCOLATE
understands