

# Walking Robot Workshop

step gait kinematics motion

NTK

50°6'14.083"N, 14°23'26.365"E

Národní technická knihovna

National Library of Technology

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# What is written in the heading?

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... today, we are about to create a »hello world« alà robotics.

# Today's Workshop

## Workshop Goals

- Make robots walk with own program.
- Describe the walk mathematically.
- Get advanced insight into robotics.
- See, that STEM is worth learning.  
... A to vše za pouhé 4 hodiny.

## Rules

- Investigate, invent, try out!
- Cooperate as you want!
- No abrupt movements with the robots.
- Work in Plocha/roboty/<today>.

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Slides are Online



[https://gitlab.fel.cvut.cz/crl/public/courses/kracejici\\_robota\\_ntk](https://gitlab.fel.cvut.cz/crl/public/courses/kracejici_robota_ntk)

# Our Robots – Today's »Robota«

Hexapod ~ ant



ROBOTIS PREMIUM King Spider

- 6 legs, 3 joints per leg.
- 24 degrees of freedom altogether.
- Statically stable walk is possible.
- Different gaits - 3pod, 4ped, 5pod...

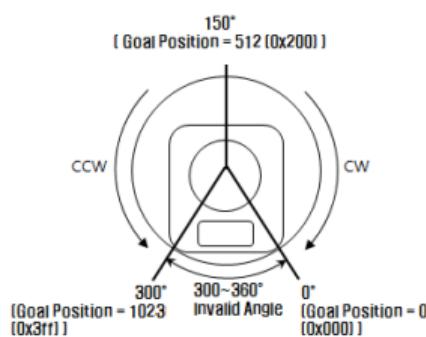
Humanoid ~ biped ~ člověk



- 6 joints per leg, 3 joints per arm.
- 18 *controllable* degrees of freedom.
- Walk not stable!



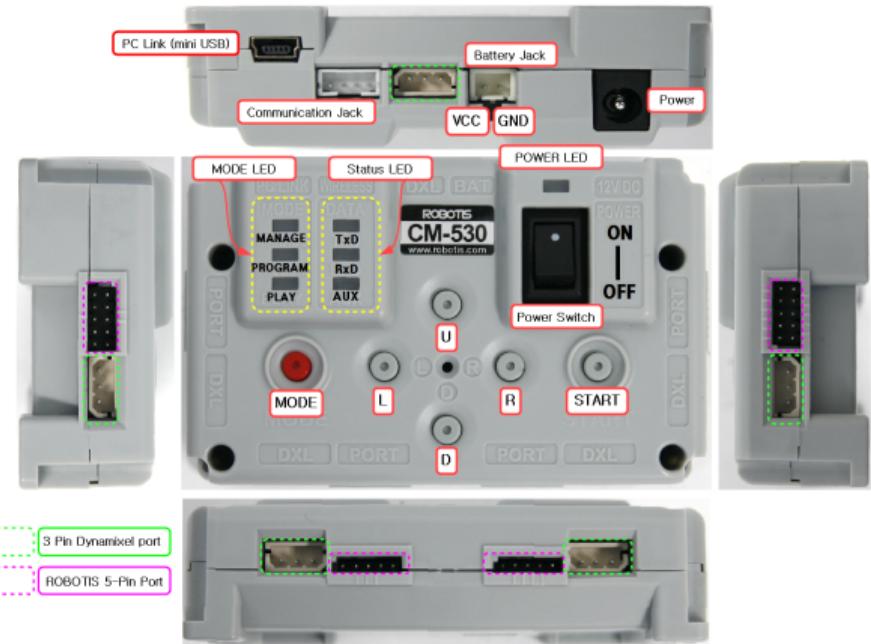
Two lines = 330°



## Robotis Dynamixel AX-12W

- DC gear electromotor with position control.  
(Beware! Shock may damage the gearbox!)
- Position feedback by potentiometer.  
(Dead angle! Rotor can not stop upside down.)
- Commanded from control unit by digital protocol.  
(Each servo was assigned unique ID number!)
- We can read or set different servo properties.  
(Speed, maximum torque, angle, temperature, stall...)
- Reference manual here.

# Control Unit

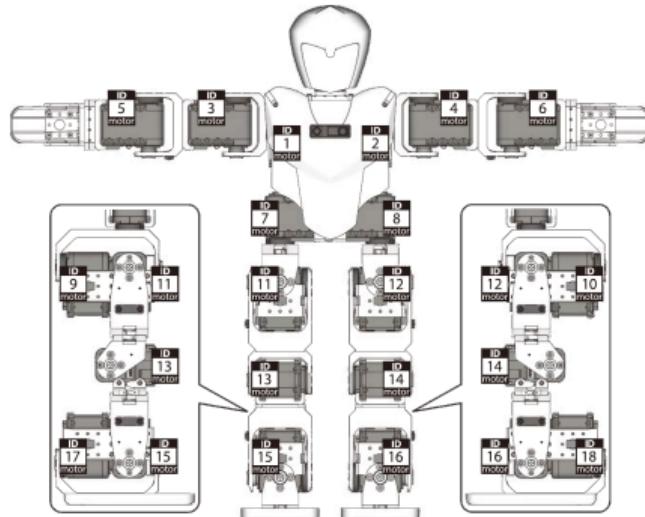
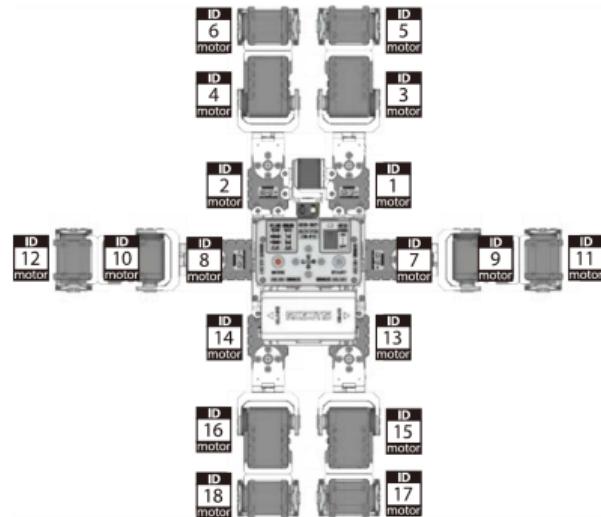


STM32F103RE ARM MCU, 72 MHz, 512 kB

- Stores and executes programs controlling the servos.
- Programmed in PC graphical interface, flashed over USB.
- Online servo inspection.
- Red button to choose »play« mode, then press »start«.
- Kill program with red button.
- Power switch in emergency.

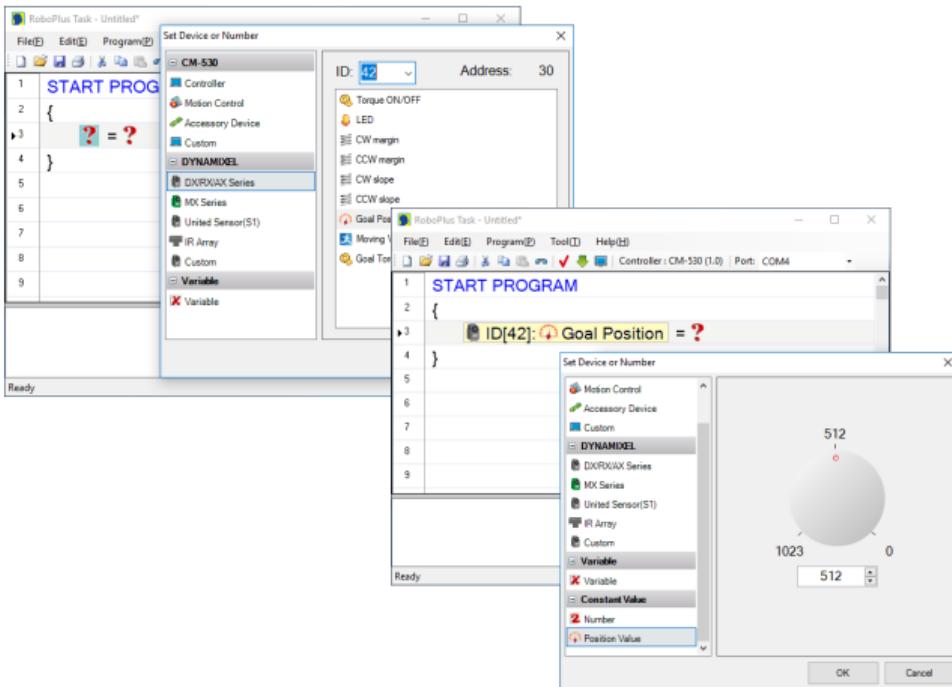
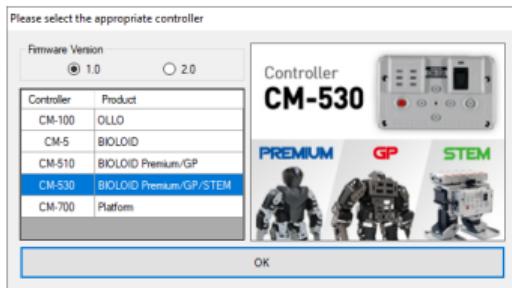
# Task: Get to Know Your Robot

- Move the robot by hand.
- See how the robot moves.
- »RoboPlus Manager« displays angles.
- Draw a robot schematics.
- Mark angle reckoning orientation.
- Where is fixed the stator/rotor?



# Task: First Steps

1. Launch »RoboPlus« → »Task«.
2. New file, choose controller type.
3. Spacebar to insert empty line.
4. Double-click to insert code.
5. Set some/all servos to 0°.
6. Upload over correct COM port.



Only one app can be connected to the robot at a time.

# [Hexapod] Task: Waving the Leg

!!! Preset movement speed may be high!

1. Set all servos movement speed to 50.
2. Set all servos angle to zero.  
(Hence define robot's initial pose.)
3. Make a leg to move there & back again.
- !! Servo is a »worker«, just follows orders.  
If the »boss« (CM-530) makes two set-angle commands without waiting, only the latter effectively happens.
4. Use WAIT WHILE with Is Moving.

[CM-530]-ukol-kvani-hexa-2

```
1: START PROGRAM
2: {
3: // Zapnutí výkonu serv
4: [ID[All]]: ⚡ Torque ON/OFF = TRUE
5: // Nastavení rychlosti serv.
6: [ID[All]]: ⚡ Moving Velocity = 50
7: // Nastavení základní pozice robotu.
8: [ID[All]]: ⚡ Goal Position = 512
9: Timer = 2.048sec
10: WAIT WHILE (Timer > 0.000sec )
11: // Kývání pravým středním femurem
12: LOOP FOR ( i = 0 ~ 6 )
13: {
14: [ID[9]]: ⚡ Goal Position = 860
15: WAIT WHILE ([ID[9]]: ⚡ Is Moving == TRUE )
16: [ID[9]]: ⚡ Goal Position = 512
17: WAIT WHILE ([ID[9]]: ⚡ Is Moving == TRUE )
18: }
19: // Povolení serv - zabráníme přehřívání
20: [ID[All]]: ⚡ Torque ON/OFF = FALSE
21: }
```

# [Humanoid] Task: Waving the Leg

- Humanoid is complex. Simple zeroing the servo angles would cause clash.

1. Invoke »Motion Index 25«. This sets convenient initial robot pose.

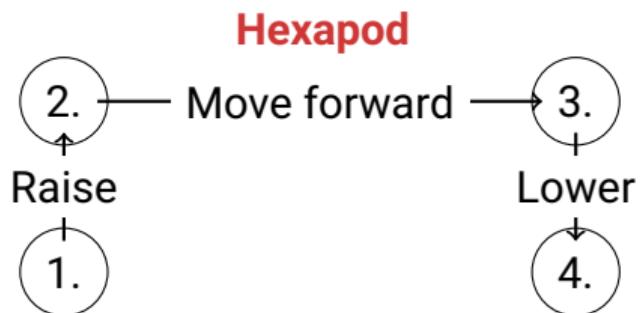
!!! Preset movement speed may be high!

2. Set all servos movement speed to 50.
3. Make a leg to move there & back again.
4. Always wait for complete motion.
  - Servos may overheat when on.
5. Turn servos off by setting »torque« off.

[CM-530]-ukol-kyvani-humanoid

```
1: START PROGRAM
2: {
3:   // Inicializace - počáteční poloha humanoida
4:   [Motion Index Number] = 25
5:   WAIT WHILE ([Motion Status] == TRUE )
6:   // Nastavení rychlosti pohybu
7:   [ID[All]; Moving Velocity] = 50
8:   // Kývání kyčlí
9:   LOOP FOR ( i = 0 ~ 5 )
10:  {
11:    [ID[8]; Goal Position] = 700
12:    WAIT WHILE ([ID[8]; Is Moving] == TRUE )
13:    [ID[8]; Goal Position] = 512
14:    WAIT WHILE ([ID[8]; Is Moving] == TRUE )
15:  }
16:  // Povolení motorů
17:  [ID[1]; Torque ON/OFF] = FALSE
18: }
```

# Task: Program One Leg Step

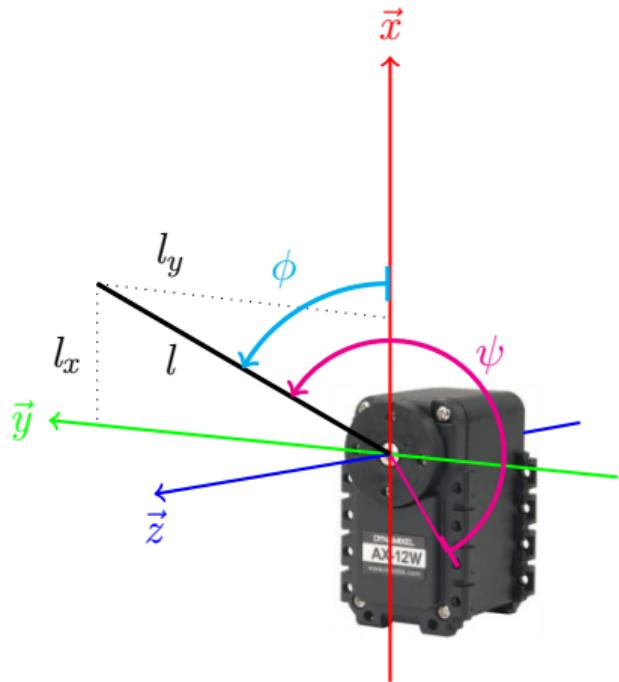


## Humanoid

- Mind the mass! Always catch the robot!
- »Motion Index 25« lowers the torso.
- Move only the ankle and hip.

- You need to identify which particular angles to set!
- Divide your work. (Each identify one leg...) Mind the servo orientation!
- There are different step trajectories. (Triangle, square, ellipse, adaptive, ...)
- Do not forget to wait before each intermediate move finishes.

# Servo Described by Math



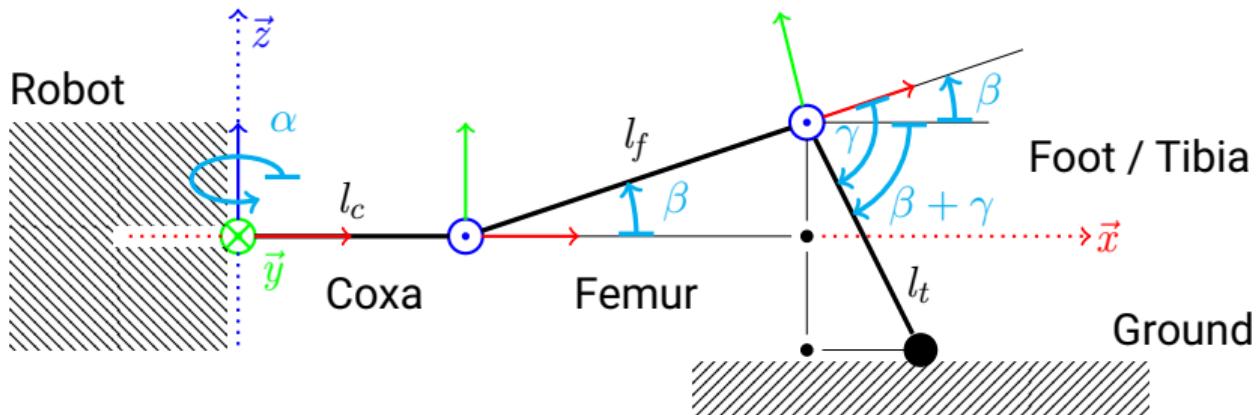
- Angle  $\psi$ : Defined by manufacturer.
  - (We set/read this when programming.)
- Angle  $\phi$ : Kinematically meaningful.
  - Positive angle along  $z$ -axis.
  - Zero-angle aligned with  $x$ -axis.
  - (Right-hand rule.)

$$l_x = l \cos(\phi)$$

$$l_y = l \sin(\phi)$$

$$\phi = \psi - 150^\circ$$

# Leg, a.k.a. kinematic chain



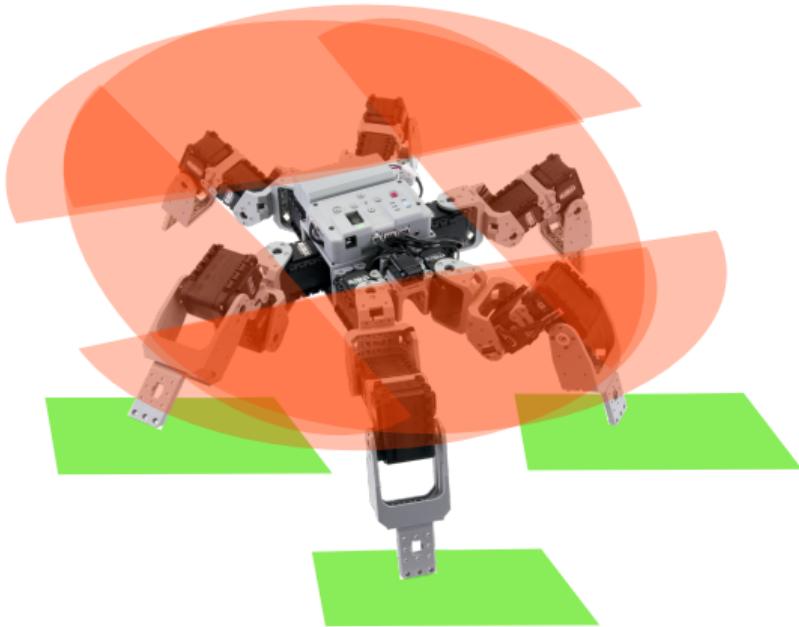
Direct kinematic task: Servomotor angles → foot coordinates.

$$x_{chod.}(\alpha, \beta, \gamma) = \cos(\alpha) [l_c + l_f \cos(\beta) + l_t \cos(\beta + \gamma)]$$

$$y_{chod.}(\alpha, \beta, \gamma) = \sin(\alpha) [l_c + l_f \cos(\beta) + l_t \cos(\beta + \gamma)]$$

$$z_{chod.}(\alpha, \beta, \gamma) = l_f \sin(\beta) + l_t \sin(\beta + \gamma)$$

# Motion Limitations



- Robot has many degrees of freedom.  
Can it use them fully?
- Joint angles are limited by design.
- Leg operation space intersects.
- Walk needs to take this into account!
- Also, environment might get in the way.  
(Terrain, obstacles, people, machines...)

1. Wrap a code for a single step into »function«.
2. Make such function for each leg. Double-check the IDs.
3. Servos may be oriented differently at each leg. Check it.
4. [Hexapod] Make a function to move all Coxas backwards, moving the robot forth.
5. Call the functions in meaningful order.

## **BEWARE!**

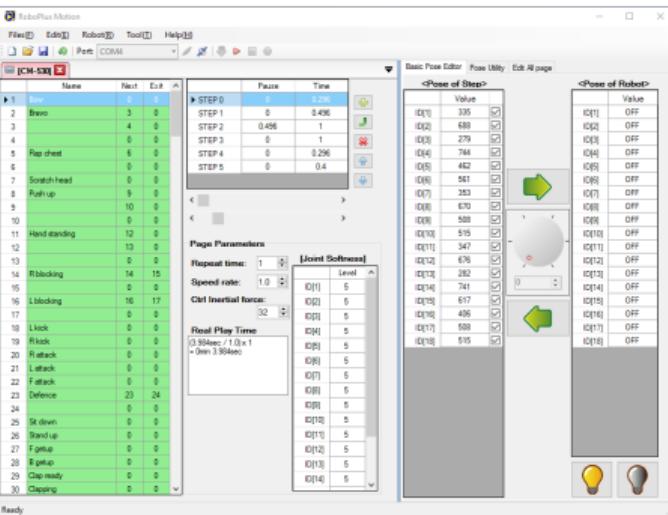
- Pay attention to leg collisions.
- Adjust the walk parameters to avoid collisions.

# Preprogrammed Motions

- Robot has several preprogrammed motions always ready.
- Use »RoboPlus Motion« to play them back.
- You can launch the motions also programmatically.

[CM-530]-stub-motion

```
1: START PROGRAM
2: {
3: // Začne vykonávat přednastavený cvik.
4: Motion Index Number = 42
5: // Program je třeba zastavit dokud není cvik dokončen.
6: WAIT WHILE ( Motion Status == TRUE )
7: }
```



Robots are furnished with distance sensors and microphone to detect clapping.

[CM-530]-stub-distance

```
1: START PROGRAM
2: {
3:     // Vyčtení hodnoty do proměnné
4:     přečteno = PORT[1]:IR Sensor
5:     // Použití hodnoty přímo v programu
6:     IF ( PORT[1]:IR Sensor <= 100 )
7:     {
8:         // ...
9:     }
10:
11:    // Senzor tlesknutí - čekám na jeden tlesk.
12:    Result of Sound Counter = 0
13:    WAIT WHILE ( Result of Sound Counter < 1 )
14:    // Zahraji melodi.
15:    Buzzer Time = Play Melody
16:    Buzzer index = Melody2
17:    WAIT WHILE ( Buzzer Time > 0 )
18: }
```



# Final Task: Make the Robots Dance

1. Robot waits until there is a clap.
2. Then, it executes some motion.
3. Then, waits for another clap.
4. Then, different motion is executed.
5. ... or anything you imagine.
6. Use sensors to avoid obstacles.
7. Accelerate the hexapod by »tripod gait«.

0x06(ACK) 0x03(EOM) 0x04(EOT) 0x19(EM) 0x1b(ESC)

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