UNISINOS

PIP/CA - ***Programa Interdisciplinar de Pós-Graduação***
Mestrado em Computação Aplicada da UNISINOS

2000/2 - 3o. Trimestre - AULA 01 / FSO

CONTROLE
&
ROBÓTICA INTELIGENTE

- **Professor Responsável:**

Prof. Dr. Fernando Osório

E-Mail: ***osorio@exatas.unisinos.br***
Web: ***http://www.inf.unisinos.br/~osorio/robi.html***

TEMAS DE ESTUDO: ***CONTROLE E ROBÓTICA INTELIGENTE***

Robôs Móveis Autônomos:

- **Robótica Autônoma - Robótica Inteligente: Conceitos básicos**
- **Robôs Móveis: Tipos, características e aplicações**
  AGV, Autônomo, Holonomic, Non-Holonomic, Artificial Life
  Khepera/Nomad Like, Car/Rover Like, Ant Like, Walking Machines

- **Sensores: Tipos, características, integração**
- **Atuadores: Tipos, características, integração sensor-atuador**
- **Controle Deliberativo: Path Planning**
  Local *x* Global Planning, Mapas Exatos *x* Aproximados
  Occupation Grid / Cell Decomposition,
  Road Map (Visibility Graph, Voronoi Diagram, Fuzzy / Probabilistic Maps),
  Potential Fields: Atração e Repulsão, Busca do Mínimo (local *x* global)
  Máquina de Estados - Finite State Automata, Petri Nets
  > Problema do Posicionamento

TEMAS DE ESTUDO: *CONTROLE E ROBÓTICA INTELIGENTE*

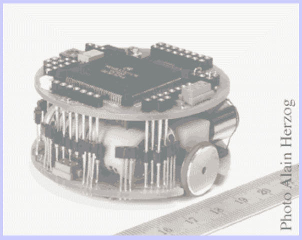
Robôs Móveis Autônomos:

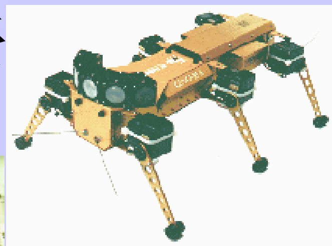
- **Controle Reativo: Sensorial-Motor**
  - Evitar colisões
  - Seguir Muros => Integração de múltiplos comportamentos
  - Seguir Luz
- **Controle Adaptativo: Aprendizado**
  - Reinforcement Learning / Q-Learning
  - Redes Neurais Artificiais
  - Algoritmos Genéticos
- **Controle Hierárquico: Brooks Subsumption**
- **Controle Híbrido:**
  - Interação entre módulos
  - Transferência de conhecimentos e dados
  - Robustez

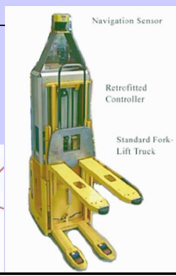
ROBÔS:

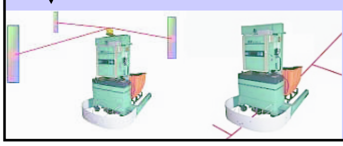
- **Robótica Autônoma - Robótica Inteligente: Conceitos básicos**
- **Robôs Móveis: Tipos, características e aplicações**

AGV
Autônomo
Holonomic
Non-Holonomic
Artificial Life
Khepera/Nomad Like
Car/Rover Like
Ant Like
Walking Machines
Indoor / Outdoor







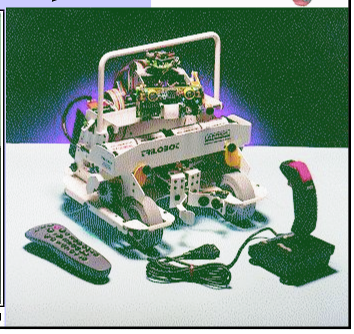


ROBÔS:

•Robótica Autônoma - Robótica Inteligente: Conceitos básicos

• Robôs Móveis: Tipos, características e aplicações

- AGV
- Autônomo
- Holonomic
- Non-Holonomic
- Artificial Life
- Khepera/Nomad Like
- Car/Rover Like
- Ant Like
- Walking Machines



ROBÔS:

•Robótica Autônoma - Robótica Inteligente: Conceitos básicos

• Robôs Móveis: Tipos, características e aplicações

Tipos:

* Terreno / Ambiente
* Locomoção
* Cinemática / Pilotagem
* Forma
* Dependência externa
* Grau de autonomia
* Robustez
* Tempo de resposta
* Custo / Complexidade

ROBÔS:

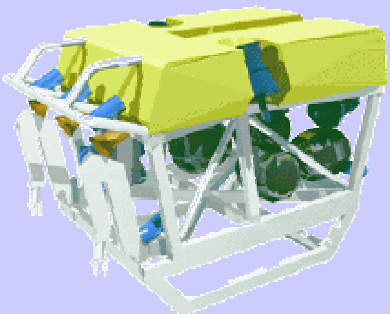
- **Robótica Autônoma - Robótica Inteligente: Conceitos básicos**
- **Robôs Móveis: Tipos, características e aplicações**

Aplicações: Robótica exploratória (vulcões)

F. OSÓRIO - UNISINOS 2000

ROBÔS:

- **Robótica Autônoma - Robótica Inteligente: Conceitos básicos**
- **Robôs Móveis: Tipos, características e aplicações**



Aplicações: Robótica submarina

F. OSÓRIO - UNISINOS 2000

ROBÔS:

• **Robótica Autônoma - Aplicações:**

- *Robótica Submarina*: Advocate Esprit Project. Web: http://advocate.e-motive.com/
- *Autonomous Land Vehicle* In a Neural Network Project - D. Pormerleau; T. Jochem, CMU. Web: http://www.cs.cmu.edu/afs/cs/project/alv/member/www/projects/ALVINN.html
- *Chernobyl Robot*. Web: http://www.robotbooks.com/Chernobyl-robot.htm
- *Volcano / Dante II* - Nasa Project. Web: http://img.arc.nasa.gov/Dante/dante.html
- *DeTeC - Demining* Tech. Center. Web: http://diwww.epfl.ch/w3lami/detec/detec.html
- *Honda Humanoid* Robot. Web: http://www.honda.co.jp/english/technology/robot/
- *Khepera (Research)*. Web: http://diwww.epfl.ch/lami/team/michel/khep-sim/
- *Mars Rover* Research - MIT. Web: http://www.ai.mit.edu/projects/mars-rovers/
- *Carros autônomos* - Praxitele Project. Web: http://www-rocq.inria.fr/praxitele/cabby.html http://www.inrialpes.fr/sharp/ http://www.inrialpes.fr/sharp/publications/bibsharp/adt.html
- *Mars Rover* - Sojourner. Web: http://mpfwww.jpl.nasa.gov/rover/about.html

>> Veja também... Introduction to Mobile Robots - Alonzo Kelly

http://www.frc.ri.cmu.edu/~alonzo/pubs/pubs.html ou /~alonzo/course/course.html

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Tipos de Sensores:**

Distância: **Luz, Som, Força**

- **Infra-Vermelho**
- **Sonar (ultrasom) e Radar**
- **Laser**
- **Câmeras de Vídeo - Linear / Matricial, Mono ou Binocular**
- **Sensor de contato (bumpers, antenas)**

Posicionamento e Orientação

- **GPS**
- **Bússolas**
- **Giroscópio**
- **Odômetros**
- **Faróis (ex. rádio) ou Câmera de Vídeo**

Outros Componentes

> Medidor de carga da bateria
> Temperatura, Pressão
> Umidade
> Fumaça, Odores, etc.

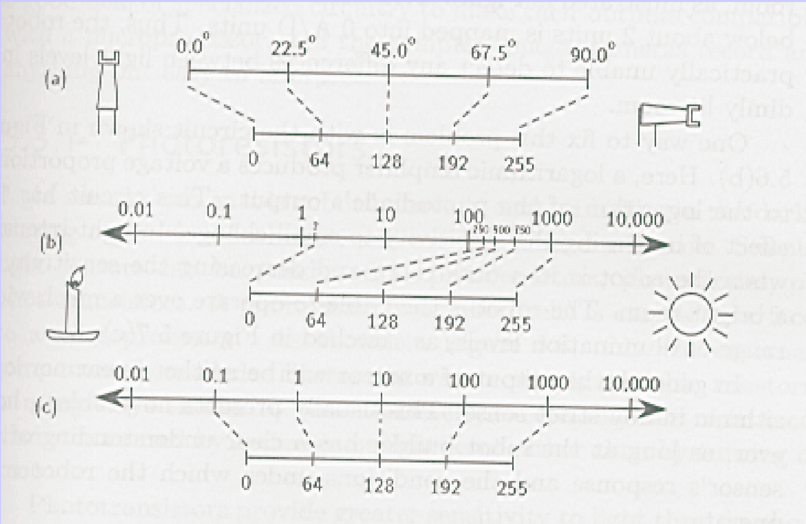
• **Referências:**

Heinen, Farlei. "Robótica Autônoma: Integração entre Planificação e Comportamento Reativo". Unisinos

Borenstein, J.; Everett, H.; Feng, L. "Where am I? Sensors and Methods for Mobile Robot Positioning". Univ. of Michigan, Oak Ridge Lab. 1996. Http://www-personal.engin.umich.edu/~johannb/

Kelly, Alonzo. "Introduction to Mobile Robots" (Perception). Robotics Institute - CMU. 1996. Http://www.frc.ri.cmu.edu/~alonzo/course/course.html

• **Sensibilidade e Intervalo de Valores...**



ROBÓTICA AUTÔNOMA: SENSORES

• **Características dos Sensores: Infra-Vermelho**

3.1 The Khepera miniature robot

3.1.1 Overview

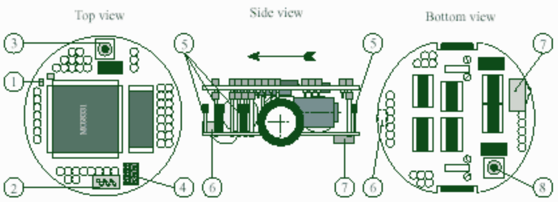


Figure 2: Position of some parts of the robot.

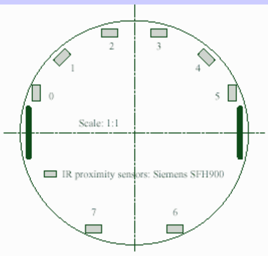


Figure 8: Position of the 8 IR sensors.

Make an external inspection of the robot.

1. LEDs
2. Serial line (S) connector.
3. Reset button.
4. Jumpers for the running mode selection.
5. Infra-Red proximity sensors.
6. Battery recharge connector.
7. ON - OFF battery switch.
8. Second reset button (same function as 3).

These sensors embed an infra-red light emitter and a receiver. For more information about these particular devices, please refer to the documentation of the sensor manufacturer. The exact part name is SFH900-2 and the manufacturer is SIEMENS.

This sensor device allows two measures:

- The normal ambient light. This measure is made using only the receiver part of the device, without emitting light with the emitter. A new measurement is made every 20 ms. During the 20 ms, the sensors are read in a sequential way every 2.5 ms. The value returned at a given time is the result of the last measurement made.
- The light reflected by obstacles. This measure is made emitting light using the emitter part of the device. The returned value is the difference between the measurement made emitting light and the light measured without light emission (ambient light). A new measurement is made every 20 ms. During the 20 ms, the sensors are read in a sequential way every 2.5 ms. The value returned at a given time is the result of the last measurement made.

The output of each measurement is an analogue value converted by a 10 bit A/D converter. The following two sections (3.1.6.1 and 3.1.6.2) illustrate the meaning of this 10 bit values.

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Características dos Sensores: Infra-Vermelho**

Sensibilidade a luz ambiente

Distância: 50 a 500mm (aproximadamente)

Valor lido: 0..450 (aproximadamente)

Dependente de: Potência = 1 Watt

Ângulo = -180 a +240 graus

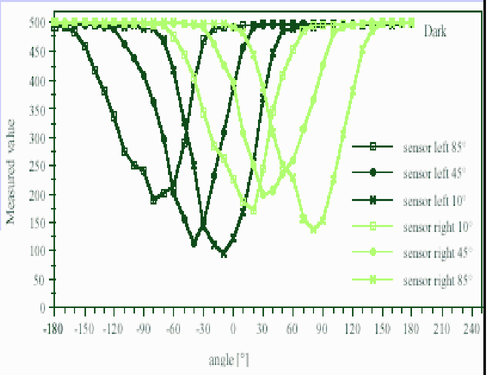
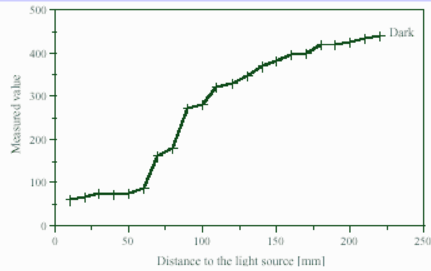


Figure 10: Typical measurement of the ambient light with a light source moving around the robot. The angle on the X axis is measured between the forward direction of the robot and the direction of the light.



Typical measurement of the ambient light versus the distance of a light source of 1 Watt.

As it can be seen, the measured value decreases when the intensity of the light increases. The standard value in the dark is around 450.

The measurement of the ambient light versus the angle between the forward direction of the robot and the direction of the light has the shape illustrated in figure 10.

Resposta do sensor em função do do ângulo deste em relação a fonte de luz

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Características dos Sensores: Infra-Vermelho**

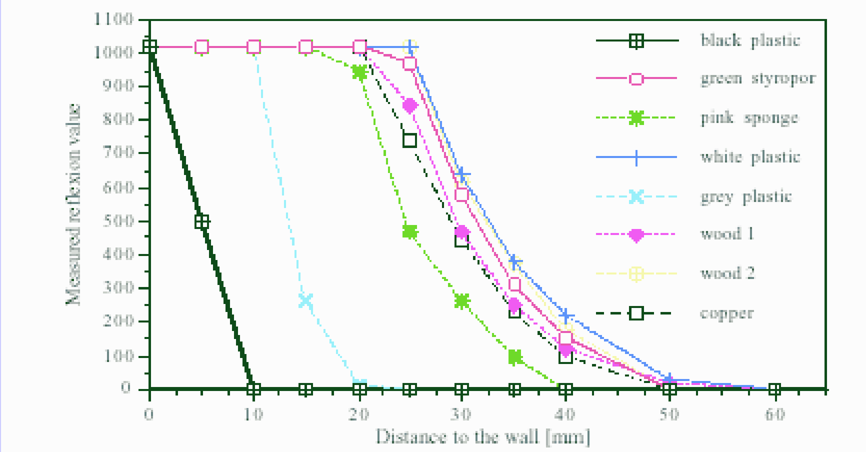


Figure 11: Measurements of the light reflected by various kinds of objects versus the distance to the object.

Medida de distância de um obstáculo: 0..1024 - Resposta em função do tipo de material (reflexão da luz depende do material)

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Características dos Sensores: Infra-Vermelho**

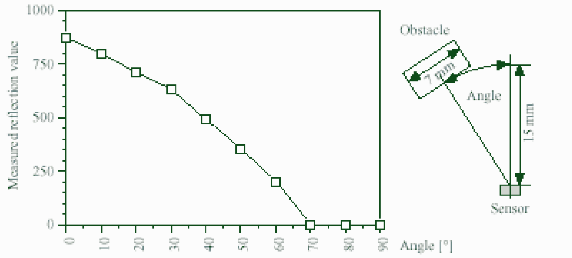
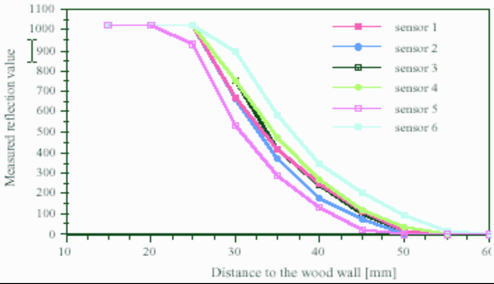


Figure 12: Typical response of a proximity sensor for an obstacle (7 mm in width) at a distance of 15 mm. The measurement is given versus the angle between the forward orientation of the robot and the orientation of the obstacle.

Campo de Visão do sensor



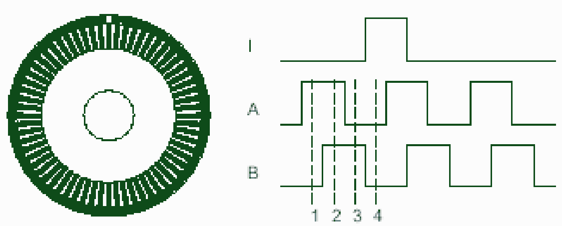
Typical measurements of the light reflected by a wall versus the distance to the wall for several sensors of the same kind and in the same conditions.

Diferença de resposta entre diferentes componentes do mesmo tipo sujeitos as nas mesmas condições

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Características dos Sensores: Posicionamento**

"Optical Encoders"



State	Ch A	Ch B
S_1	High	Low
S_2	High	High
S_3	Low	High
S_4	Low	Low

Figure 1.1: The observed phase relationship between Channel A and B pulse trains can be used to determine the direction of rotation with a phase-quadrature encoder, while unique output states S_1 - S_4 allow for up to a four-fold increase in resolution. The single slot in the outer track generates one index pulse per disk rotation [Everett, 1995].

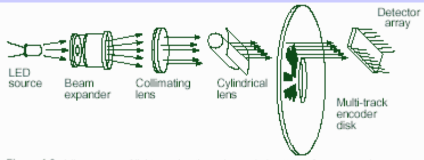


Figure 1.2: A line source of light passing through a coded pattern of opaque and transparent segments on the rotating encoder disk results in a parallel output that uniquely specifies the absolute angular position of the shaft. (Adapted from [Agent, 1991].)

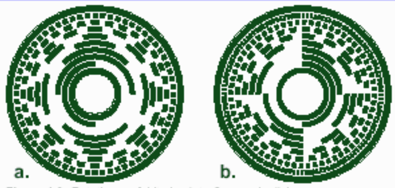
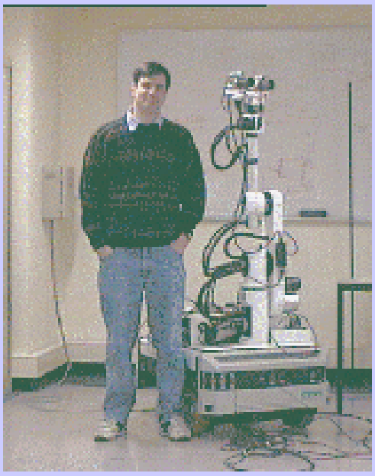


Figure 1.3: Rotating an 8-bit absolute Gray code disk.

ROBÓTICA AUTÔNOMA: *SENSORES*

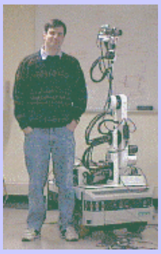
• **Características dos Sensores: Posicionamento**

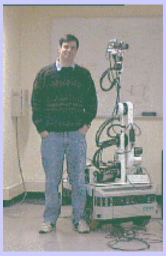
Posicionamento baseado em uma Câmera de Vídeo



Original

>> >> >> <<





Deslocamentos:

- **Esquerda, Direita**
- **Para frente, para trás**

ROBÓTICA AUTÔNOMA: *SENSORES*

• **Integração de dados provenientes de múltiplos sensores**

- **Integração de dados a partir de múltiplas leituras;**
- **Integração de múltiplos sensores de mesmo tipo;**
- **Integração de múltiplos sensores com diferentes sensibilidades;**
- **Integração de múltiplos sensores com diferentes tipos de percepção;**

• **Problemas da leitura sensorial:**

- **Modelo de simulação: modelo comportamental e o erro**
- **Comportamentos anômalos: experiência da "lata de lixo luminosa" [Bessière]**
- **Informações de muito baixo nível...**

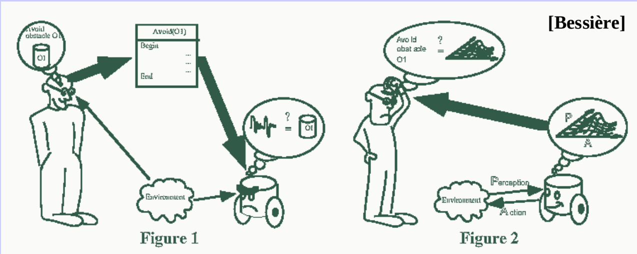
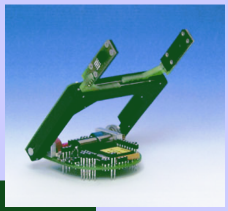


Figure 1   Figure 2

• **Tipos de Atuadores:**

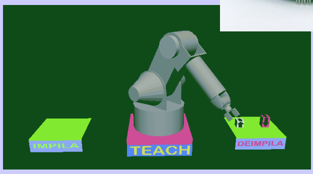


Locomoção:

- **Motor de Passo: rodas, esteiras - velocidade, direção, rotação**
- **Pernas e pés (problema do equilíbrio)**
- **Propulsão (submarino, aéreo)**

***Manipulação*:**

- **Pinças (grippers)**
- **Braço robótico => Prof. Adelmo Cechin!**



• **Referências:**

Kelly, Alonzo. "Introduction to Mobile Robots" (Kinematics). Robotics Institute - CMU. 1996.

Http://www.frc.ri.cmu.edu/~alonzo/course/course.html

Jones, J.; Seiger, B.; Flynn, A. "Mobile Robots: Inspiration to Implementation".

A. K. Peters, 1999. (Biblioteca Unisinos)

K-Team. "Khepera User Manual". Lausanne, 12/03/99.

Http://www.k-team.com/download/khepera.html

ROBÓTICA AUTÔNOMA: *ATUADORES*

• **Características dos Atuadores: Motor de Passo do Khepera**

3.1.5 Motors and motor control

Every wheel is moved by a DC motor coupled with the wheel through a 25:1 reduction gear. An incremental encoder is placed on the motor axis and gives 24 pulses per revolution of the motor. This allows a resolution of 600 pulses per revolution of the wheel that corresponds to 12 pulses per millimetre of path of the robot.

The Khepera main processor has the direct control on the motor power supply and can read the pulses of the incremental encoder. An interrupt routine detects every pulse of the incremental encoder and updates a wheel position counter.

The motor power supply can be adjusted by the main processor by switching it ON and OFF at a given frequency and during a given time. The basic switching frequency is constant and sufficiently high not to let the motor react to the single switching. By this way, the motor react to the time average of the power supply, which can be modified by changing the period the motor is switched ON. This means that only the ratio between ON and OFF periods is modified, as illustrated in figure 5. This power control method is called "pulse width modulation" (PWM). The PWM value is defined as the time the motor is switched ON.

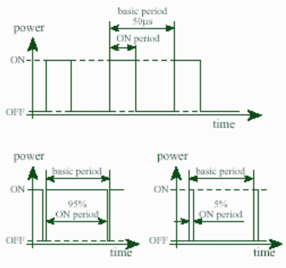


Figure 5: The "pulse width modulation" (PWM) power supply mode is based on a ratio between the ON time and the total time. The basic switching frequency is constant.

The PWM values can be set directly, or can be managed by a local motor controller. The motor controller can perform the control of the speed or position of the motor, setting the correct PWM value according to the real speed or position read on the incremental encoders.

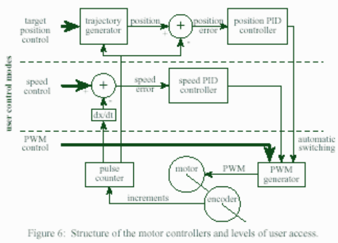


Figure 6: Structure of the motor controllers and levels of user access.

Both DC motors can be controlled by a PID controller executed in an interrupt routine of the main processor. Every term of this controller (Proportional, Integral, Derivative) is associated to a constant, setting the weight of the corresponding term: K_p for the proportional, K_i for the integral, K_d for the derivative.

The motor controller can be used in two control modes: The speed and the position modes. The active control mode is set according to the kind of command received. If the controller receives a speed control command, it switches to the speed mode. If the controller receives a position control command, the control mode is automatically switched to the position mode. Different control parameters (K_p, K_i and K_d) can be set for each of the two control modes.

ROBÓTICA AUTÔNOMA: *ATUADORES*

• **Características dos Atuadores: Motor de Passo do Khepera**

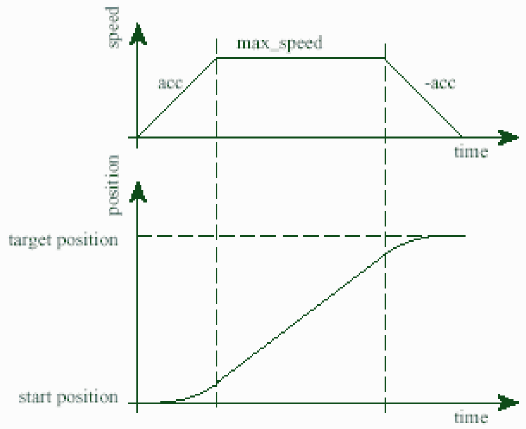


Figure 7: Speed profile used to reach a target position with a fixed acceleration (acc) and a maximal speed (max speed).

ROBÓTICA AUTÔNOMA: *ATUADORES*

• **Controle dos atuadores:**

- **Controle Deliberativo**
- **Controle Reativo**
- **Controle Hierárquico**
- **Controle Híbrido**

• **Principais problemas relacionado aos atuadores:**

- **Problemas de precisão;**
- **Deslocamento: controle da posição precisa do robô;**
- **Detecção de panes e sua eventual correção;**

DESAFIOS: Modelagem, Simulação, Controle do robô Real

ROBÓTICA AUTÔNOMA na WEB:

* FAQ: http://www.frc.ri.cmu.edu/robotics-faq/

* Associações:

• Intelligent Autononous Systems Society. Web: http://www.science.uva.nl/research/neuro/ias-ras/
• Society for Study of Artificial Intelligence and Simulation of Behaviour. Web: http://www.cogs.susx.ac.uk/aisb/
• International Conference on Intelligent Robots and Systems. Web: http://iros2000.iis.u-tokyo.ac.jp/

* Universidades e Projetos de Pesquisa:

• MIT AI (Artificial Intelligence) Lab. Web: http://www.ai.mit.edu/projects/
• Autonoumous System Lab. - LAMI - EPFL. Web: http://dmtwww.epfl.ch/isr/asl/
• Field and Space Robotics Laboratory - MIT. Web: http://robots.mit.edu/
• Lab. for Perceptual Robotics-UMass. Web: http://www-robotics.cs.umass.edu/robotics.html
• The Robotics Institute - Carnegie-Mellon University. Web: Web: http://www.ri.cmu.edu/
• Stanford Robotics Lab. Web: http://robotics.stanford.edu/home.html
• Khepera - Robot and Simulator. Web: http://diwww.epfl.ch/lami/team/michel/khep-sim/
• Laboratoire Leibniz - Equipes Réseaux d'Automates e Laplace. IMAG, INPG - Grenoble, France.
  Web: http://www-leibniz.imag.fr/RESEAUX/ e http://www-leibniz.imag.fr/LAPLACE/
• Equipe SHARP - INRIA, France. Web: http://www.inrialpes.fr/sharp/
  Publications: http://www.inrialpes.fr/sharp/publications/bibsharp/adt.html
• Robocup Official Site. Web: http://www.robocup.org/

* Empresas: (http://www.cs.virginia.edu/~gsw2c/robots.html)

• Arrick Robotics. Web: http://www.robotics.com/ . AGVs. http://www.agvp.com/home.htm
• Cybermotion Cyberguard. Web: http://www.cybermotion.com/ . IS Robotics. http://www.isr.com/
• Nomadic Technologies Inc. Web: http://www.robots.com/
• Lego MindStorm Site. Web: http://www.lego.com/mindstorms/ ou http://www.legomindstorms.com
• Robotics Industries Association - RIA. Web: http://www.robotics.org/
• Robotics OnLine. Web: http://www.roboticsonline.com/

F. OSÓRIO - UNISINOS 2000