Agricultural tools guidance assistance by using machine vision
Why to assist agricultural tools guidance?

- The classical method for sugarbeet and chicory:
Why to assist agricultural tools guidance?

- The classical method for sugarbeet and chicory:

![Diagram showing agricultural tools guidance]

- Harvesting
- Drilling

6 shares

Previous furrow

New furrow

6, 8, 12, 16, 18, 24 rows
Why to assist agricultural tools guidance?

- The classical method for sugarbeet and chicory:

![Diagram showing agricultural tools](image)

- Harvesting
- Drilling
- New furrow
- Previous
- 6 shares
- 6, 8, 12, 16, 18, 24 rows
Why to assist agricultural tools guidance?

- A recent methods for sugarbeet and chicory:

  Previous furrow

  6, 8, 12, 16, 18, 24 rows

  New furrow

  Harvesting

  Drilling

6 shares

8 shares
Why to assist agricultural tools guidance?

- New methods for sugarbeet and chicory:
  - 8 row width instead of 6
- Requirements:
  - Precision during drilling
  - Guidance of the harvesting shares
The general regulation

\[
\begin{align*}
\hat{x}_{br}(\hat{\alpha})_k &= \text{Signal treatment} \\
\text{Regulation} &\rightarrow \text{Process} \\
\text{Target position}^+ &\rightarrow dx \\
\text{Process noise} &\rightarrow \text{True position} \\
\text{Measurement noise} &\rightarrow \text{Measurement} \\
\end{align*}
\]
The devices

• The seed drill

*Seed drill*

*Frame controlling the lateral movements*

*Camera*

*Previous seed rows*
The devices

- The harvesting shares

Camera

Chicory rows after topper
The measurement

• Image acquisition and treatment

  – Sowing:
    • straight lines ➔ Hough transform
    • important noise
    • shadows
    • lures ➔ adapted image treatment ➔ adapted Hough transform
The measurement

- Image acquisition and treatment
  - Extraction of the green channel
  - Resizing
  - Gaussian filtering
The measurement

- Image acquisition and treatment
  - resizing
    → background
The measurement

- Image acquisition and treatment
  - background subtraction
    - noise ±
    - shadows √
    - lures ×
The measurement

- Image analysis

Classical Hough transform

The « Hough space »

Reference point: projection line
integration direction

, + : theoretical position
, . : true position
The measurement

- Image analysis

Classical Hough transform

The "Hough space"

Reference point: projection line
: integration direction
+ : theoretical position
. : true position
The measurement

- Image analysis
The measurement

• Image analysis

\[ \alpha, r \]
The measurement

• The harvest of chicory

  – wide variety of colours in the “objects” (roots, petioles, flesh) and in the background (soil of different humidity, tire, wheel, rests of leaves, weeds, ...)
  → classification of the pixels using a neural network

  – use of the adapted Hough transform
The measurement

- The harvest of chicory
The measurement

- The harvest of chicory
The measurement

- The harvest of chicory
The signal treatment
The signal treatment

- $a$ and $r$ were used as independent state variables:

$$
\begin{pmatrix}
\alpha_e \\
r_e
\end{pmatrix}_k =
\begin{pmatrix}
a_{\alpha} & 0 \\
0 & a_r
\end{pmatrix}
\begin{pmatrix}
\alpha_m \\
r_m
\end{pmatrix}_k +
\begin{pmatrix}
1-a_{\alpha} & 0 \\
0 & 1-a_r
\end{pmatrix}
\begin{pmatrix}
\alpha_e \\
r_e
\end{pmatrix}_{k-1} +
\begin{pmatrix}
0 \\
dr_r
\end{pmatrix}_{k-1}
$$

The noise was not white nor Gaussian

$$
a_{\alpha} = c_{\alpha} \exp\left( -\frac{\left[ \left( \alpha_e \right)_{k-1} - \alpha_m \right]^2}{s_{\alpha}^2} \right)
$$

$$
a_r = c_r \exp\left( -\frac{\left[ \left( r_e + dr_r \right)_{k-1} - r_m \right]^2}{s_r^2} \right)
$$
The regulation and the process

- \( v = p \cdot t + q \Rightarrow \frac{dt_r'}{dt_r''} = \frac{-q \pm \sqrt{(q^2 + 4p \cdot dx)}}{2 \cdot p} \)

- The electro–hydraulic mechanism transforms \( dt \) into \( dx \)
The field tests

- The experimental set up:
The field tests

- Seed drill guidance:
  - 3 tests with “straight driving style”
    - 2 with sunny conditions
    - 1 with cloudy conditions
  - 2 tests with “sinusoidal driving style”
    - both with sunny conditions

- During harvest:
  - 1 “straight” test, 1 sinusoidal test, both in cloudy conditions
## Results

### Sowing

<table>
<thead>
<tr>
<th>Test Description</th>
<th>$s_T$</th>
<th>$A_T$</th>
<th>$m_D$</th>
<th>$s_D$</th>
<th>$A_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, straight, sunny</td>
<td>75.1</td>
<td>295</td>
<td>459</td>
<td>19.4</td>
<td>91</td>
</tr>
<tr>
<td>2, sinusoidal, sunny</td>
<td>102</td>
<td>340</td>
<td>448</td>
<td>29</td>
<td>115</td>
</tr>
<tr>
<td>3, straight, sunny</td>
<td>81</td>
<td>245</td>
<td>523</td>
<td>13</td>
<td>60</td>
</tr>
<tr>
<td>4, sinusoidal, sunny</td>
<td>55</td>
<td>301</td>
<td>516</td>
<td>35</td>
<td>140</td>
</tr>
<tr>
<td>5, straight, cloudy</td>
<td>54</td>
<td>180</td>
<td>390</td>
<td>17</td>
<td>95</td>
</tr>
</tbody>
</table>

### Harvesting

<table>
<thead>
<tr>
<th>Test Description</th>
<th>$s_T$</th>
<th>$A_T$</th>
<th>$s_D$</th>
<th>$A_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, straight, cloudy</td>
<td>19</td>
<td>65</td>
<td>17</td>
<td>55</td>
</tr>
<tr>
<td>2, sinusoidal, cloudy</td>
<td>67</td>
<td>260</td>
<td>44</td>
<td>175</td>
</tr>
</tbody>
</table>
Results

• Field measurements

Straight
\( s_T = 75, A_T = 295 \)
\( s_D = 19, A_D = 91 \)

Sinusoidal
\( s_T = 102, A_T = 340 \)
\( s_D = 29, A_D = 115 \)
Results

- Histograms

Straight
\[ s_T = 75, A_T = 295 \]
\[ s_D = 19, A_D = 91 \]

Sinusoidal
\[ s_T = 102, A_T = 340 \]
\[ s_D = 29, A_D = 115 \]
Results

- Frequencies

![Graphs showing frequency and amplitude relationships for straight and sinusoidal cases.](image)

**Straight**

- Frequency of tractor’s position: $s_T = 75$, $A_T = 295$
- Frequency of drill’s position: $s_D = 19$, $A_D = 91$

**Sinusoidal**

- Frequency of tractor’s position: $s_T = 102$, $A_T = 340$
- Frequency of drill’s position: $s_D = 29$, $A_D = 115$
Results

- Frequencies

![Graph showing frequencies of tractor's and drill's position](image-url)
Results

- Computer data & field measures
Results

• Computer data: filtered vs non filtered data
Conclusion

• Trueness (< 30 mm) depends on
  - the mounting of the camera
  - trace aspect

• Precision
  - 23 mm for seed–drill
  - 31 mm for harvesting

• Spatial cutting frequency : 0.14 m\(^{-1}\)
Conclusion

- Accurate mounting of the camera is required for