

Steering of a seeding process with a multi-sensor system

Heiner Kuhlmann, Markus Wieland

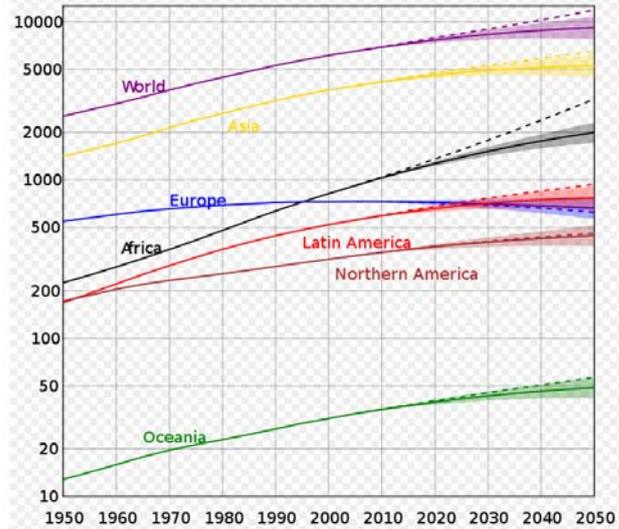


FIG WORKING WEEK 2012

May 6–10 2012
Rome, Italy

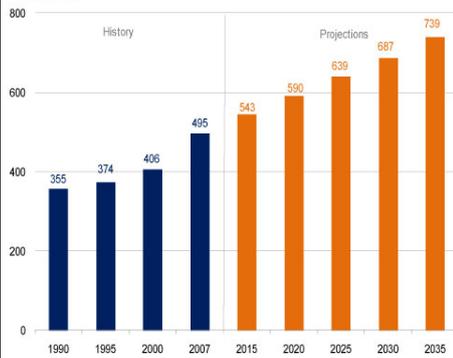


world population



www.wikipedia.org from UNO

Figure 12. World marketed energy consumption, 1990-2035
quadrillion Btu



Source: US energy information administration, July 2010

Energy consumption

Figure 16. World marketed energy use by fuel type, 1990-2035
quadrillion Btu

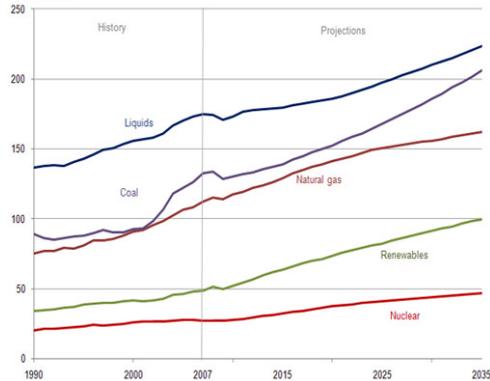
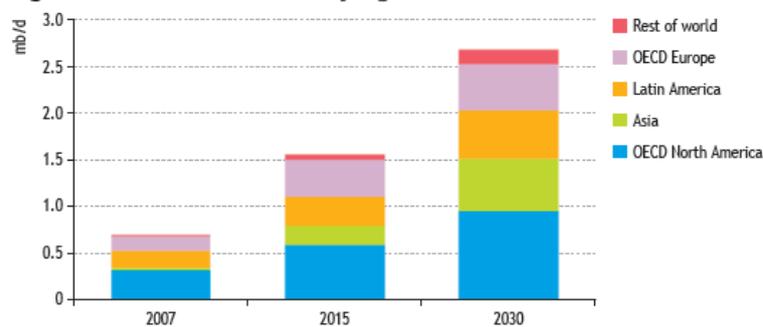


Figure 1.10 • Biofuels demand by region in the Reference Scenario



Source: International Energy Agency, 2009

Changed dietary habits

Table 5.2-2

Consumption of meat, milk and milk products in various world regions.

¹Without butter; ²Mean for the 3-year span

Source: FAO, 2006b

	Meat [kg/person/year]			
	1969/1971 ²	1999/2001 ²	2030	2050
<i>Developing countries</i>	10.7	26.7	38	44
Sub-Saharan Africa	10.2	9.5	14	18
North Africa/Middle East	12.6	21.7	35	43
Latin America	33.5	58.5	79	90
South Asia	3.9	5.5	12	18
East & South-East Asia	9.2	39.8	62	73
<i>Transition countries</i>	49.5	44.4	59	68
<i>Industrialized countries</i>	69.7	90.2	99	103
World	26.1	37.4	47	52

+ 30%

WISSENSCHAFTLICHER BEIRAT DER BUNDESREGIERUNG
GLOBALE UMWELTVERÄNDERUNGEN

Changed dietary habits

Table 5.2-5

Land requirement of foods in relation to the energy content of the consumable product (based on yields in the USA, case study of New York state).

Source: Peters et al., 2007

Land requirement

animal/plant 7

	Land requirement [m ² /1.000 kcal]
Animal-based foods	
Beef	31.2
Poultry	9.0
Pork	7.3
Eggs	6.0
Full-cream milk	5.0
Plant-based foods	
Oil fruits	3.2
Fruit	2.3
Pulses	2.2
Vegetables	1.7
Cereals	1.1

WISSENSCHAFTLICHER BEIRAT DER BUNDESREGIERUNG
GLOBALE UMWELTVERÄNDERUNGEN

Food crisis

**Change in price
June to December
2010**

	[%]
Wheat	75
Sorghum	88
Beans	48
Rice	17
maize	73

**the world bank,
food price watch 2011**

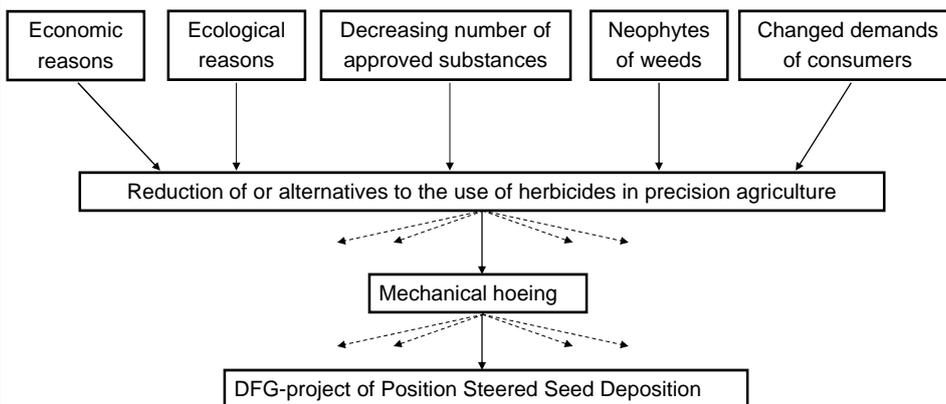
	Total population (millions)	Poverty rate change (millions)
Low-income countries	828	9,5
Midle-income countries	4.758	34,1
total	5.586	43,7

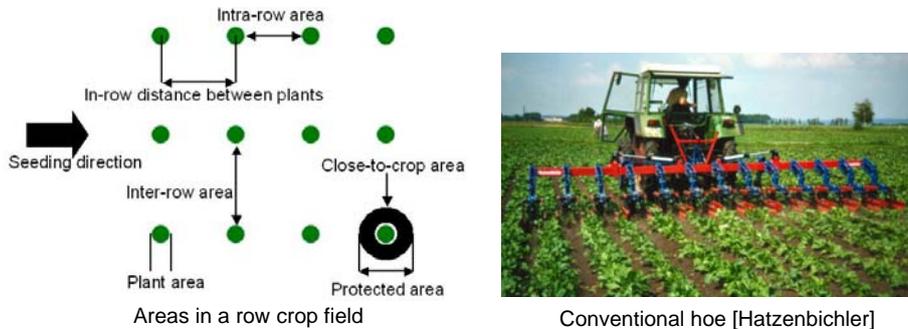
**Poverty line:
1,25\$ per
person per
day**

conclusion

- **Increasing world population**
- **Increasing energy consumption**
- **Increasing biofuel**
- **Change in dietary habits**
- **Decreasing arable land (desertification, ...)**

Increase of efficiency necessary





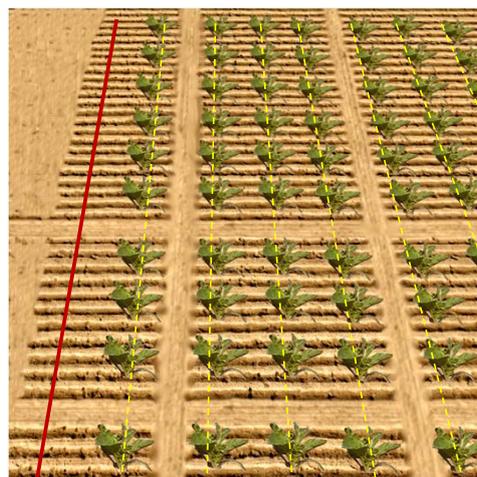
Conventional hoe [Hatzenbichler]

No problem: Inter-row area (~ 80% of the area)

PROBLEM: Intra-row area

controlled seed deposition

- longitudinal and lateral rows
- knowledge of each crop plant position
- seed map
- automated phenotyping techniques
- autonomous robotic weed control
- intra-row weeding

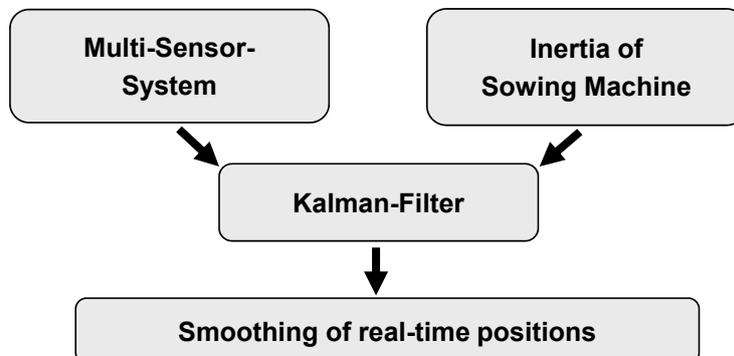


absolute reference spacing

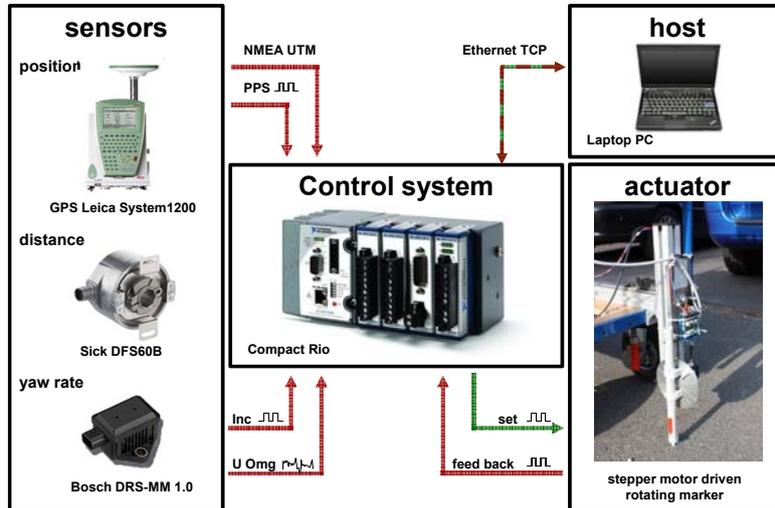


Kverneland Monopill SE (Kverneland)

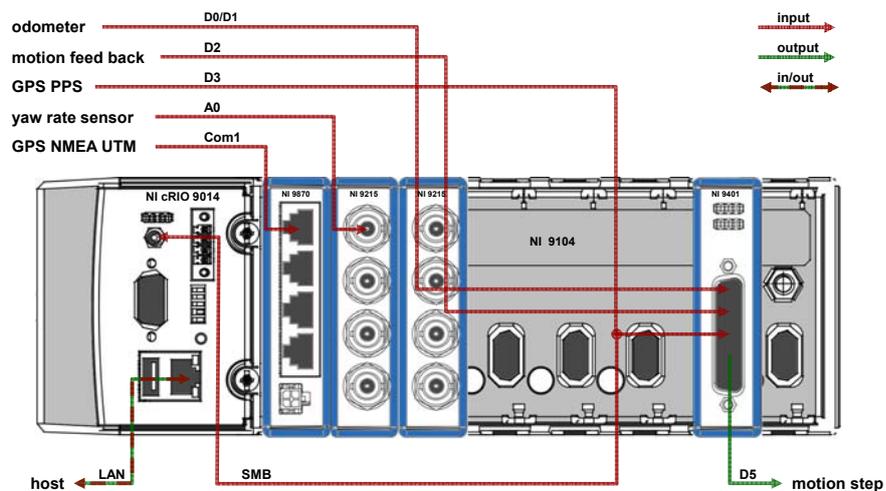
- Implementation in form of a special filter approach and a realisation of measurement acquisition
- Standard deviation with 1 cm at a velocity of 1,5 m/s under field conditions

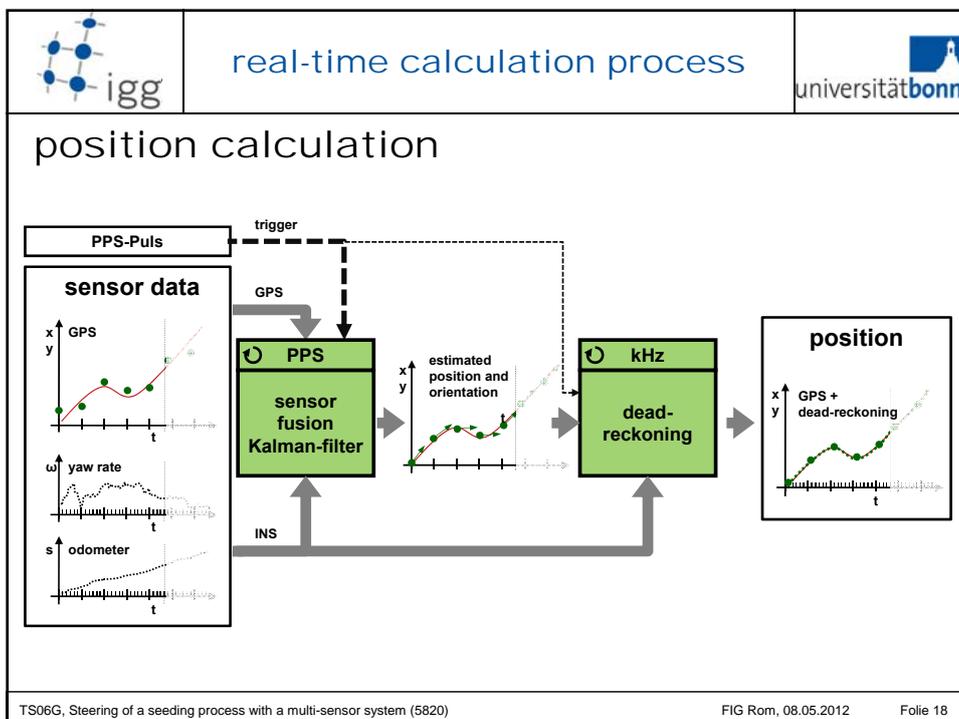
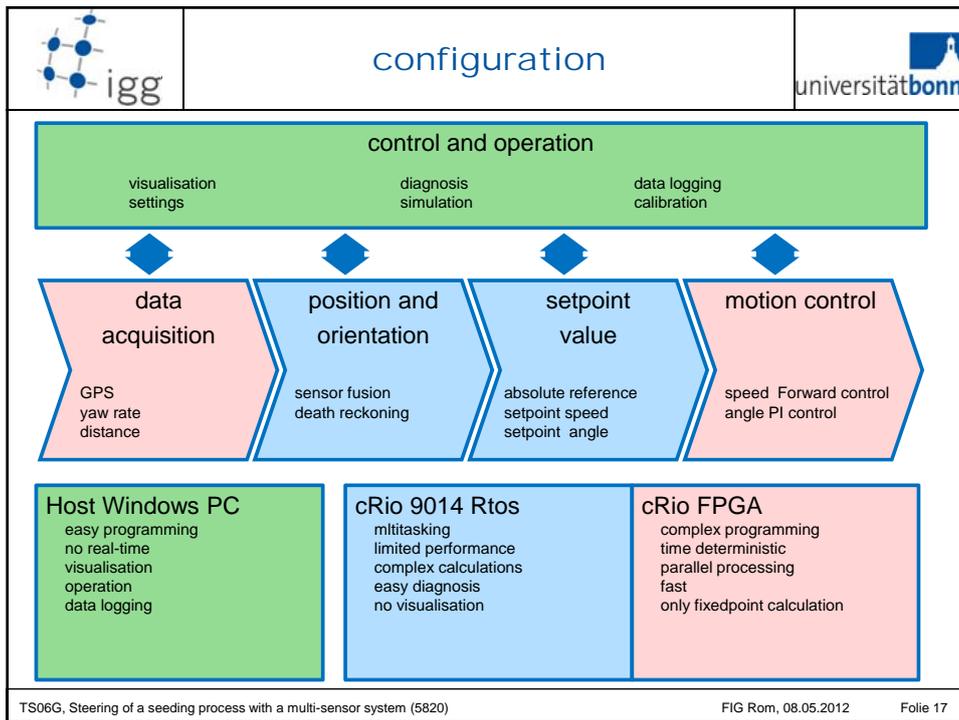


mobile platform



measurement and control hardware





Kalman filter cycle

system and measurement equation

$$X_{(k)} = T \cdot X_{(k-1)} + S \cdot w_{(k)}$$

$$L_{(k)} = A \cdot X_{(k)} + D$$

$$w_{(k)} = \begin{bmatrix} \alpha_{(k)} \\ d_{(k)} \end{bmatrix}$$

designmatrix

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 0 & 0 & \Delta t \end{bmatrix}$$

system noise coupling

$$S = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ \Delta t & 0 \\ 0 & \Delta t \end{bmatrix}$$

observation noise

$$Sll = \begin{bmatrix} \sigma_x & 0 & 0 & 0 \\ 0 & \sigma_y & 0 & 0 \\ 0 & 0 & \sigma_\phi & 0 \\ 0 & 0 & 0 & \sigma_\omega \end{bmatrix}$$

system noise

$$SwW = \begin{bmatrix} \sigma_w & 0 \\ 0 & \sigma_d \end{bmatrix}$$

While Δt			
input	$x_{(k)}, y_{(k)}$ $\Delta\phi_{(k)}, \Delta\omega_{(k)}$	$L_{(k)} = \begin{bmatrix} x_{(k)} \\ y_{(k)} \\ \Delta\phi_{(k)} \\ \Delta\omega_{(k)} \end{bmatrix}$	observation
	$\bar{X}_{(k)} = \begin{bmatrix} x_{(k)} \\ y_{(k)} \\ \phi_{(k)} \\ \omega_{(k)} \end{bmatrix} = \begin{bmatrix} x_{(k-1)} + v_{(k)} \cdot \Delta t \cdot \cos(\phi_{(k-1)}) \\ y_{(k-1)} + v_{(k)} \cdot \Delta t \cdot \sin(\phi_{(k-1)}) \\ \phi_{(k-1)} + \omega_{(k-1)} \cdot \Delta t \\ \omega_{(k-1)} \end{bmatrix}$		prediction
	$T_{(k)} = \begin{bmatrix} 1 & 0 & v_{(k)} \cdot \Delta t \cdot \sin(\phi_{(k-1)}) & 0 & \Delta t \cdot \cos(\phi_{(k-1)}) \\ 0 & 1 & v_{(k)} \cdot \Delta t \cdot \cos(\phi_{(k-1)}) & 0 & \Delta t \cdot \sin(\phi_{(k-1)}) \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$		
	$\bar{S}xx_{(k)} = T_{(k)} \cdot Sxx_{(k-1)} \cdot T_{(k)}^T + S \cdot SwW \cdot S^T$		
	$D_{(k)} = L_{(k)} - A \cdot \bar{X}_{(k)}$		innovation
	$Sdd_{(k)} = A \cdot \bar{S}xx_{(k)} \cdot A^T + Sll$		Kalman gain
	$K_{(k)} = \bar{S}xx_{(k)} \cdot A^T \cdot Sdd_{(k)}^{-1}$		update
	$X_{(k)} = \bar{X}_{(k)} + K_{(k)} \cdot D_{(k)}$ $Sxx_{(k)} = \bar{S}xx_{(k)} - K_{(k)} \cdot Sdd_{(k)} \cdot K_{(k)}^T$	output	
		$x_{(k)}, y_{(k)}, \phi_{(k)}$	

TS06G, Steering of a seeding process with a multi-sensor system (5820)
FIG Rom, 08.05.2012
Folie 19

dead-reckoning

```

while ms
  read FPGA: UOmega, nEncoder
  calc: dphi = f(UOmega)
       ds = f(nEncoder)
  Aphi += dphi
  Ax += ds cos(phi)
  Ay += ds sin(phi)
  As += ds
  PPS?
  true
  false
  set: x, y, Aphi, As
  AphiOld = Aphi
  AxOld = Ax
  AyOld = Ay
  Aphi = Ax = Ay = As = 0
  get: xe, ye, phi_e
  phi = phi_e + AphiOld + Aphi
  x = xe + AxOld + Ax
  y = ye + AyOld + Ay
  calc: set value
  phiMotion, omegaMotion = f(x, y)
  set FPGA: phiMotion, omegaMotion
  log: UOmega, nEncoder, x, y, ...

```

setpoint value

```

spacing, A, B, C
while ms
  get: x, y
  dist = Ax + By + C
  mdist = modul(dist, Spacing)
  phi = 2Pi * mdist / Spacing
  ddist = (dist - distold) / dt
  omega = ddist * DPhi / DSeed
  set FPGA: phiMotion, omegaMotion
  distold = dist

```

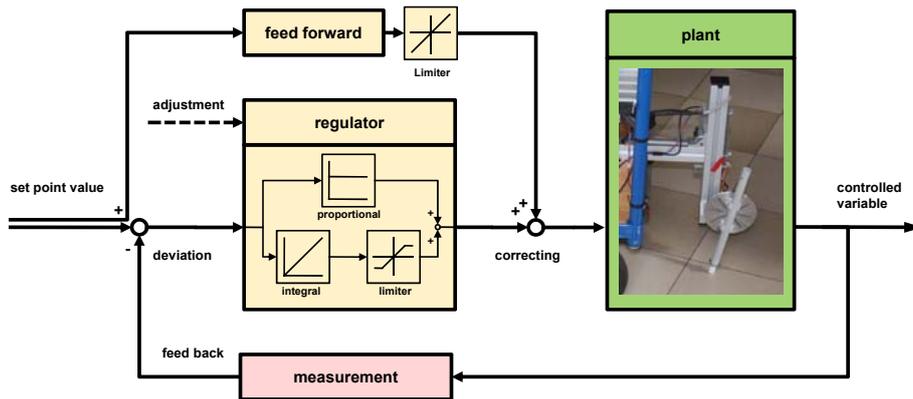
$$P1, P2 = A \cdot x + B \cdot y + C = 0$$

$$dist_{(k)} = A \cdot x_{(k)} + B \cdot y_{(k)} + C$$

TS06G, Steering of a seeding process with a multi-sensor system (5820)
FIG Rom, 08.05.2012
Folie 20

closed loop control

- PI-controller with feed forward
- motor angle feed back

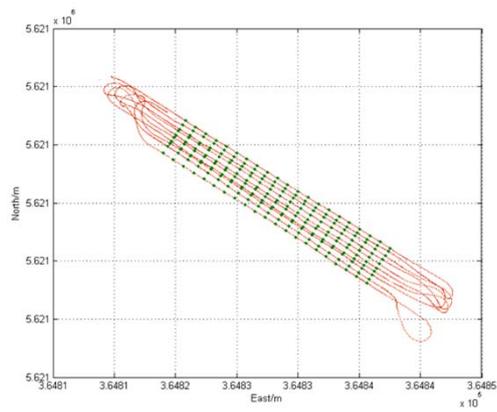


experiment

- speed 1m/s
- track length 18m
- spacing 1m
- 180 points
- diameter 5mm



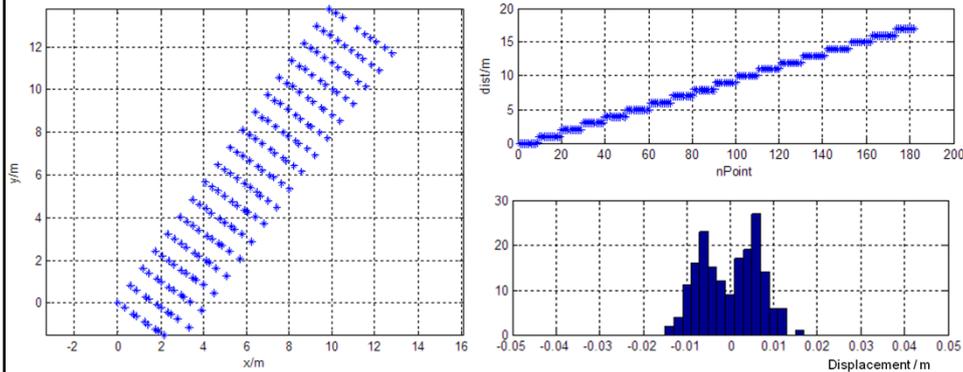
host application with actual position, track and seeding positions



seeding map with motion path in UTM coordinates

result

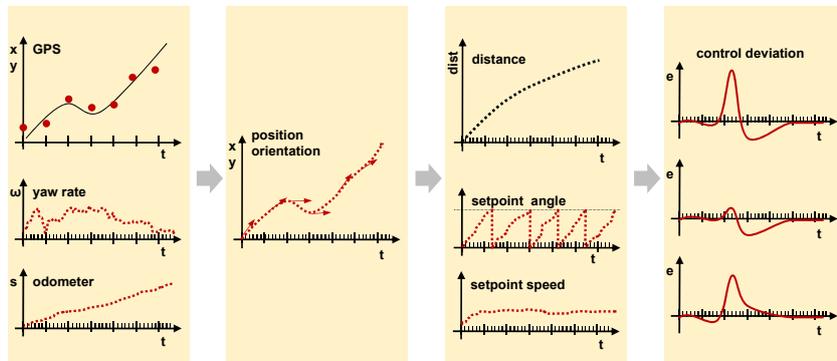
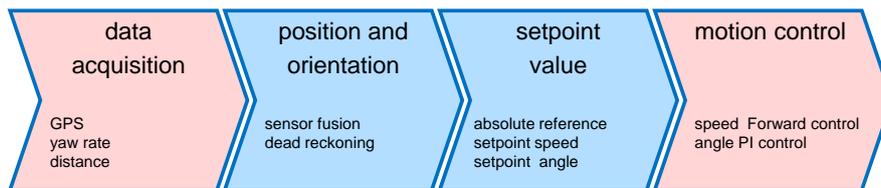
- surveyed with a Leica total station and prism pole
- eccentricity forward and backward track direction
- standard deviation less than 1cm was reached



TS06G, Steering of a seeding process with a multi-sensor system (5820)

FIG Rom, 08.05.2012

Folie 23



TS06G, Steering of a seeding process with a multi-sensor system (5820)

FIG Rom, 08.05.2012

Folie 24



- **the National Instruments hardware and software concept gives an opportunity to develop complex and fast measurement and control applications**
- **it is possible to process the position with high accuracy just in time with a reliable RTK-GPS position and low cost inertial sensors in a Kalman filter**
- **a standard deviation of less than 1cm was reached so that it is possible to create lateral rows in the field for the weed control like intra-row weeding**
- **development system gives the opportunity to create additional applications like taking precise georeferenced photos of defined objects with orientation**