Baxter the friendly robot: Applications, architecture, and features

Dr. James B. Dabney and Dr. Thomas L. Harman
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1. Condition ring
2. Attention ring
3. Display
4. Work lights
5. Navigator
6. Lower front panel
7. Waist
8. Training cuff with parallel gripper
9. Training cuff with vacuum gripper
10. Pedestal
Miscellaneous Specifications

Screen Resolution 1024 x 600 pixels

Positional Accuracy +/- 5 mm

Max Payload (including end-effector) 5 lb / 2.2 kg

Gripping Torque (max) 10 lb / 4.4 kg

Infrared Sensor Range 1.5 – 15 in / 4 – 40 cm

Standard 120VAC power. Robot power bus and internal PC both have “universal” power supplies and support 90 - 264V AC (47 - 63Hz)

6A at 120V AC, 720W max per unit
COMPUTER INSIDE

Processor 3rd Gen Intel Core i7-3770 Processor (8MB, 3.4GHz) w/HD4000 Graphics

Memory 4GB, NON-ECC, 1600MHZ DDR3

Hard Drive 128GB Solid State Drive
A FACE TO LOVE

MANUFACTURING VERSION OF BAXTER
A FACE TO USE
A ROBOT’S EMOTIONS

Brooks didn’t set out to build a humanoid robot, but he found that giving Baxter a face was the most intuitive way to communicate information.

**NEUTRAL**
Ready for training

**ASLEEP**
On standby

**CONCENTRATING**
Learning a task

**FOCUSED**
Working away without a problem

**SURPRISED**
A human has approached

**CONFUSED**
Having trouble finding an object or otherwise completing a task

**SAD**
Given up trying to complete a task; there’s a problem
TRAINING NOT PROGRAMMING
APPLICATIONS OF RESEARCH BAXTER
Human-Robot Interaction -
Quadriplegic using Baxter and electric wheelchair

David Using Jammster

Baxter does Magic

Magic Robot - The Illusion of the Thinking Machine

Baxter On Wheels

Baxter on wheels retrieving jacket

SEE Rethink Robotics WEB site
Baxter Kinects

Baxter Robot control using body tracking with Kinect

Baxter Dresses Someone

Clothing and Unclothing Assistance by Baxter
Planning and Manipulation

- Baxter Coordinated Dual-Arm Force Control
- Baxter Research Robot Solves Rubik's Cube

- Teaching with Gestures
  - Baxter Research Robot: Mimicry using Kinect
  - Online human upper body imitation using BAXTER robot
Manipulation and Mechatronics

Baxter Recognizes bicycle tires (soft objects)

- Optimal Parameter Identification of Flexible Objects via Manipulation
- Teleoperating Multiple Baxter Robots Using Kinect v2  Dan Kruse
Computer Vision - Baxter Knows Colors

- Happy Easter from the RRC Robotics and Automation Team - Sort the Easter Eggs
- Automated Lego Sorting
- Automated Checked Baggage Inspection System
- BAXTER Sort Colored Balls - Author's View

Brandon Boyce
Programming Research Baxter

1. UBUNTU OPERATION SYSTEM
2. ROBOT OPERATING SYSTEM - ROS
3. PYTHON SCRIPTS
4. BAXTER API SCRIPTS
5. OUR OWN SCRIPTS
6. SIMULATORS
Network Connection

Ubuntu Development Workstation
- Example Programs
- ROS Tools e.g. Rviz, Rxconsole
- Stock ROS

Baxter Research Robot
- Diagnostics
- TF
- Robot State Publisher
- Motor Controller

Network Connection

Gigabit Ethernet Switch
SIMULATION

- MOVE IT
- GAZEBO

THESE USE THE URDF FORMAT TO DESCRIBE THE ROBOTS
SIMULATORS, ROBONAUT AND BAXTER

http://wiki.ros.org/Robots/Robonaut2

GAZEBO SIMULATOR
Universal Robotic Description Format (URDF) is an XML file format used in ROS to describe all elements of a robot.

robot name is: baxter

---------- Successfully Parsed XML ----------
root Link: base has 3 child(ren)
  child(1): collision_head_link_1
  child(2): collision_head_link_2
  child(3): torso
    child(1): head
      child(1): dummyhead1
      child(2): head_camera
      child(3): screen
        child(1): display
    child(2): left_arm_mount
      child(1): left_upper_shoulder
      child(1): left_lower_shoulder
        child(1): left_upper_elbow
          child(1): left_lower_elbow
          child(1): left_upper_forearm
THE MATHWORKS PROGRAMS BAXTER
How to Use MATLAB-ROS Interface to Prototype Robotics Algorithm for ROS-Powered Robots

Yanliang Zhang (MathWorks)
Ren Sang Nah (MathWorks)
Remo Pillat (MathWorks)
Carlos Santacruz-Rosero (MathWorks)
Giampiero Campa (MathWorks)
See the live demo at MathWorks booth

CHECKERS ANYONE?
With MATLAB ROS I/O Package

Distributed “Nodes”

Message Exchange

Hardware Drivers

Algorithm Libraries
MATLAB ROS I/O Package

- Interact with Simulator
- Interact with Real Robot
- Process Data
- Visualize and Analyze
- Design and Test
Interactive Exploration of Robot Data

ROS Node
VICON Camera

ROS Node
Kinect

ROS Node
Motors/Sensors

ROS Node

Explore ROS messages from the MATLAB command line

```matlab
>> Node
equals
>> VelPub
getClass
>> VelPub
getInstance
>> vLin
getInvocationHandler
>> vLin
getProxyClass
>> Message
Message
>> Message
getY
>> Message
getZ
```
Closing Remarks

- Allow MATLAB/ROS users to take advantage of both
  - Power of MATLAB in data analysis and algorithm design
  - Flexibility of ROS in handling a network of applications
- Enable multi-platform access to ROS from MATLAB
- Available for download at official MathWorks website
  - [http://www.mathworks.com/ros](http://www.mathworks.com/ros)
  - Search for “MATLAB ROS”
- TurtleBot example available at MATLAB Central
  - Search for “MATLAB ROS TurtleBot”
the quest for robotic vision

Peter Corke
Baxter Kinematics  Dr. James Dabney

• Each arm independent
• Seven degrees of freedom (per arm)
• Additional degrees of freedom in gripper or end effector
• All arm joints are revolute
Joint Configuration

• **S0** - Shoulder Roll
• **S1** - Shoulder Pitch
• **E0** - Elbow Roll
• **E1** - Elbow Pitch
• **W0** - Wrist Roll
• **W1** - Wrist Pitch
• **W2** - Wrist Roll

Source: http://sdk.rethinkrobotics.com/wiki/Arms#Joint_Naming
Series Elastic Actuators

• Improve operational safety
• More closely model human operator
• Easier (much) to control force
  • Springs convert force control into position control
  • Large error tolerance
Series Elastic Actuator Dynamics

- Electrically actuated
- Springs for compliance
- Actuator equation of motion

\[ J\ddot{\theta}_M + c\dot{\theta}_M + k(\theta_M - \theta_L) = \tau_L \]

where \( \theta_M \) is the motor angular position, \( c \) is internal damping, and \( k \) is the spring constant. \( J \) is the moment of inertia of the motor and gear train.

Baxter Actuators

Baxter Control Strategies

- Simple control via Python scripts
  - Position
  - Torque
- Native control using flexible manipulator techniques
- Impedance-based control developed for haptic systems
RESEARCH OBJECTIVES AT UHCL

1. MODEST RESEARCH GOALS

• DETERMINE PRECISION OF GRIPPING AND VISION
• USE BAXTER AS AN ASSEMBLY ASSISTANT
• IMPLEMENT GESTURE AND VOICE CONTROL

2. WORK WITH MATHWORKS TO IMPLEMENT AND TEST MATLAB MODULES WITH BAXTER
COORDINATE MULTIPLE BAXTERS
RESEARCH OBJECTIVES AT UHCL

Dr. McKay’s “Big Idea”