

**USP - ICMC - SSC
SSC 0714 (RMA) - 1o. Semestre 2010**

**Disciplina de
Robôs Móveis Autônomos
SSC-0714**

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Wiki ICMC: <http://wiki.icmc.usp.br/index.php/SSC-714>

Aula 02 – Robôs Móveis Autônomos

Agenda:

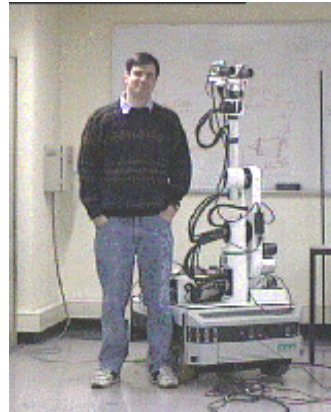
Robôs Móveis Autônomos:

- 1. História**
- 2. Tipos de RMAs**
- 3. Exemplos de Aplicações**
- 4. Desafios**
- 5. Futuro?**

Robôs Móveis Autônomos

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Da ficção científica à realidade...



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Histórico

History Making Mobile-Robots - HM



(Not yet included in list - Stanford Cart, Xee, Hebot1.....)

Significant Robots - and time-line events



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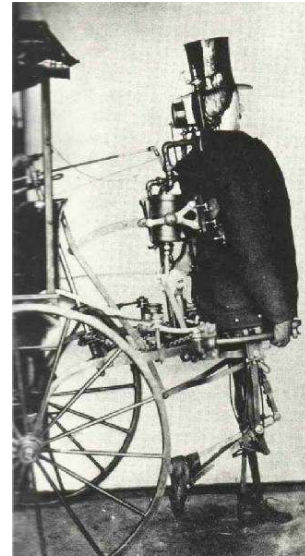
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<http://davidbuckley.net/DB/HistoryMakers.htm>

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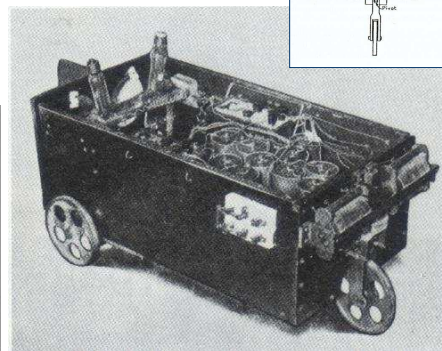
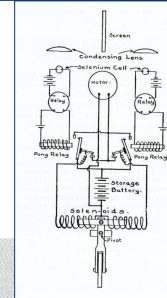
Histórico – 1868: A Steam Man
Mr. Zadock Deddrick¹, a Newark machinist,
has invented a man; one that, moved by steam,
will perform some of the most important functions of
humanity; that will, standing upright, walk or run...



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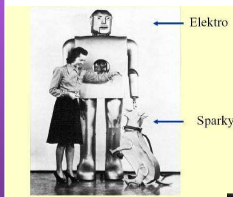
Histórico – Electric Dog - 1912
An electric dog, the ancestor of all phototropic self-directing robots,
was designed in 1912 and constructed in the USA by researchers
John Hammond, Jr. and Benjamin Miessner



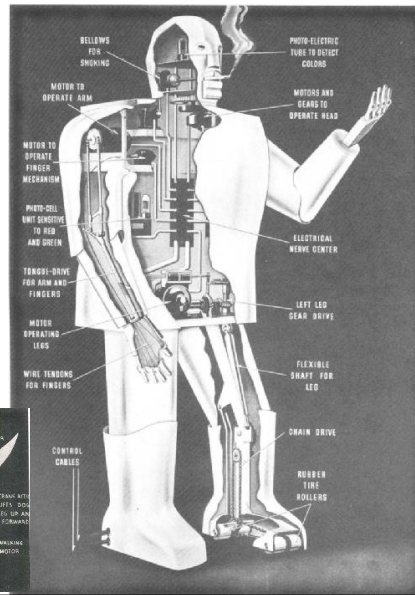
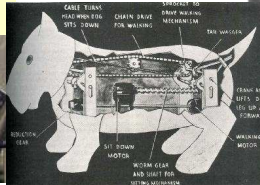
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Histórico – Elektro
 Westinghouse Elektro - 1937
 Westinghouse Sparko – 1940
 Elektro was built in 1937/38 by Westinghouse



New York World's Fair, 1939
 (Westinghouse Historical Collection)

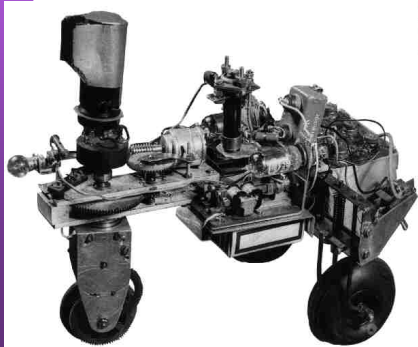


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Histórico – 1948 - William Grey Walter, first tortoise Elmer
 1949 - William Grey Walter. Elsie, Walter's second tortoise

- * Walter, W. Grey - A machine that learns. Scientific American, 184(8): 60-63, August 1951.
- * Walter, W. Grey - An imitation of life. Scientific American, 182(5): 42-45, May 1950.
- * Walter, W. Grey - The Living Brain, W. W. Norton, New York, 1963.



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Histórico - 1944 - II World War - German Tank
Goliath (YouTube)
Human Controlled Vehicle
"Remote Control"



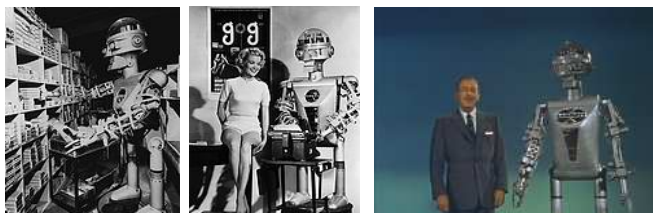
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Histórico - 1944: The robot Garco was created by Harvey Chapman.
The robot, built from discarded aircraft parts, is operated by remote control.
Human Controlled Humanoid - "Remote Control"



• Popular Science December 1953 - details of how Garco works



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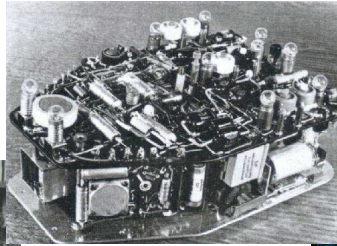
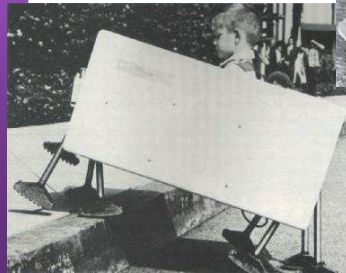
Histórico

1960: Zemanek build a series of robots to model combination of conditioned reflexes

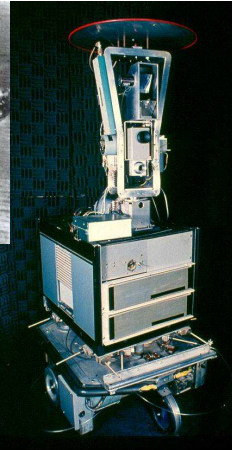
1965: Moonwalker - an 8-leg 'wheelchair' developed by Aerojet General for the University of California

1966: Shakey Shakey
Stanford Research Institute

Moonwalker



Zemanek



Shakey

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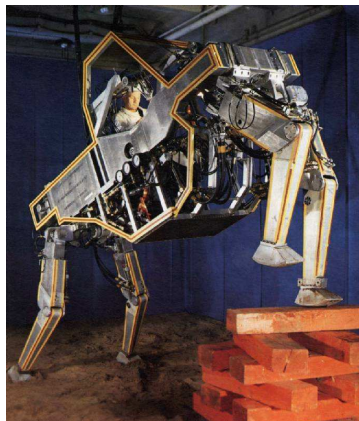
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Histórico:

GE Walking Truck 1968

The Walking Truck was developed by Ralph S. Mosher for General Electric under a commission in 1966 from the US Army.



David Ride 2000

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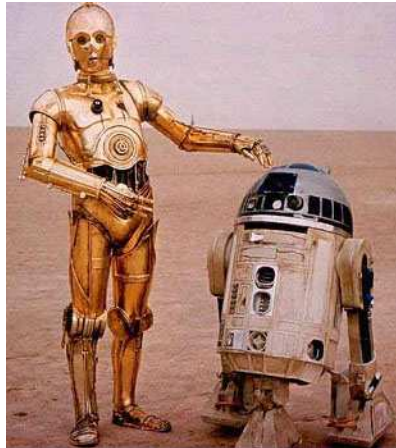
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Histórico - Ficção Científica

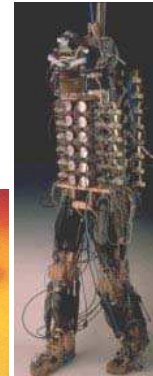
1977 Droids - Film: Star Wars - R2-D2, C-3PO



1983: Zeaker
by David Buckley



1988: Shadow
Biped Walker
by David Buckley



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Histórico

1989: Genghis - a 1Kg six legged robot which walks under **subsumption control** and has an extremely distributed control system.
Brooks, Rodney - MIT AI Lab



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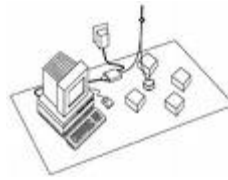
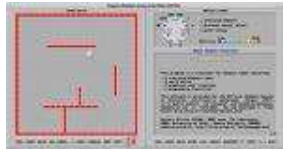
Histórico – 1996 Khepera (EPFL)

Khepera mobile robot [From Wikipedia]

The first generation Khepera robot released in 1996

The Khepera is a small (5.5 cm) differential wheeled mobile robot that was developed at the LAMI laboratory of Prof. Jean-Daniel Nicoud at EPFL (Lausanne, Switzerland) in the mid '90s. It was developed by Edo. Franzi, Francesco Mondada, André Guignard and others.

Small, fast, and architected around a Motorola 68331, it served researchers for 10 years, widely used by over 500 universities worldwide. It is now outdated, even with its upgraded processor and flash in version 2.0.



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Histórico – 1996: Honda P2

Honda's first public showing of a Biped Robot after a 10 year development program

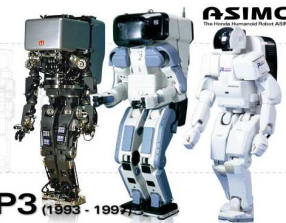
P2

Prototype Model 2
1993-1997

First humanoid stunned the public with realistic movement.

The world's first self-regulating, two-legged humanoid walking robot debuted in December, 1996.

Height: 1,820mm, Weight: 210kg. Using wireless techniques, the torso contained a computer, motor drives, battery, wireless radio and other necessary devices, all of which were built in. Independent walking, walking up and down stairs, cart pushing and other operations were achieved without wires, allowing independent operation.



P1-P2-P3 (1993 - 1997)
History of Humanoids

Home > History > History of Humanoids > P1 - P2 - P3

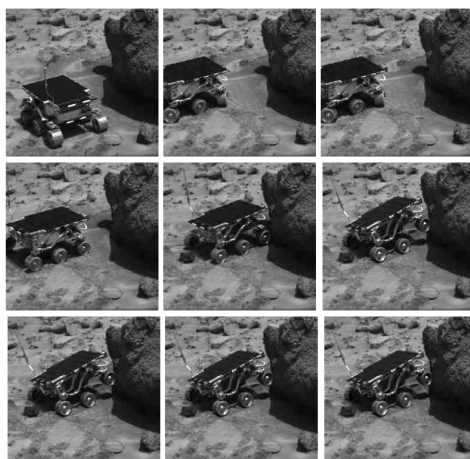
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1997 Mars Rover: Sojourner / PathFinder



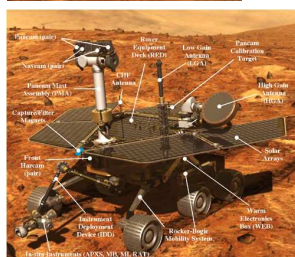
The rover goes a little too far and begins to climb Yogi (NASA)



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2004: Spirit and Opportunity



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Histórico:

ActivRobots / MobileRobots 1995 – Pioneer

iRobot 2002 – Roomba

The Roomba is a robotic vacuum cleaner made and sold by iRobot.

The Roomba was introduced in 2002; several updates and new models have since been released. As of January 2008, over 2.5 million units have been sold.

Boston Dynamics 2005 – BigDog

Sony 1999-2006 - Aibo



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Mobile Robots – Wikipedia : http://en.wikipedia.org/wiki/Mobile_robots

- 1995 The Pioneer programmable mobile robot becomes commercially available at an affordable price, enabling a widespread increase in robotics research and university study over the next decade as mobile robotics becomes a standard part of the university curriculum.
- 1996-1997 NASA sends the Mars Pathfinder with its rover Sojourner to Mars. The rover explores the surface, commanded from earth. Sojourner was equipped with a hazard avoidance system. This enabled Sojourner to autonomously find its way through unknown martian terrain.
- 1999 Sony introduces Aibo, a robotic dog capable of seeing, walking and interacting with its environment. The PackBot remote-controlled military mobile robot is introduced.
- 2001 Start of the Swarm-bots project. Swarm bots resemble insect colonies. Typically they consist of a large number of individual simple robots, that can interact with each other and together perform complex tasks.
- 2002 Appears Roomba, a domestic autonomous mobile robot that cleans the floor.
- 2004 Robosapien, a biomorphic toy robot designed by Mark Tilden is commercially available. In 'The Centibots Project' 100 autonomous robots work together to make a map of an unknown environment and search for objects within the environment.
- 2004 In the first DARPA Grand Challenge competition, fully autonomous vehicles compete against each other on a desert course.
- 2005 Boston Dynamics creates a quadruped robot intended to carry heavy loads across terrain too rough for vehicles.
- 2006 Sony stops making Aibo and HelpMate halts production, but a lower-cost PatrolBot customizable autonomous service robot system becomes available as mobile robots continue the struggle to become commercially viable. The US Department of Defense drops the MDARS-I project, but funds MDARS-E, an autonomous field robot. TALON-Sword, the first commercially available robot with grenade launcher and other integrated weapons options, is released. Honda's Asimo learns to run and climb stairs.
- 2007 History is made with the DARPA Urban Grand Challenge, with six vehicles autonomously completing a complex course involving manned vehicles and obstacles. Seekur, the first widely available, non-military outdoor service robot, pulls a 3-ton vehicle across a parking lot, drives autonomously indoors and begins learning how to navigate itself outside. Meanwhile, PatrolBot learns to follow.

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DARPA Challenge

2004 - Darpa Grand Challenge – Prêmio: US\$ 1 Milhão - Sem Vencedores

First Grand Challenge, held on March 13, 2004, when only 13 teams were able to field machines for the **142-mile course and none cleared the first mountain crossing** (see "A New Race of Robots," by W. Wayt Gibbs; SCIENTIFIC AMERICAN, March 2004).

2005 - Darpa Grand Challenge – Prêmio: US\$ 2 Milhões - Vencedor: Stanley / Stanford

Five out of 23 competing robots successfully navigated a 132-mile course through the Mojave Desert in October 2005 as part of the DARPA Grand Challenge race.

To qualify for the \$2-million prize, the driverless vehicles had to finish in less than 10 hours. Four turned in elapsed times under 7.5 hours.

2007 – Darpa Urban Challenge – Prêmio: US\$ 2 milhões – Vencedor: Boss / CMU

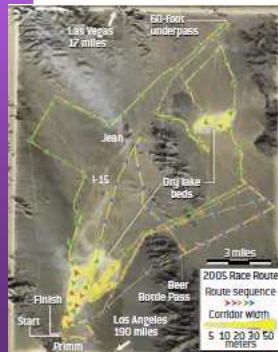
The Urban Challenge, announced in April 2006, called for autonomous vehicles to drive 97 km through an urban environment, interacting with other moving vehicles and obeying the California Driver Handbook. Interest in the event was immense, with 89 teams from around the world registering interest in competing. Competition took place on November 3, 2007.

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DARPA Grand Challenge



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DARPA Grand Challenge



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A MOTORCYCLE THAT STEERS ITSELF

- When not in motion, the motorbike rests on retractable landing gear (a).
- Guided by microelectro-mechanical sensors that measure the bike's orientation, onboard computers steer the front wheel (g) left or right to keep the vehicle upright and driving straight (b).
- To make a right turn, the robot first jerks its front wheel briefly to the left (c), which causes the body to lean over to the right...
- ... then straightens its wheel as the chassis continues to tip right (d), and finally steers right (e) to halt its fall. The vehicle holds this pose, in which the push of centrifugal force balances the pull of gravity, for the duration of the turn.
- To exit the turn, the robot kicks the front wheel even farther to the right (f), which increases the centrifugal force and rights the motorbike.
- A quick flick of the wheel to the left (g) halts the rotation of the chassis and puts the vehicle back on a straight heading (h).

A human rider turns a motorcycle both by leaning weight to the inside of the turn and by twisting the handlebars in the turn direction. Anthony Levandowski, leader of the Blue Team in Berkeley, Calif., knew that it would not be practical to move a large mass on the top of his autonomous motorbike, so he invented a new approach that uses the front wheel alone to lean the bike through turns.

GHOST RIDER ran unassisted for 20 miles at a time in desert testing.



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DARPA Grand Challenge

ROBOTS THAT SEE AROUND CORNERS

Spinning 64-laser scanner

Obstacle (utility tower)

3-D point cloud

Cost map

Utility tower

Most laser scanners pass a single infrared beam over a region, then translate the reflections into a 3-D model called a point cloud. Team DAD's novel scanner spins 64 fixed lasers at about 600 rpm, tracing out a highly detailed model. From this model, obstacle-detection software creates a 2-D "cost map" in which smooth, level ground has a low cost (green) and anything that slopes or rises above the ground carries a higher cost (red). The optimal path presents the lowest cost and permits the highest speed.

Pitch axis

Roll axis

Antireflective glass windshield

Long-range laser scanner

Three-axis gimbal on the Red Team's Highlander and Sandstorm robots is able to pitch, roll and yaw to point the laser scanner in any forward direction.

Highlander

Gimbal

Unreliable scan

DAD

Highlander

Gimbal

Reliable scan

Hairpin turns are typically blind turns for robots. But DAD, Highlander and Sandstorm can often see the other side of a tight curve before they get there. DAD has a full 180-degree field of view; the Red Team robots swivel their gimbals.

Rough roads jostle fixed lasers, creating gaps in the 3-D model. The Red Team gimbal senses such jolts with fiber-optic gyroscopes; then uses its actuators to cancel out the motion. The results are more reliable perception, especially when looking far ahead.

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DARPA Grand Challenge

VISION LINKED TO SPEED

Smart speed switch, which helped Stanley win the 2005 Grand Challenge, combines laser and video sensors in a four-step process. First, the robot filters its laser data to identify a section of terrain ahead that is smooth and relatively flat [green]. Second, a program finds the corresponding patch of road in the video frame sent by the onboard camera [blue outlines]. Next, the system highlights all other areas in the same video frame that match that pattern, which it equates with good, drivable road [pink areas]. Finally, the software checks whether the matching area completely fills the robot's intended path for the next 130 feet [orange]. If it does, then the system concludes that a long stretch of open road lies ahead, and it informs the onboard planning computer that it is safe to step on the gas.

Trinocular Terramax [right] can build a 3-D stereo view of the world from any of three pairs [arrows] of color video cameras. The closest cameras [purple], used at slow speeds, can detect obstacles up to 50 feet away. At fast speeds the robot selects its widest pair [orange], which can pick up objects 65 to 165 feet ahead. The third pair [pink] offers a happy medium.



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DARPA Grand Challenge

Ganhadores – Stanley / Stanford University

Sebastian Thrun, Mike Montemerlo, Hendrik Dahlkamp, David Stavens, Andrei Aron, James Diebel, Philip Fong, John Gale, Morgan Halpenney, Gabriel Hoffmann, Kenny Lau, Celia Oakley, Mark Palatucci, Vaughan Pratt, and Pascal Stang
Stanford Artificial Intelligence Laboratory - Stanford University - Stanford, California 94305
 Sven Strohband, Cedric Dupont, Lars-Erik Jendrossek, Christian Koelen, Charles Markey, Carlo Rummel, Joe van Niekerk, Eric Jensen, and Philippe Alessandrini
Volkswagen of America, Inc. - Electronics Research Laboratory - Palo Alto, California
 Gary Bradschi, Bob Davies, Scott Ettinger, Adrian Kaehler, and Ara Nefian
Intel Research - 2200 Mission College Boulevard
 Santa Clara, California 95052
 Pamela Mahoney
Mohr Davidow Ventures
 Menlo Park, California 94025



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DARPA Urban Challenge

Boss, the autonomous Chevy Tahoe that won the 2007 DARPA Urban Challenge

Tartan Racing – CMU Carnegie Mellon University

Pittsburgh, Pennsylvania

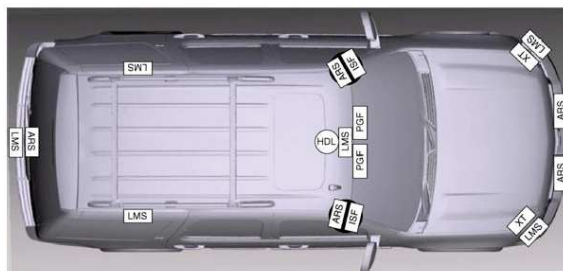


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Sensor	Characteristics
Applanix POS-LV 220/420 GPS/IMU (APLX)	<ul style="list-style-type: none"> Submeter accuracy with Omnistar VBS corrections Tightly coupled inertial/GPS bridges GPS outages
DARPA Urban Challenge SICK LMS 291-S05/S14 LIDAR (LMS)	<ul style="list-style-type: none"> 180/90 deg × 0.9 deg FOV with 1/0.5-deg angular resolution 80-m maximum range
Velodyne HDL-64 LIDAR (HDL)	<ul style="list-style-type: none"> 360 × 26-deg FOV with 0.1-deg angular resolution 70-m maximum range
"Boss" CMU Continental ISF 172 LIDAR (ISF)	<ul style="list-style-type: none"> 12 × 3.2 deg FOV 150-m maximum range
IBEO Alasca XT LIDAR (XT)	<ul style="list-style-type: none"> 240 × 3.2 deg FOV 300-m maximum range
Continental ARS 300 Radar (ARS)	<ul style="list-style-type: none"> 60/17 deg × 3.2 deg FOV 60-m/200-m maximum range
Point Grey Firefly (PGF)	<ul style="list-style-type: none"> High-dynamic-range camera 45-deg FOV



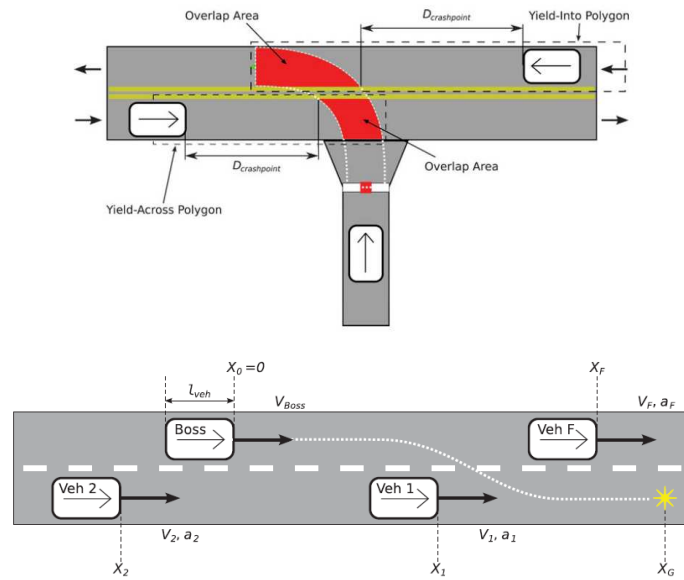
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Robôs Móveis Autônomos

DARPA
Urban
Challenge

"Boss"
CMU



Robótica Autônoma Tipos de Robôs

Tipos de Robôs

Tipos de Robôs

Tipo de Mobilidade

- Base Fixa (manipuladores, braço robótico)
- Base Móvel: Com Restrição (grua) / Sem Restrição (veículo)

Tipo de Mecanismo de Locomoção

- Pernas, Rodas, Esteiras, Propulsão

Tipo de Local de Atuação

- Indoor (locais fechados, internos)
- Outdoor: Estruturados (estradas), Não Estruturados (off-road)

Tipo de Autonomia

- Controle e Ações Pré-Definidas
- Tele-Operados (tele-comandado)
- Semi-Autônomo (tele-operado + ações independentes)
- Autônomo : sem intervenção humana durante a operação

Percepção
Decisão
Ação

* Robôs Manipuladores:

- Braços Robóticos de Base Fixa
Manipuladores Industriais
- Braços Manipuladores Embarcados
- Gruas Robotizadas

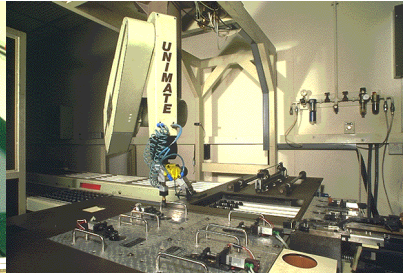
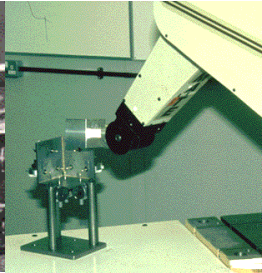
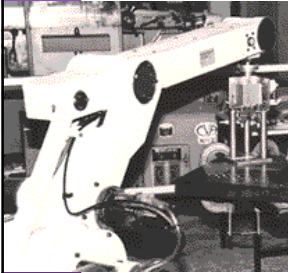
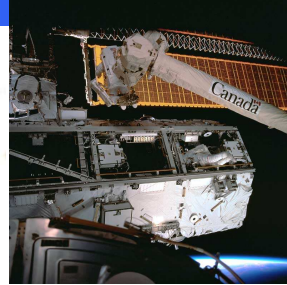
* Robôs Móveis:

- AGV Industriais (Automated Guided Vehicles)
- Robôs Indoor: Veículos, Holonômicos, Humanoides, ...
- Robôs Outdoor: Terrestres (estradas, todos-terrenos),
Sub-Marinos, Aéreos, Inter-Planetários, ...

Robótica Autônoma Tipos de Robôs

* Robôs Manipuladores:

- Braços Robóticos de Base Fixa
Manipuladores Industriais
- Braços Manipuladores Embarcados
- Gruas Robotizadas



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Robótica Autônoma Tipos de Robôs

* Robôs Manipuladores:

- Braços Robóticos de Base Fixa
Manipuladores Industriais
- Braços Manipuladores Embarcados
- Gruas Robotizadas



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Robótica Autônoma Tipos de Robôs

* Robôs Manipuladores:

- Braços Robóticos de Base Fixa
Manipuladores Industriais
- Braços Manipuladores Embarcados
- **Gruas Robotizadas**

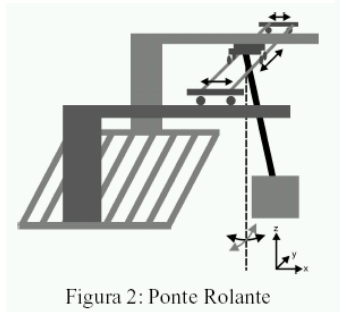


Figura 2: Ponte Rolante

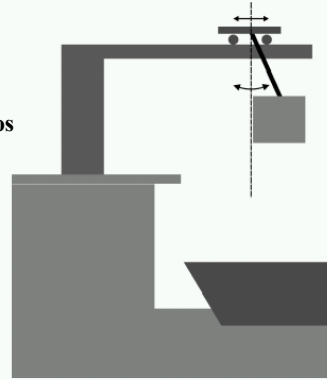


Figura 1: Ponte Rolante para Carga e Descarga de Containers

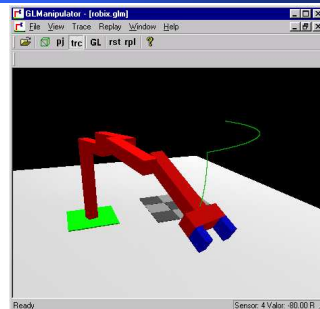
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Robótica Autônoma Tipos de Robôs

* Robôs Manipuladores:

Braços Robóticos de Base Fixa

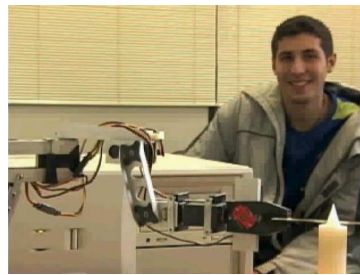
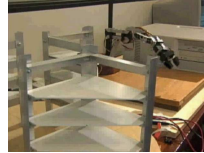


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* Robôs Manipuladores: Braços Robóticos de Base Fixa



Robótica Autônoma Tipos de Robôs

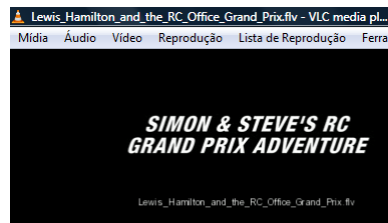
* Robôs Móveis:



B. Robôs Móveis Semi-Autônomos => AGV

Autonomia

Robôs Móveis Autônomos - PRESENTE



Lewis Hamilton and the RC Office Grand Prix
RCGPGuys

YouTube

<http://www.youtube.com/watch?v=FiLoANg6nNY>

http://www.youtube.com/results?search_type=&search_query=Hamilton+F1+RC&aq=f



Using a Data-Glove to Recognize Postures
ANN Gesture Recognition

Control RC Car

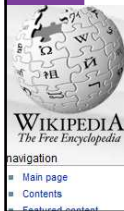
F. Osório, S. Musse, A. Tavares, M. Gomez, F. Garat
L. Poltosi, G. P. Breyer, F. Heinen

Robôs Móveis: Autonomia

Robôs Móveis: Autônomos e Inteligentes



iPhone + Hamilton F1
x
Airport Shuttle



Bombardier CX-100

From Wikipedia, the free encyclopedia

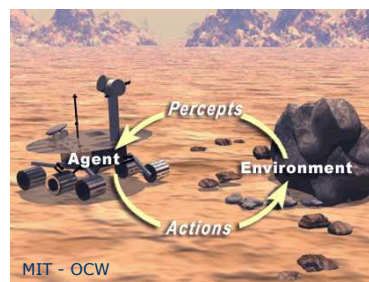
Bombardier CX-100 is an automated people mover (APM) rolling stock first developed by Adtranz (now **Bombardier Transportation**), intended mainly for airport connections and light rail in towns. They are operated by Automatic Train Control (ATC) **making it fully automatic and driverless**.

The CX-100 is an evolution of Adtranz's previous people mover vehicle, the C-100. Bombardier's intended successor to the CX-100 is the Innovia, which made its debut on Dallas-Fort Worth International Airport's Skylink APM. However, the CX-100 continues to be offered by Bombardier and will remain in service at many airports for years to come.

Robôs Móveis: Autonomia

Robôs Móveis: Autônomos e Inteligentes

Robôs Móveis:
Agentes Autônomos dotados de **SENSORES** e **ATUADORES**



SENSORES
ATUADORES
CONTROLE INTELIGENTE

Aplicações

Robôs Móveis Autônomos

Exemplos de Aplicações...

O que aprendemos de todas estas aplicações?



Robôs Móveis Autônomos

Robôs Móveis Autônomos

Exemplos de Aplicações...



Robôs Móveis Autônomos

Robôs Móveis Autônomos

Exemplos de Aplicações...



Robôs Móveis Autônomos

Robôs Móveis Autônomos Aplicações

UAVs

UAVs - UnManed Aerial Vehicles
Exemplos de Aplicações... LRM - ICMC - USP



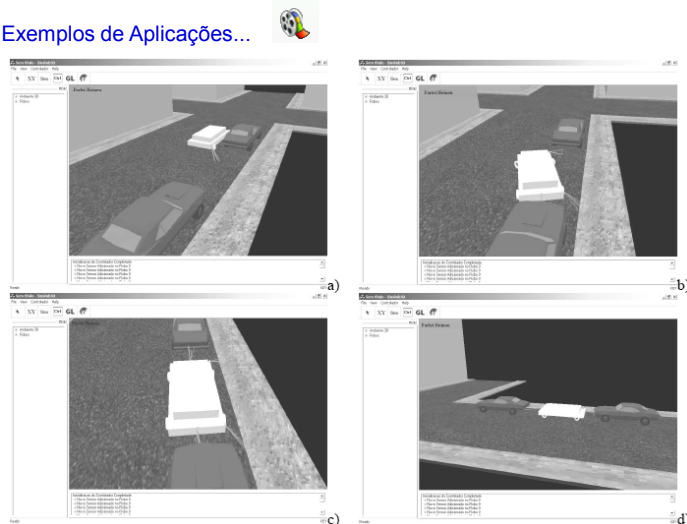
47
Abril 2009

YouTube: Seach AGPLANE - MEMBECA 2008

6. Robôs Móveis Autônomos

Robôs Móveis Autônomos

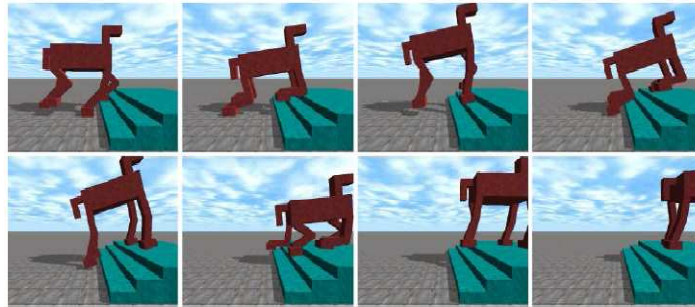
Exemplos de Aplicações...



Março 2010

Robôs Móveis Autônomos

Robôs Móveis Autônomos



Março 2010

Robôs Móveis Autônomos

Robôs Móveis Autônomos



Scientific American - January 2007

A Robot in Every Home

The leader of the PC revolution predicts that the next hot field will be robotics

By Bill Gates

Imagine being present at the birth of a new industry.

It is an industry based on groundbreaking new technologies, wherein a handful of well-established corporations sell highly specialized devices for business use and a fast-growing number of start-up companies produce innovative toys, gadgets for hobbyists and other interesting niche products. But it is also a highly fragmented industry with few common standards or platforms.

Projects are complex, progress is slow, and practical applications are relatively rare. In fact, for all the excitement and promise, no one can say with any certainty when—or even if—this industry will achieve critical mass. If it does, though, it may well change the world.

Of course, the paragraph above could be a description of the computer industry during the mid-1970s, around the time that Paul Allen and I launched Microsoft.

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Março 2010

Robôs Móveis Autônomos

Referências usadas nesta Aula:

Web Histórico

- <http://davidbuckley.net/DB/HistoryMakers.htm>
- http://en.wikipedia.org/wiki/Mobile_robots
- http://www.youtube.com/watch?v=I_dr0arBlU

Material Complementar:

- Darpa Challenge Papers:
<http://osorio.wait4.org/RMA/Darpa-Papers/>
Ver também: Wikipedia

Robôs Móveis Autônomos

Referências Complementares...

Exemplos de Aplicações desenvolvidas no LRM no ICMC

YouTube

- Curso de Programação de Robôs
<http://www.youtube.com/watch?v=pulqmRyBeO0>
- Robôs Móveis (Sist. de Visão)
<http://www.youtube.com/fsosorio>

SlideShare

- Curso de Programação de Robôs à Distância (PUC-RS + ICMC)
<http://www.slideshare.net/fsosorio>
(Robôs localizados em São Carlos controlados de Porto Alegre)

6. Robôs Móveis Autônomos

Robôs Móveis Autônomos

Referências Complementares...

Exemplos de Aplicações desenvolvidas no LRM no ICMC

Fotos Picasa:

<http://picasaweb.google.com/fosorio/USPICMCLRMLaboratorioDeRoboticaMovei#>

<http://picasaweb.google.com/fosorio/USPProjetoSENAGisa#>



SemComp 2009

Palestra Robot NAO

Veículo com Sensores



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Março 2010



INFORMAÇÕES SOBRE A DISCIPLINA

USP - Universidade de São Paulo - São Carlos, SP
ICMC - Instituto de Ciências Matemáticas e de Computação
SSC - Departamento de Sistemas de Computação

Prof. Fernando Santos OSÓRIO

PAE Maurício Acconcia Dias

Web institucional: [Http://www.icmc.usp.br/ssc/](http://www.icmc.usp.br/ssc/)

Página pessoal: [Http://www.icmc.usp.br/~fosorio/](http://www.icmc.usp.br/~fosorio/)

E-mail: [fosorio\[at\] icmc.usp.br](mailto:fosorio@icmc.usp.br), gmail.com } # [maccddias\[at\]gmail.com](mailto:maccddias@gmail.com)

Disciplina de Robôs Móveis Autônomos

Web Disciplinas: [Http://www.icmc.usp.br/~fosorio/](http://www.icmc.usp.br/~fosorio/)

Wiki ICMC: <http://wiki.icmc.usp.br/index.php/SSC-714>

> Programa, Material de Aulas, Critérios de Avaliação,

> Material de Apoio, Trabalhos Práticos

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Março 2010