# Chapter 17

## UNI EN ISO 9283 industrial robots: performance criteria and related tests methods

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# UNI ISO EN 9283

- technical standard (voluntary application, useful)
- define the meaning of some parameters describing the robot performances (e.g. accuracy, repeatability, stabilization time…)
- standardizes the procedure to measure them

# aim of the standards

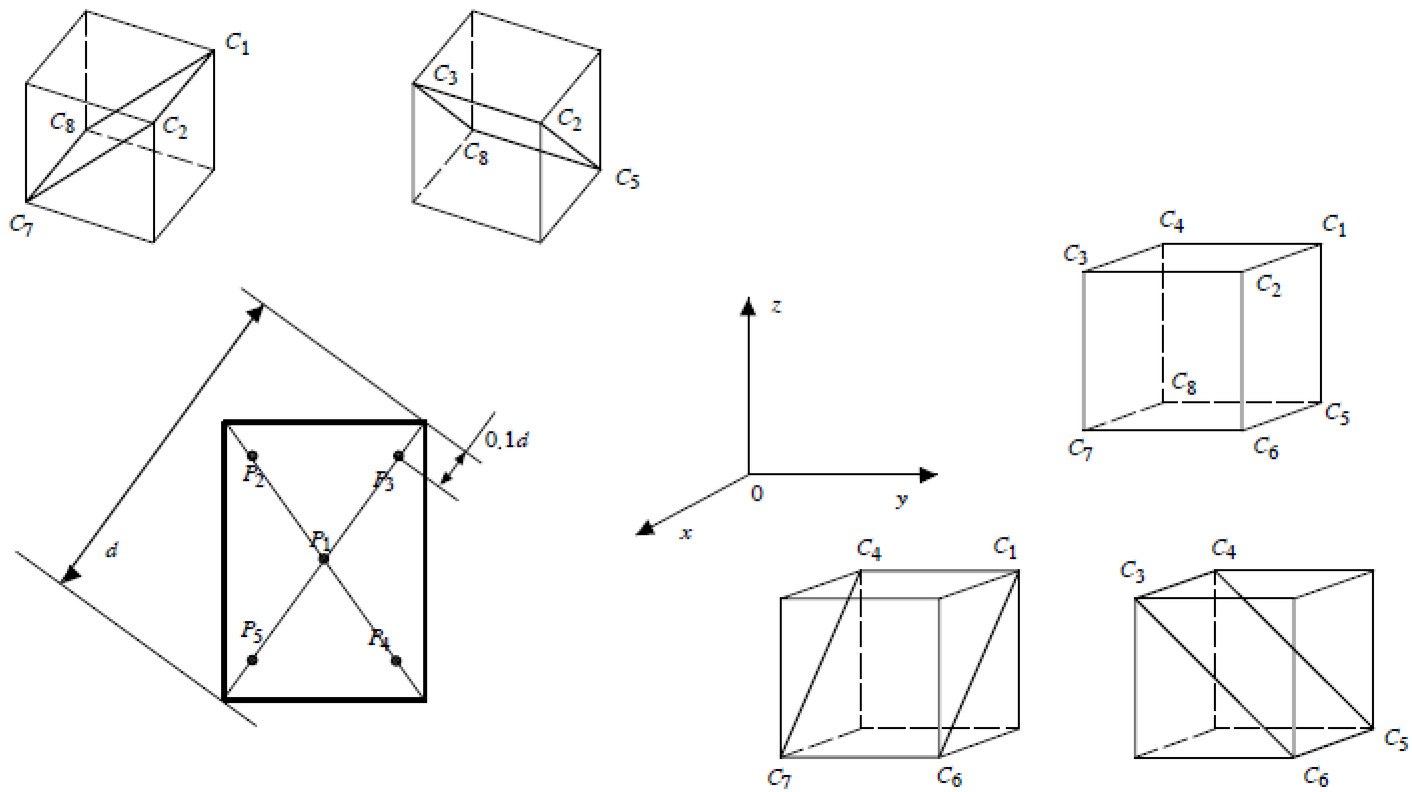
- highlight the major kinematics or dynamic performances of robots
- method: statistics. The performances depend on many factors (robot position, velocity, load… so standard parameters are defined and tests are performed on standard predefined conditions)

# some basic concept

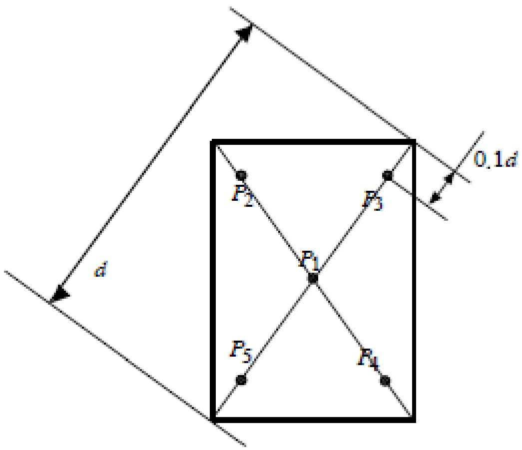
- robot under test must be prepared according to manufacturing instruction
- robot must be in standard condition similar to those of normal use
- possibly use non contact measure
- the precision of the sensor and instrumentation must be better than 25% of the values to be certified

# tests to be performed in some of the 5 predefined points $P_1$, $P_2$, $P_3$, $P_4$, $P_5$

- biggest cube with sides parallel to base axis xyz
- choose one of the 4 planes indicated



# for each test the points to be used are indicated by the standard




| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ |
|---|---|---|---|---|---|
| accuratezza e ripetibilità unidirezionali | # | # | # | # | # |
| variazione di accuratezza multidirezionale | # | # | | # | |
| distanza | | # | | # | |
| tempo di stabilizzazione del posizionamento | # | # | # | # | # |
| overshoot | # | # | # | # | # |
| deriva | # | | | | |

# standard conditions

- for each test standard condition of test are indicated, e.g.:
  25%, 50%, 100% of velocity
  25%, 50%, 100% of load

# position errors

- ***Command pose (or commanded)***:
  pose the robot is required to reach
- ***Response pose (or reached)***:
  effectively pose reached

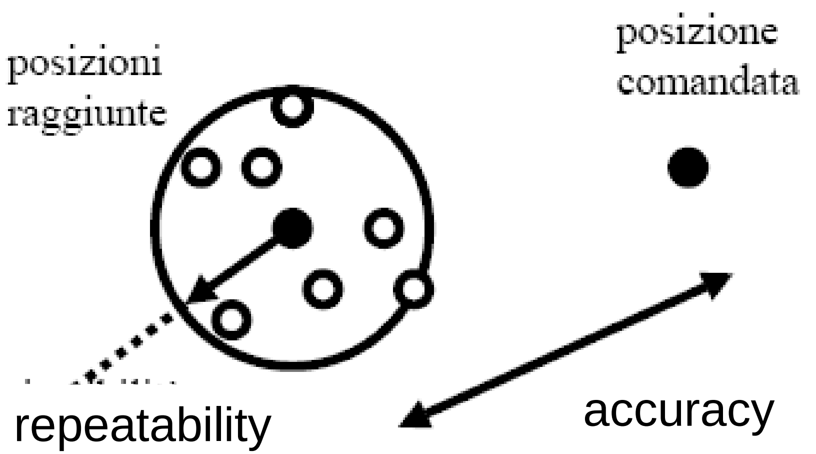



Figura 1.17 Accuratezza e ripetibilità di un robot.

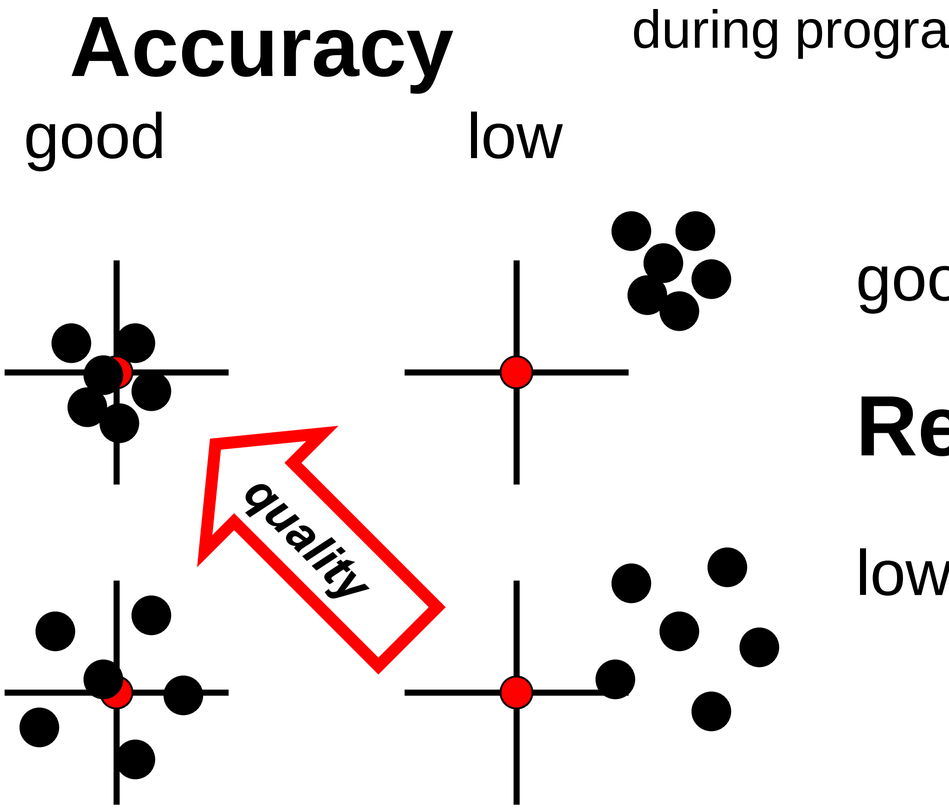
***Repetitive errors***:
geometric, constructive or assembling errors, thermal dilatations, constant deformations loads

***Variable error (random)***:
backlash, transducers' resolution, deformation caused by variable loads, ...

- ***Accuracy***: capability of reaching a required position
- ***Repeatability***: capability of a robot of coming back to the same pose

# Accuracy and repeatability (1)

generally robot have **good repeatability**,
(absolute) **accuracy can be low** ->
-> calibration or program adjustment
during programming may be necessary



# accuracy and repeatability (2)

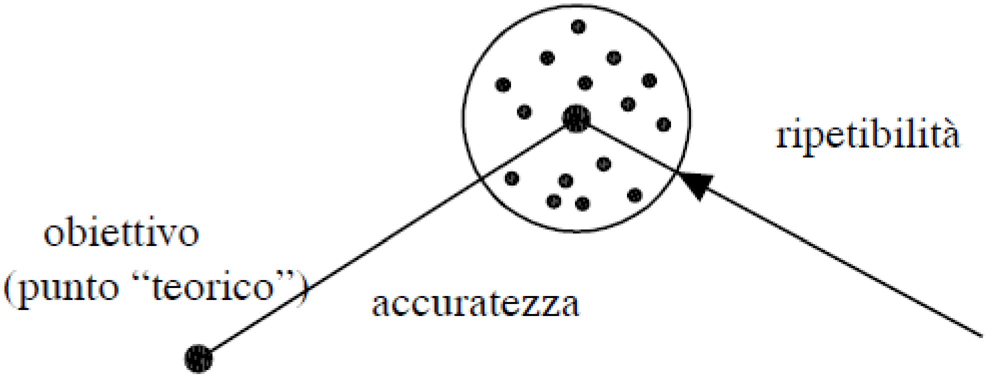



**Figura 17.2** Ripetibilità e accuratezza.

test based on 30 cycles in one of the two indicated sequences (user choice)

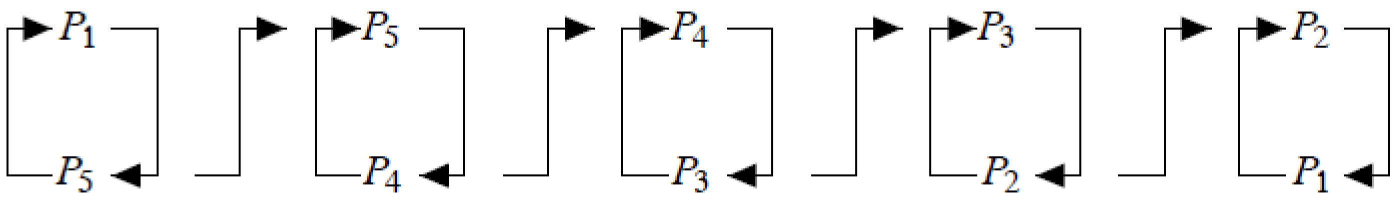



**Figura 17.4** Misura di ripetibilità e accuratezza per posizionamento unidirezionale: percorso 2

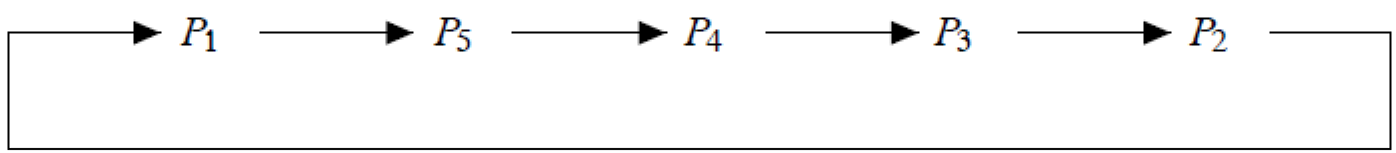



**Figura 17.3** Misura di ripetibilità e accuratezza per posizionamento unidirezionale: percorso 1

# accuracy and repeatability (3)

center of the “clouds of points”

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i; \qquad \bar{y} = \frac{1}{n} \cdot \sum_{i=1}^{n} y_i; \qquad \bar{z} = \frac{1}{n} \cdot \sum_{i=1}^{n} z_i;$$

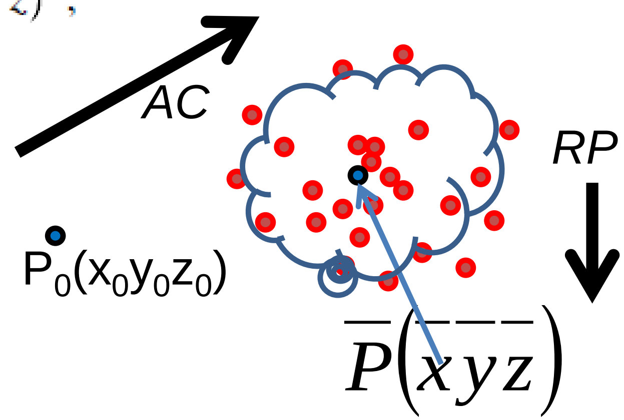
$$\boxed{n = 30}$$

accuracy *AC*

$$AC = \sqrt{(x_0 - \bar{x})^2 + (y_0 - \bar{y})^2 + (z_0 - \bar{z})^2};$$

$x_0$, $y_0$, $z_0$ commanded position

$x_i$, $y_i$, $z_i$ reached position




$$d_i = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2 + (z_i - \bar{z})^2}; \qquad \bar{d} = \frac{1}{n}\sum^{n} d_i$$

repeatability *RP*

$$RP = \bar{d} + 3\sigma \qquad \sigma = \sqrt{\sum_{i=1}^{n} \frac{(d_i - \bar{d})^2}{n-1}}$$

RP is a sort of «equivalent radius» of the cloud containing the reached points

# important issues

- the measures must be performed after the robot had the time to stabilize its position
- Limit:
  The “theoretically true” position is difficult to be verified→ the robot must be placed in this position under the operator responsibility → the “accuracy” may be badly estimated → some brand does not declare the accuracy
- The distance error give an idea of the accuracy

# error on distances

$$AC = \|d_m - d_v\| \qquad RP = 3\sigma_d$$

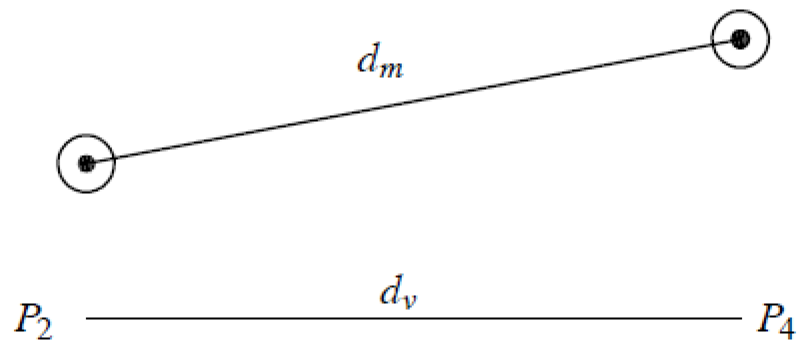
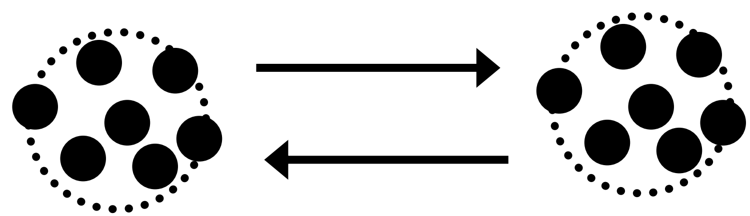



**Figura 17.6** Accuratezza e ripetibilità di distanza.



# variation of accuracy for multidirectional positioning

- one point is reached by three different directions xyz and the three “clouds” of attained positions are created

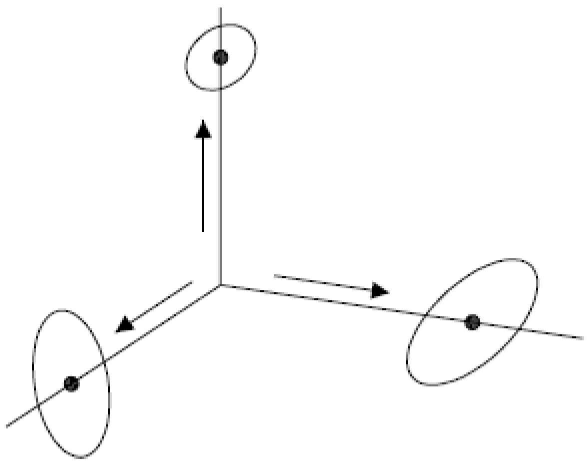


Figura 17.5 Variazione di accuratezza per posizionamento multidirezionale.

the maximum distance between “clouds” is evaluated

# stabilization time

- the time from when the robot says “I have arrived” to the time at which it enters in the band of accepted tolerance without exiting from it

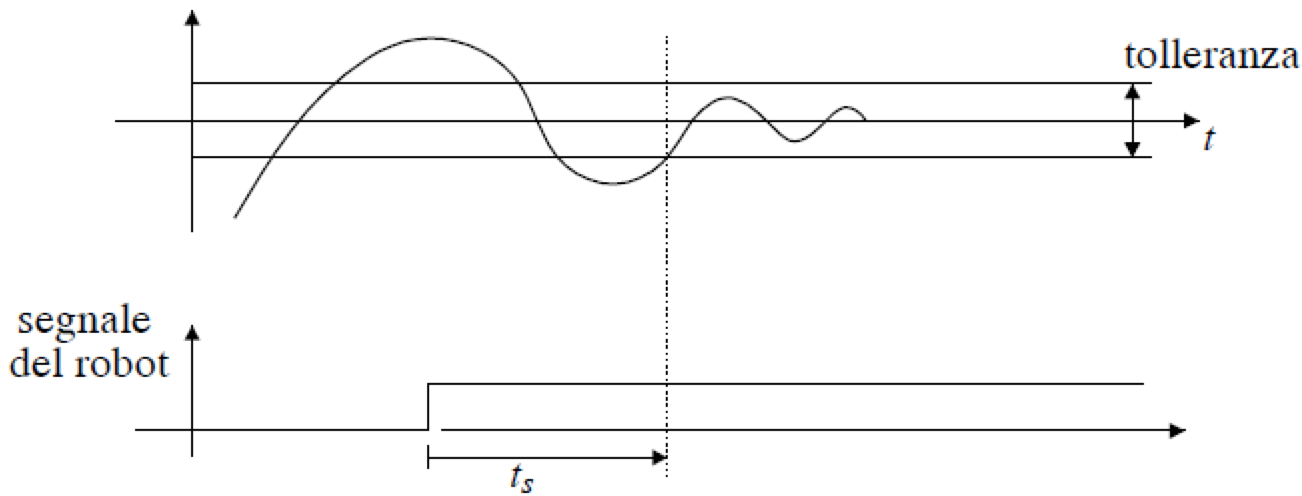



**Figura 17.7** Tempo di stabilizzazione.

# overshoot

- maximum position error from the time when the robot says “I have arrived”

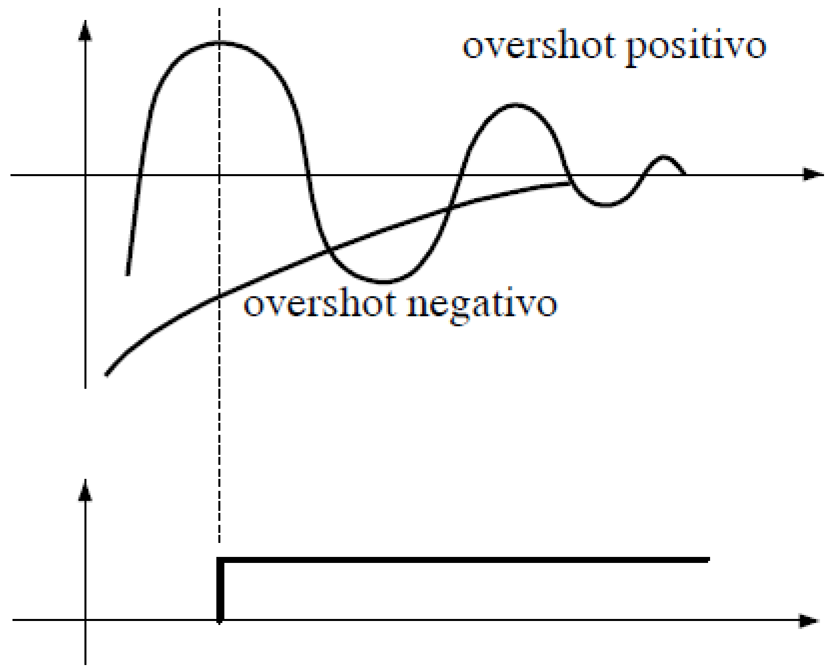



**Figura 17.8** Sovraelongazione di posizionamento.

# variability of parameters with time

the robot is requested to perform some working cicle. At fixed interval of time, it task is interrupted and the required test is performed. Data are displayed by graphical representation

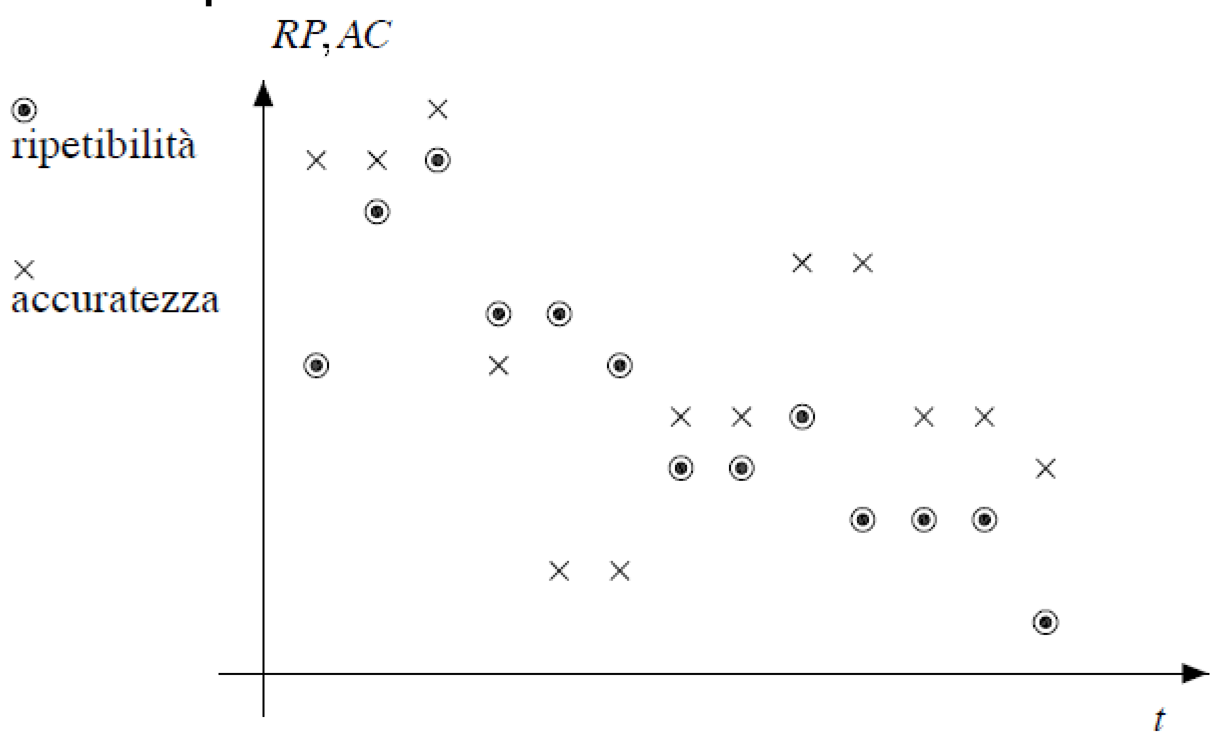



**Figura 17.10** Rappresentazione della deriva temporale degli errori di posizionamento.

# trajectory error

- Pt theoretical position
- Pr real position
- P projection of Pr on trajectory
- |P-Pr| trajectory error

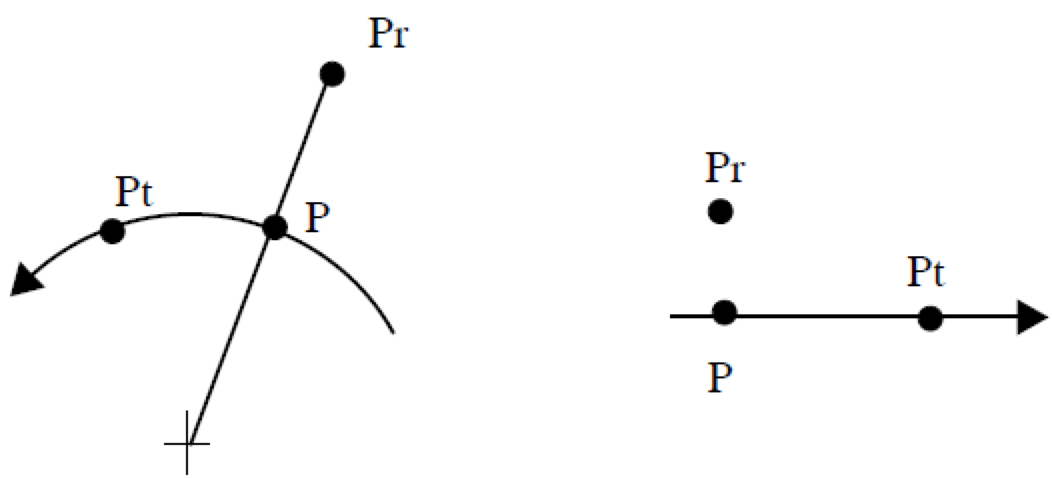
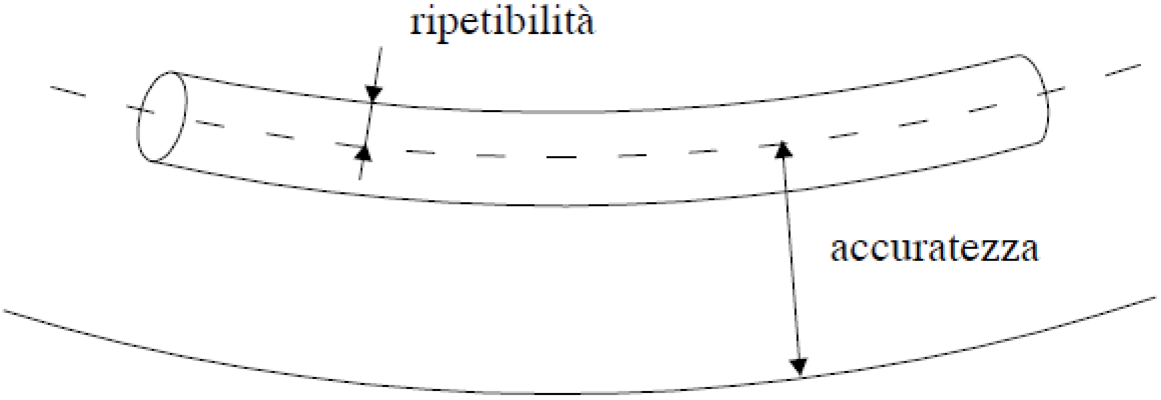



**Figura 17.12** Definizione di errore di traiettoria $e_t = \|P_r - P\|$ (casi di traiettorie circolare e lineare).

# trajectory accuracy and repeatability



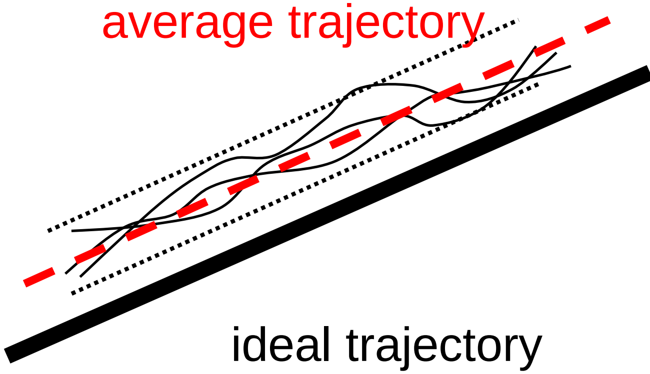




**Figura 17.11** Accuratezza e ripetibilità di esecuzione di traiettorie.

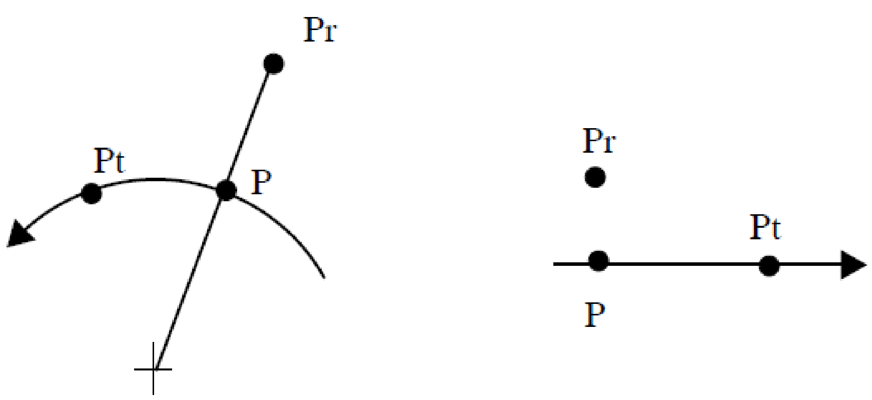



**Figura 17.12** Definizione di errore di traiettoria $e_t = \|P_r - P\|$ (casi di traiettorie circolare e lineare).

# deviation from corners, overshoot

## in trajectories with corners

- deviation from corner: minimum distance of the trajectory from the corner

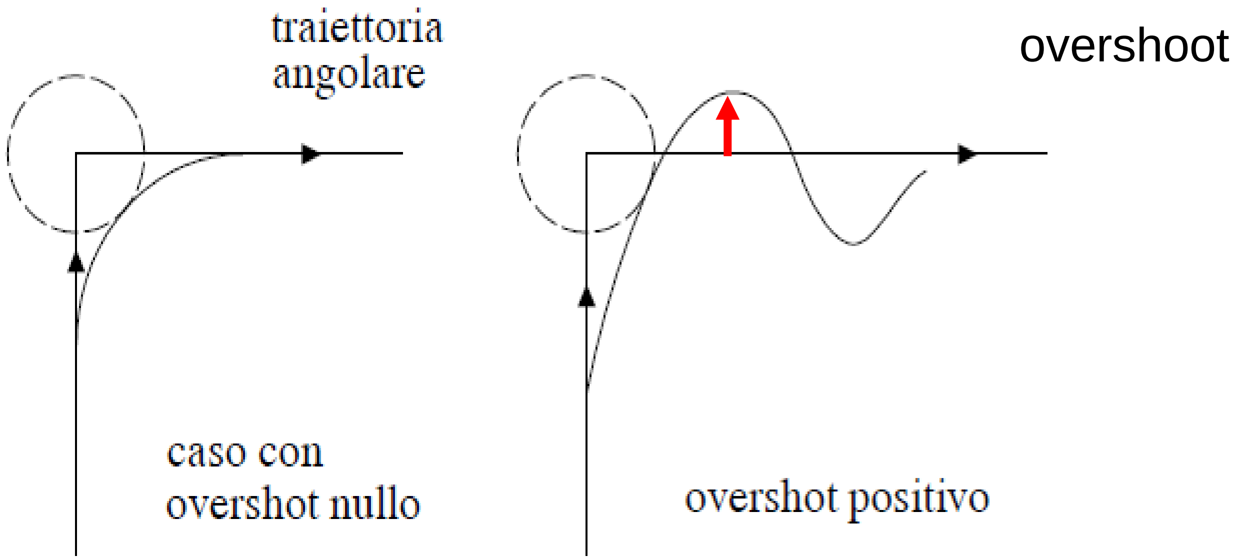



**Figura 17.13** Overshoot e deviazione in percorsi con angoli.

# velocity error

- accuracy and repeatability of the velocity

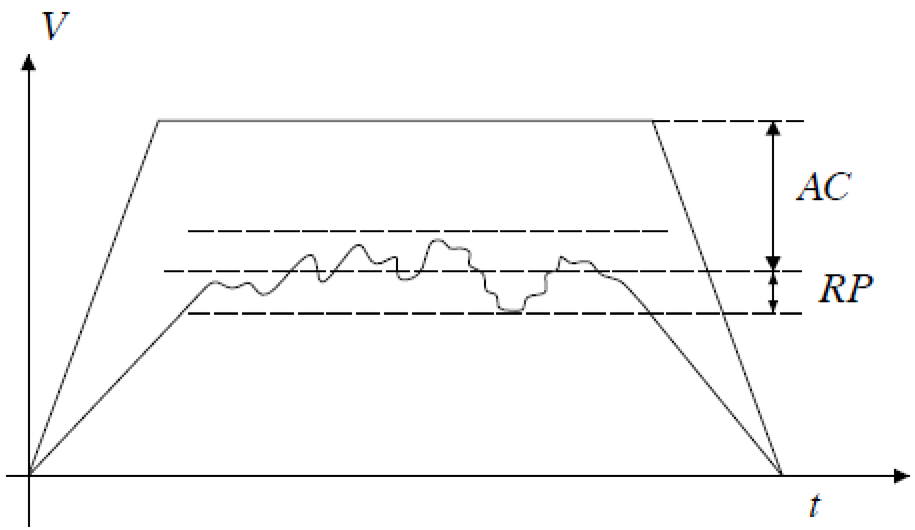



**Figura 17.14** Accuratezza e ripetibilità della velocità.