GET Lab

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MINTernational

Einsatz eines Online-Angebots zur Internationalisierung der Hochschullehre im Bereich Robotik

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Workshop der Universität Paderborn und der TU Bergakademie Freiberg:
Virtuell, Praktisch, International – Innovative Lehr-/Lernformate für die internationale Hochschule

Fachkonferenz „Wie international soll MINT sein? Globale Talente – interkulturelle Kompetenzen“

Übersicht

- Hintergrund und Motivation
- Robotics Wiki
- Demonstration
- Evaluierung

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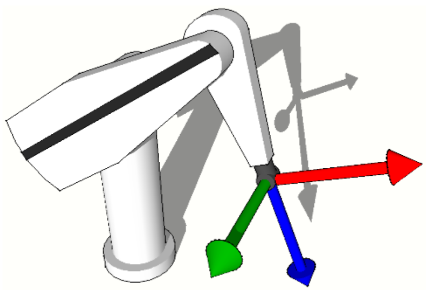
Hintergrund und Motivation (I)

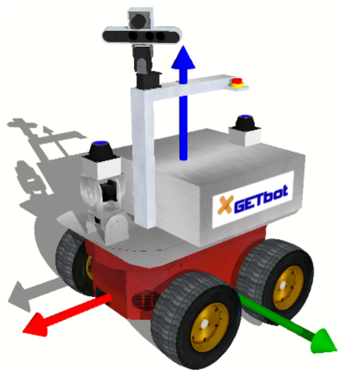
Exemplarischer Bezug:

Lehrveranstaltungen *Robotics* und *Advanced Topics in Robotics* in internationalen Masterstudiengängen der UPB.

Hier werden u. a. die Kinematik und Dynamik von Roboterarmen und mobilen Robotern behandelt. Dazu sind teilweise fortgeschrittene Mathematikkenntnisse erforderlich, z. B.:

- Lineare Algebra
- Quaternionen
- Projektive Geometrie





Hintergrund und Motivation (II)

Der Studienerfolg im Bereich Ing. wird signifikant durch die Mathematikkenntnisse beeinflusst [z. B. Alpers et al., 2013].

Jedoch mehrere Herausforderungen bzgl. Mathematik:

- Große Heterogenität der Kenntnisse auch aufgrund unterschiedlicher nationaler Standards.
- Häufig große Lücke zwischen erwarteten und tatsächlich beherrschten Themen.
- Teilweise auch Schwierigkeiten mit grundlegenderen Themen [Nickchen & Mertsching, 2016][1].
- Authentischer Kontext in Mathematikveranstaltungen oft nicht gegeben ⇒ Transferleistung unsicher.

[1]Nickchen, D., & Mertsching, B. (2016). Combining mathematical revision courses with hands-on approaches for engineering education using web-based interactive multimedia applications. *Procedia-Social and Behavioral Sciences*, *228*, pp. 482-488.

Hintergrund und Motivation (III)

Weitere Herausforderungen:

- In Robotik LV oftmals Fokussierung auf theoretische Aspekte, ohne diese tatsächlich praktisch einzusetzen.
- Praktischer Einsatz ermöglicht jedoch Reflexion und Vertiefung der Kenntnisse.
- Internationale Studierende unzufrieden mit Beratungs- und Unterstützungsangeboten [GES, 2014].
- Es findet häufig keine Vernetzung zwischen nationalen und internationalen Studierenden statt ⇒ Integrationsschwierigkeiten.

Ansatz:
Einsatz eines situierten Online-Angebots („Robotics Wiki“) zur Unterstützung im Bereich Mathematik, zur Erhöhung des Praxisbezugs, sowie zur Förderung der Integration.

Hintergrund und Motivation (IV)

Weitere Ziele:

- Studienvorbereitung (Online-Assessment)
- Werbung nationaler und internationaler Studieninteressierter

Umsetzung u. a. im Rahmen des Projekts I-WIRE:

Internationalization Through Web-based
Interactive Robotics Education

MINTernational

Weitere Partner:

khd m kompetenzzentrum hochschuldidaktik mathematik

InnoVersity

Internationales Studienkolleg an der Universität Paderborn

MANATECH

Kompetenzforum INTERNATIONAL

Initiative für Beschäftigung OWL e.V.

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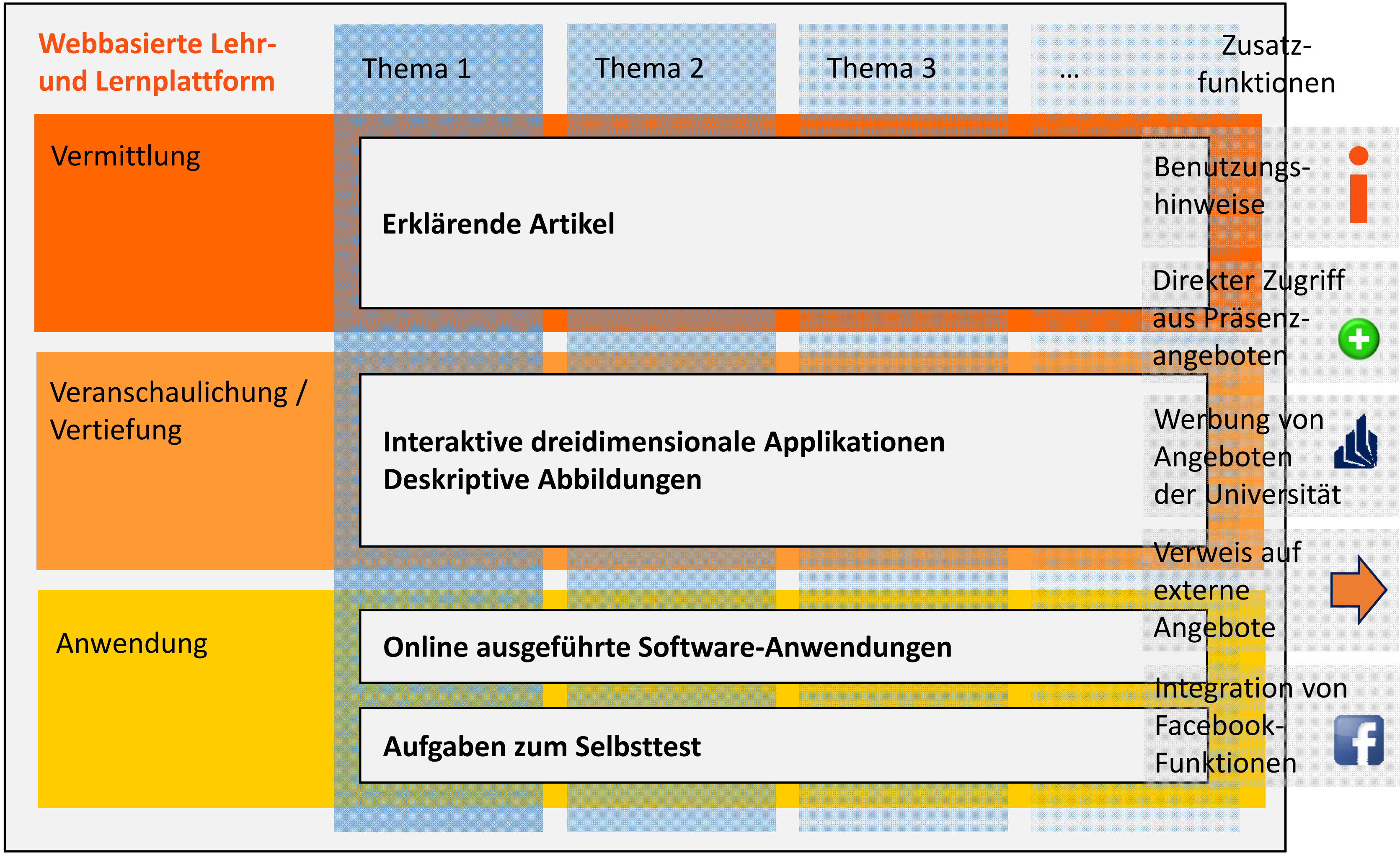
Einsatz des Wikis im Rahmen eines Blended Learning Szenarios mit komplementären Zwecken:

i) Kurze (!) math. Exkurse in Präsenzveranstaltungen.
ii) Individueller Einsatz außerhalb der Präsenzveranstaltungen zur Adressierung individueller Schwierigkeiten sowie zur praktischen Vertiefung.

- Einbettung in Skript und Übungsblättern.
- Insbesondere Berücksichtigung unterschiedlicher Vorkenntnisse (Heterogenität der Studierenden).
- Umfangreiche direkte Verlinkung von Begriffen und Themen.
- Darüber hinaus Verknüpfung mit sozialen Netzwerken.

Robotics Wiki (II)

Visualisierung des didaktischen Designs:



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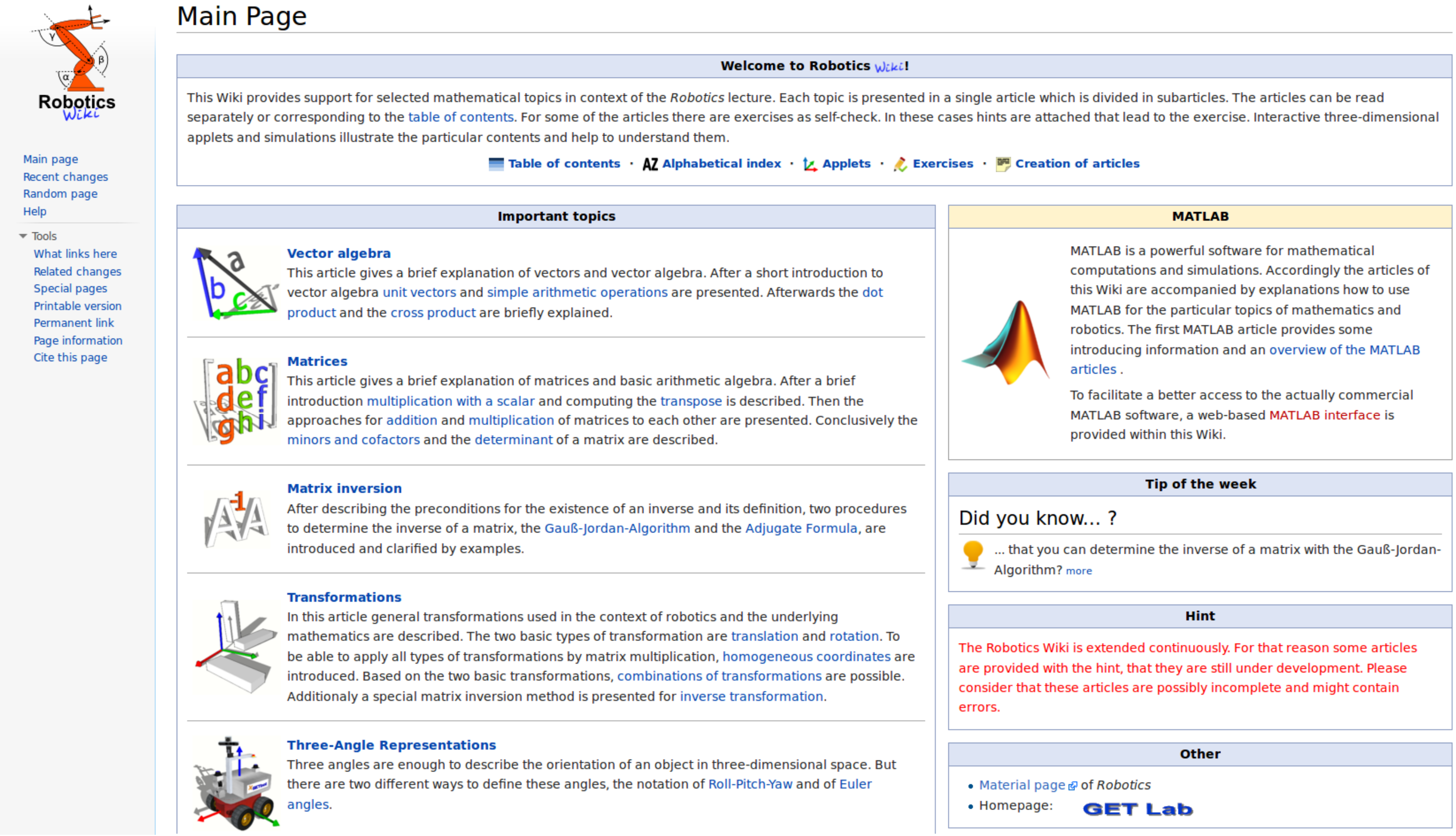
Demonstration: Screenshot der Startseite



Robotics Wiki

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Main Page

Welcome to Robotics Wiki!

This Wiki provides support for selected mathematical topics in context of the *Robotics* lecture. Each topic is presented in a single article which is divided in subarticles. The articles can be read separately or corresponding to the table of contents. For some of the articles there are exercises as self-check. In these cases hints are attached that lead to the exercise. Interactive three-dimensional applets and simulations illustrate the particular contents and help to understand them.

Table of contents · **Alphabetical index** · **Applets** · **Exercises** · **Creation of articles**

Important topics

Vector algebra
This article gives a brief explanation of vectors and vector algebra. After a short introduction to vector algebra unit vectors and simple arithmetic operations are presented. Afterwards the dot product and the cross product are briefly explained.

Matrices
This article gives a brief explanation of matrices and basic arithmetic algebra. After a brief introduction multiplication with a scalar and computing the transpose is described. Then the approaches for addition and multiplication of matrices to each other are presented. Conclusively the minors and cofactors and the determinant of a matrix are described.

Matrix inversion
After describing the preconditions for the existence of an inverse and its definition, two procedures to determine the inverse of a matrix, the Gauß-Jordan-Algorithm and the Adjugate Formula, are introduced and clarified by examples.

Transformations
In this article general transformations used in the context of robotics and the underlying mathematics are described. The two basic types of transformation are translation and rotation. To be able to apply all types of transformations by matrix multiplication, homogeneous coordinates are introduced. Based on the two basic transformations, combinations of transformations are possible. Additionaly a special matrix inversion method is presented for inverse transformation.

Three-Angle Representations
Three angles are enough to describe the orientation of an object in three-dimensional space. But there are two different ways to define these angles, the notation of Roll-Pitch-Yaw and of Euler angles.

MATLAB

MATLAB is a powerful software for mathematical computations and simulations. Accordingly the articles of this Wiki are accompanied by explanations how to use MATLAB for the particular topics of mathematics and robotics. The first MATLAB article provides some introducing information and an overview of the MATLAB articles .

To facilitate a better access to the actually commercial MATLAB software, a web-based MATLAB interface is provided within this Wiki.

Tip of the week

Did you know... ?

... that you can determine the inverse of a matrix with the Gauß-Jordan-Algorithm? more

Hint

The Robotics Wiki is extended continuously. For that reason some articles are provided with the hint, that they are still under development. Please consider that these articles are possibly incomplete and might contain errors.

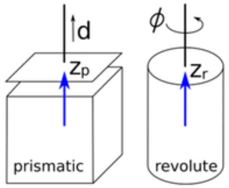
Other

- Material page of *Robotics*
- Homepage: GET Lab

Demonstration: Beispiel eines Artikels

Types of joints

← **Back:** Notation of links, joints and coordinate frames **Overview:** Denavit-Hartenberg Convention **Next:** Common normal →



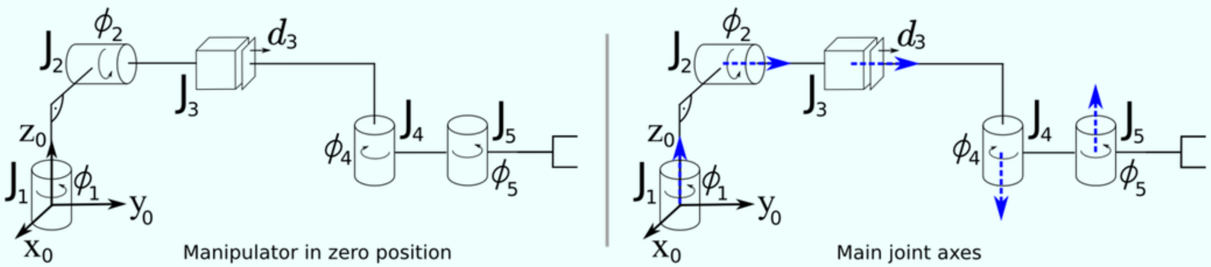
There are two types of joints used for robotic arms, each with one single degree of freedom. In the following the abstractions shown in the figure on the left will be used. The first type is the **prismatic joint**, that allows for translational movement along the joint axis. The displacement is described by the joint variable, for example d like in the figure. The direction of the positive displacement is always indicated with a small arrow. The second joint type is the **revolute joint**. A revolute joint allows for a rotation about the joint or rotation axis, respectively, and its joint parameter is the rotation angle, named ϕ in the figure. The curved arrow around the rotation axis indicates the rotation direction for positive angles. The Puma560 for example has three revolute joints, marked as J_1, J_2 and J_3 in the figure on the right.

For the assignment of coordinate frames, the **main joint axes** are important. Like can be seen as blue arrows in the above figure on the left, the main axis z_p of a prismatic joint is the axis along which the displacement in positive direction is applied. For a revolute joint, the main axis z_r is the rotation axis. The direction of the rotation axis and so of the main axis is depending on the positive rotation direction. When you hold your right hand like shown on the right and point your thumb in the direction of the rotation axis, the four other fingers indicate the rotation direction for positive angles. So the right hand can be used to determine the direction of the main axis. In the figure on the left, the thumb of the right hand has to point upwards, so that the four fingers correspond to the direction of the arrow indicating the positive rotation direction. Thus the main axis is directed upwards as well.

Example: *The main joint axes of a manipulator*

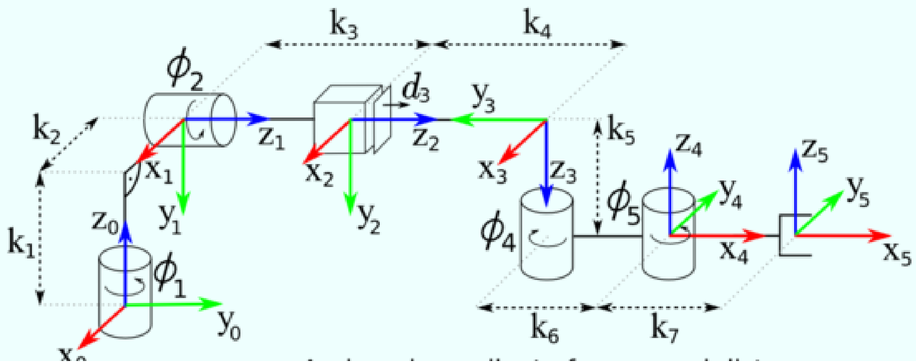
The left side of the figure below shows a manipulator consisting of 4 revolute joints and one prismatic joint.

Regarding the arrows indicating the rotation direction and using the right hand rule, the main joint axes can easily be determined for the revolute joints. For the prismatic joint it is quite easier, as the arrow is already showing the positive direction of the translation. The resulting main joint axes are shown as dashed blue arrows on the right side of the figure.



Example: *Determination of the Denavit-Hartenberg parameters*

The table below contains the Denavit-Hartenberg parameters for the manipulator shown in the figure on the right. For further information about the already assigned coordinate frames, have a look on the examples of the previous articles. The necessary lengths of certain parts of the manipulator are indicated by the variables k_1 to k_7.



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Example: *The common normals of a manipulator*

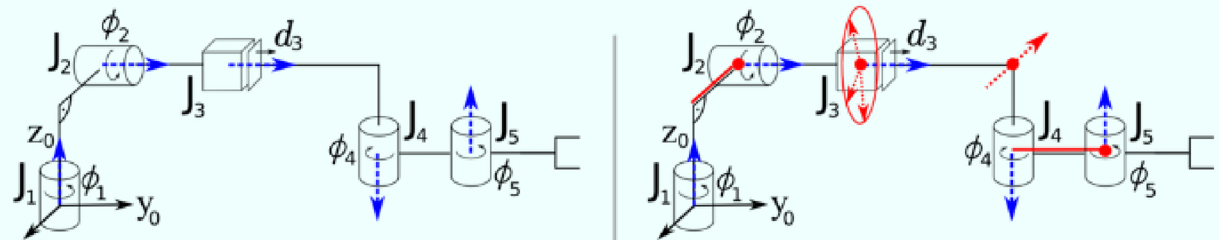
The left side of the figure below shows a 5-link manipulator in its zero position with already assigned main joint axes. The common normals now are determined based on each two consecutive main joint axes. The result is shown on the right side of the figure.

The main axis of J_1 is pointing upwards and the one of J_2 to the right. As J_2 is translated along the negative x_0-axis into the figure, the two lines are non-intersecting. This is the general case. So the shortest line perpendicular to both lines is pointing into the figure at the height of J_2. This is shown as a dashed red line with a red dot at its end.

For J_2 and J_3 we have the *collinear* case. So the length of the common normal is 0 and both its position along and its orientation about the line are not distinct. In such a case the position is chosen at the origin of the distal joint. This and the choice of the direction are explained in the next article about the assignment of coordinate frames.

The axes of J_3 and J_4 intersect. So this is special case 2. The length of the common normal is 0. But its location (red dot) and direction (dashed red arrow) are distinct.

Special case 1 appears between J_4 and J_5 because the two main joint axes are antiparallel. Thus the direction of the common normal is distinct and shown as a red line with a red dot at the end. Its location along the axes is not unique. In such cases, the origin of the distal joint is chosen for simplification. Further information about this follows in the article about the assignment of coordinate frames



Manipulator in zero position

Common normals

Demonstration: Aufgaben zum Selbsttest

Selftest: Multiplication of matrices

← **Previous exercise:** Addition of matrices | **Exercises** for chapter Matrices | Article: Multiplication of matrices | **Next exercise:** Determinant of a matrix →

- Right
- Wrong
- Not answered

1. Consider the matrix multiplication $\mathbf{A} \cdot \mathbf{B}$. Which statement describes the requirements for this multiplication correctly?

- ○ number of rows of $\mathbf{A}$ has to equal number of colums of $\mathbf{B}$
- ○ number of rows of $\mathbf{A}$ has to equal number of rows of $\mathbf{B}$
- ◉ number of colums of $\mathbf{A}$ has to equal number of rows of $\mathbf{B}$
- ○ number of colums of $\mathbf{A}$ has to equal number of colums of $\mathbf{B}$

2. Which dimensions does the resulting matrix of a multiplication of an l-by-m with an m-by-n matrix have?

- ○ m-by-m
- ◉ l-by-n
- ○ l-by-m
- ○ m-by-n

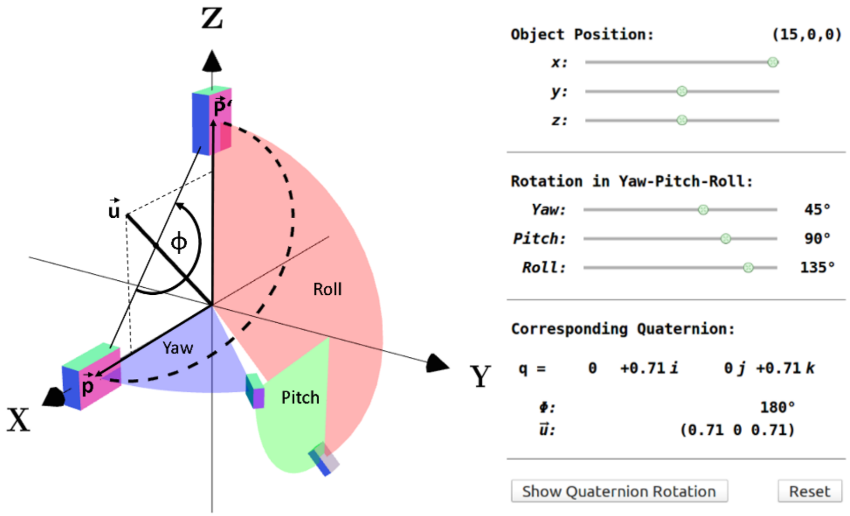
3. Mark the correct calculation specification for the following matrix multiplication:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ b_{31} & b_{32} \end{bmatrix} =$$

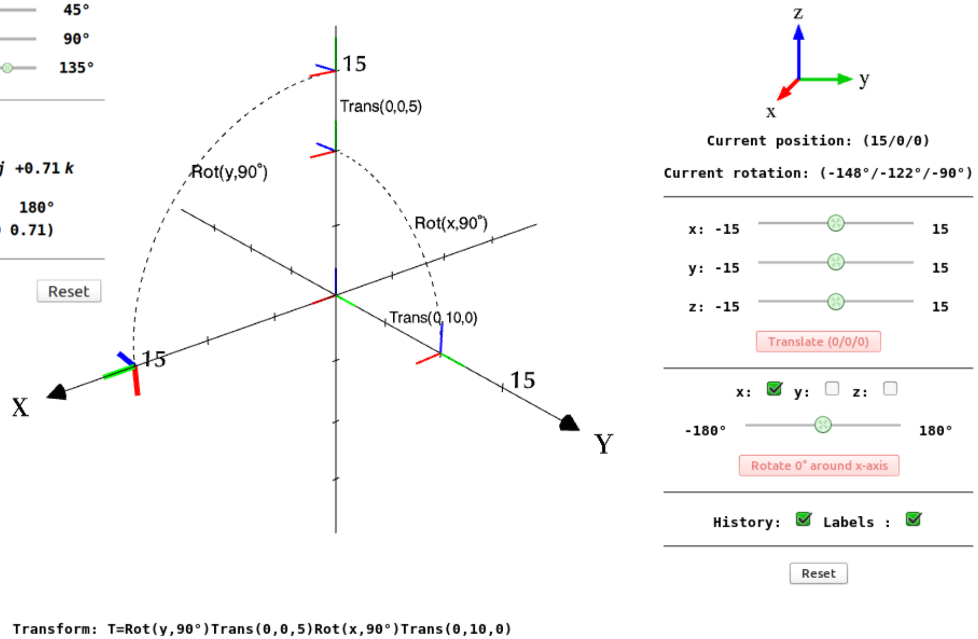
- ○ $\begin{bmatrix} a_{11}b_{11} & a_{12}b_{21} & a_{13}b_{31} \\ a_{21}b_{12} & a_{22}b_{22} & a_{23}b_{32} \end{bmatrix}$

Demonstration: Interaktive 3D Visualisierungen

Anschauliche Verdeutlichung komplexer technischer und mathematischer Zusammenhänge und Motivationssteigerung, direkt im Browser ausführbar.



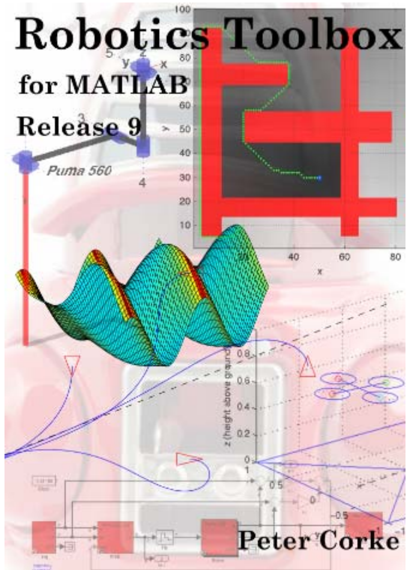
Yaw-Pitch-Roll und Quaternionen



3D Transformationen

Demonstration: Octave und Robotics Toolbox (I)

- Modifikation der für Matlab entwickelten Robotics Toolbox [Corke, 2011] zur Nutzung mit der freien Software Octave.
- Einbettung in das Wiki (keine Softwareinstallation), Verwendung in Präsenzveranstaltungen und zu Hause.
- Zusätzliche Artikel zur Erklärung der Verwendung der Toolbox.

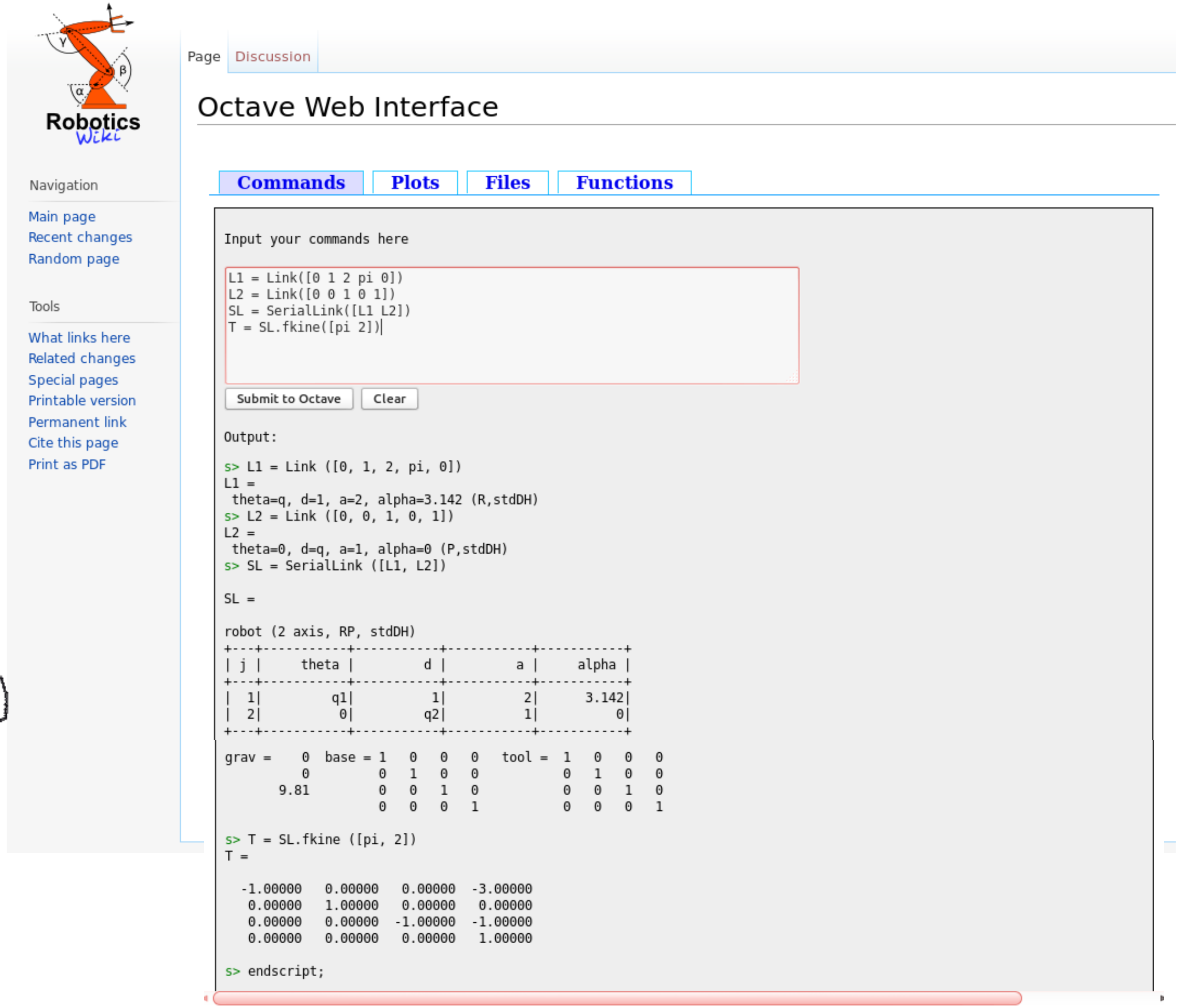


MATLAB

Demonstration: Octave und Robotics Toolbox (II)

Ausführung des Codes unmittelbar im Wiki.

Beispiel:
Konfiguration eines seriellen Manipulatorarms und Berechnung der Vorwärtskinematik.



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Evaluierung

- Abschlussphase der Entwicklung des Robotics Wikis.
- Evaluierung in Anlehnung an Wiki für den Einsatz in Grundlagenveranstaltungen [Hennig & Mertsching, 2015].
- Evaluierung wird zur Zeit durchgeführt.
- Fragebögen und Eingangstest insbes. zu linearer Algebra [Nickchen & Mertsching, 2016].

Einige vorläufige Ergebnisse:

- Kaum Schwierigkeiten z. B. bei Vektorrechnung, Multiplikation von Matrizen mit Skalaren, Transposition.
- Große Schwierigkeiten z. B. mit Kreuzprodukt, Matrizenmultiplikation und Matrixinversion.