Dribbling for Holonomic Robots

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Introduction

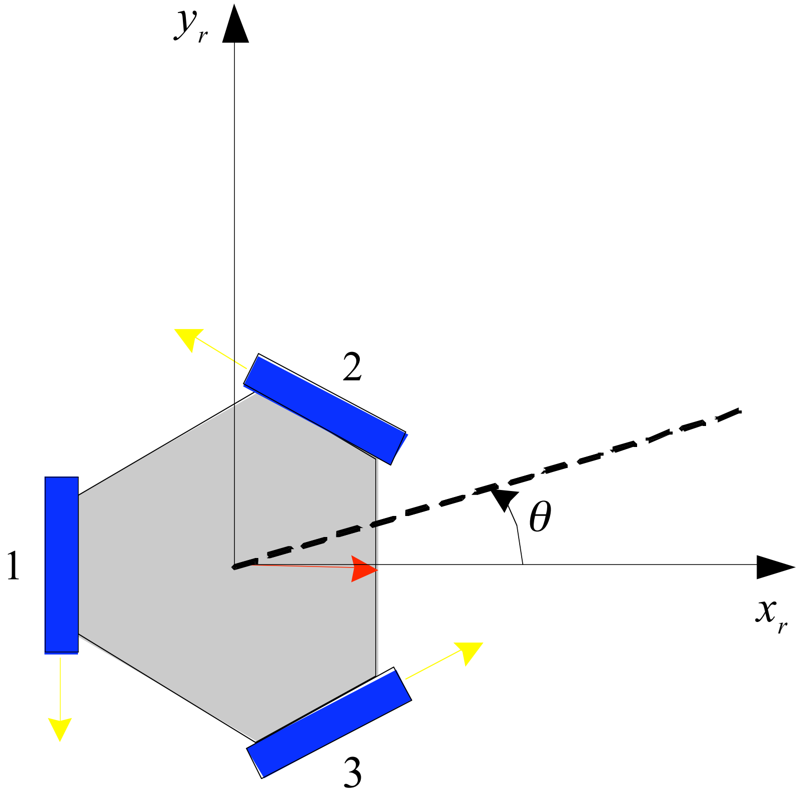
- Kinematics
- Frames
- Movements
- Potential Fields
- Dribbling
- Conclusion
- Q & A

- **Kinematics**

Kinematics

- **The direct kinematics is derived from the physical model of the robot,**
- **The inverse kinematics is obtained inverting the direct kinematics model,**
- **The direct and inverse kinematics are both assumed with respect to the robot’s frame.**

Kinematics – Physical model



Kinematics - Direct Kinematics

$$\begin{bmatrix} V_x \\ V_y \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{\sqrt{3}}r & \frac{1}{\sqrt{3}}r \\ -\frac{2}{3}r & \frac{1}{3}r & \frac{1}{3}r \\ \frac{r}{3l} & \frac{r}{3l} & \frac{r}{3l} \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix}$$

$$V_x = \frac{1}{\sqrt{3}} r(-\omega_2 + \omega_3)$$

$$V_y = \frac{1}{3} r(-2\omega_1 + \omega_2 + \omega_3)$$

$$\dot{\theta} = \frac{r}{3l}(\omega_1 + \omega_2 + \omega_3)$$

Kinematics – Inverse Kinematics

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{r} & \frac{l}{r} \\ -\frac{\sqrt{3}}{2r} & \frac{1}{2r} & \frac{l}{r} \\ \frac{\sqrt{3}}{2r} & \frac{1}{2r} & \frac{l}{r} \end{bmatrix} \begin{bmatrix} V_x \\ V_y \\ \dot{\theta} \end{bmatrix}$$

$$\omega_1 = \frac{1}{r}(-V_y + l\dot{\theta})$$

$$\omega_2 = \frac{1}{r}(-\frac{\sqrt{3}}{2}V_x + \frac{1}{2}V_y + l\dot{\theta})$$

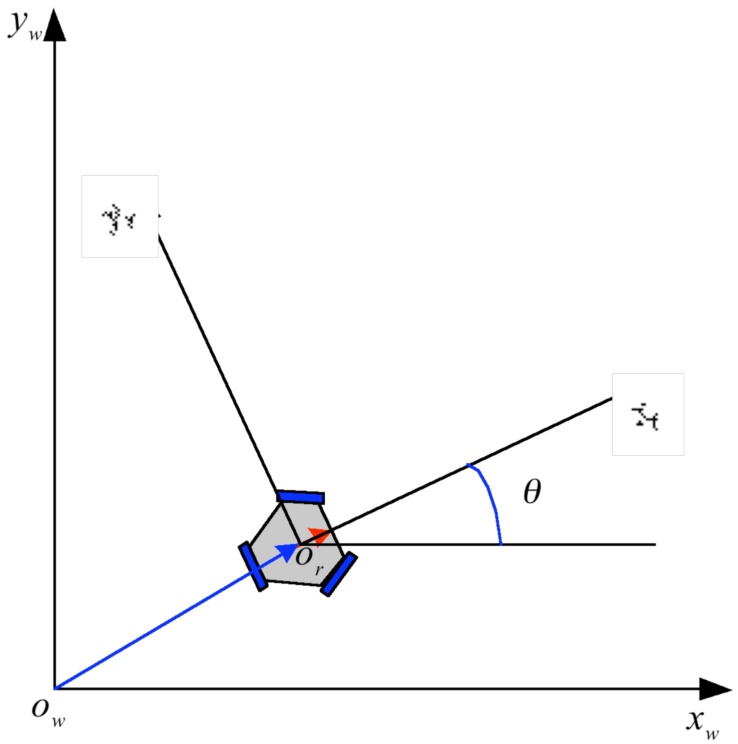
$$\omega_3 = \frac{1}{r}(\frac{\sqrt{3}}{2}V_x + \frac{1}{2}V_y + l\dot{\theta})$$

- **Kinematics**
- **Frames**

Frames

- **For soccer robots, a set of transformations between robot and world frames, and vice-versa is very important;**
- **Position conversion:**
  - **Robot to world frame;**
  - **World to robot frame;**
- **Velocity conversion:**
  - **Robot to world frame;**
  - **World to robot frame;**

Frames – Position conversion



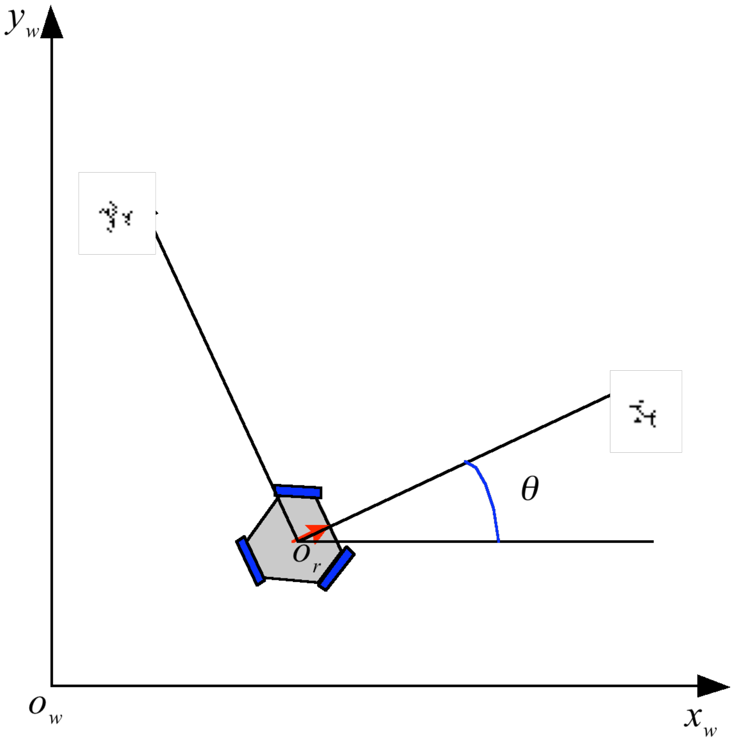
- **Robot's world frame position from robot's robot frame position given by:**
  - **$P_w = T.R.P_r$;**
- **Robot's robot frame position from robot's world frame position given by:**
  - **$P_r = R^{-1}.T^{-1}.P_w$;**
- **More precisely…**

Frames – Position conversion

$$\begin{bmatrix} x_w \\ y_w \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} x_r \\ y_r \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x_r \\ y_r \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} 1 & 0 & -t_x \\ 0 & 1 & -t_y \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} x_r \\ y_r \\ 1 \end{bmatrix}$$

Frames – Velocity conversion



- Velocities conversion between frames is affected solely by robot's orientation,
- Robot frame velocities to world frame velocities is given by:
  - $V_w = R.V_r$;
- World frame velocities to robot frame velocities is given by:
  - $V_r = R^{-1}.V_w$;
- More precisely…

Frames – Velocity conversion

$$\begin{bmatrix} vx_w \\ vy_w \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} vx_r \\ vy_r \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} vx_r \\ vy_r \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} vx_w \\ vy_w \\ 1 \end{bmatrix}$$

- **Kinematics**
- **Frames**
- **Movements**

Movements

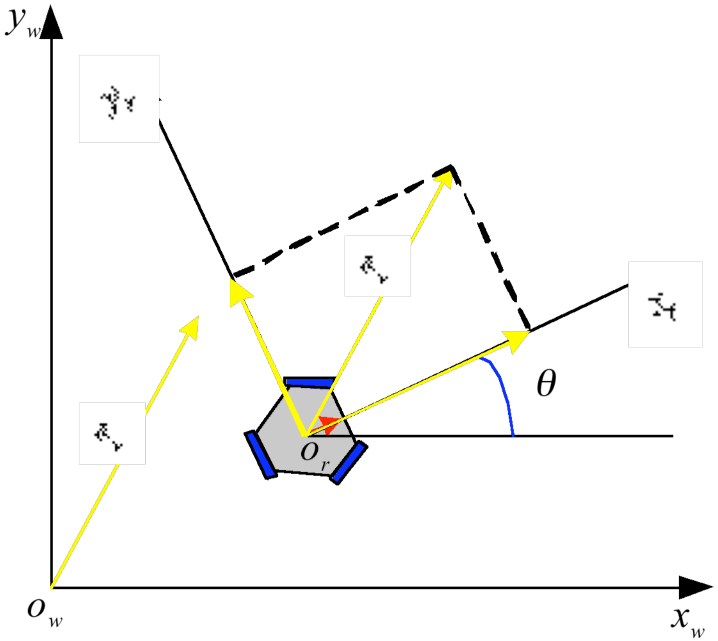
- **With Holonomic robots the set of movements can be restricted to two kinds:**
  - **Basic:**
    - **Kind of movements that can be achieved without segmentation of the trajectory;**
    - **As consequence these can be achieved with fixed wheel speeds;**
  - **Complex:**
    - **Kind of movements that can be achieved with trajectory segmentation;**
    - **As consequence these can only by achieved with wheel speeds manipulations;**

Movements – Basic movements

- **Basic movements can be of two sorts:**
  - **Rectilinear;**
  - **Circular;**
- **Although basic, these movements are extremely important for the majority of the behaviors,**
- **Linear and rotational velocities of the robot are coupled;**

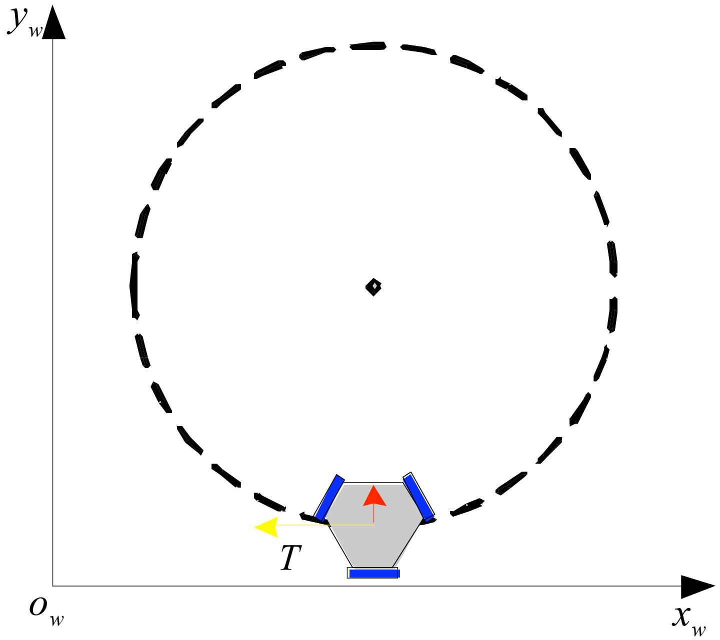
Basic movements - Rectilinear

- **Vector T represents the wished velocity,**
- **If T is described in the robot frame, we can use directly inverse kinematics;**
- **If T is described in the world frame, we have to transform them to the robot frame and use inverse kinematics;**



Basic movements – Circular

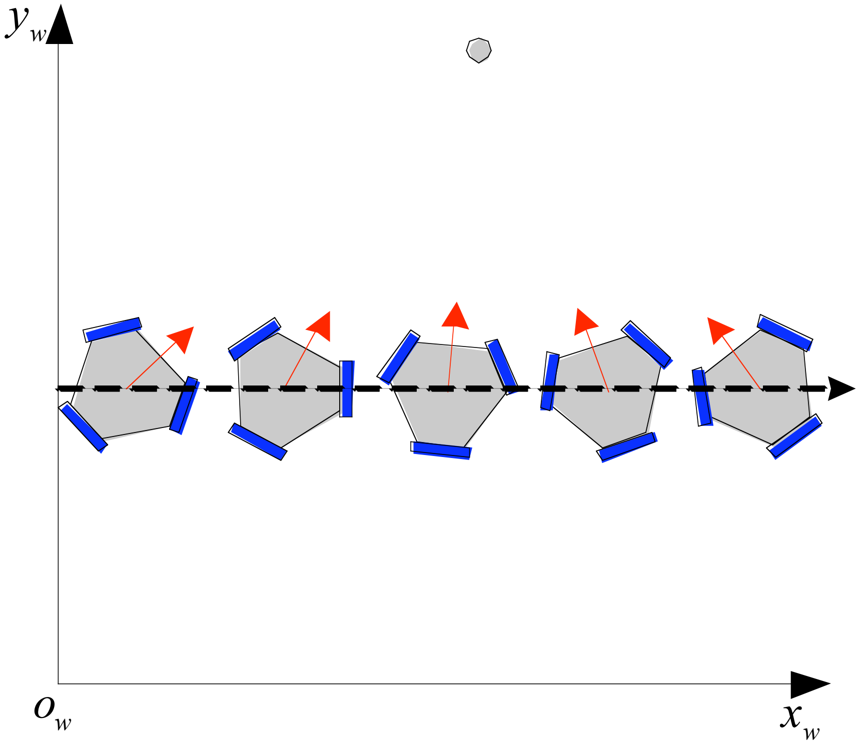
- §In this circular movements the robots assume a fixed posture w.r.t the trajectory;
- §For this movement ω specifies both the robot own rotation speed as the circular angular velocity;
- §The vector T needs only to be fixed w.r.t the robot’s frame;
- §V = r.ω ∫r = V/ ω, r being the radius of the circle path;
- §It’s quite intuitive;



Complex movements

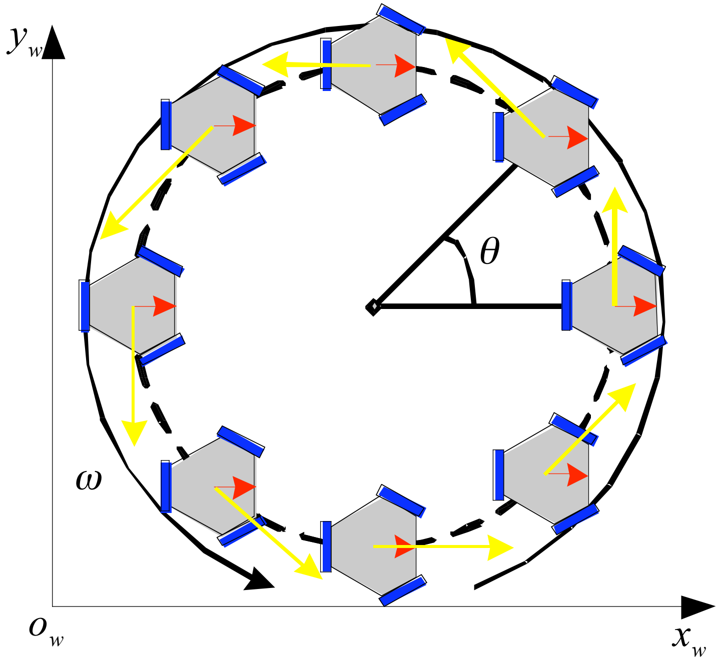
- **Complex movements can be of various sorts:**
  - **Rectilinear;**
  - **Circular;**
  - **Any other trajectory that can be composed with known paths;**
- **Complex movements can be devised with these basic movements,**
- **Linear and rotational velocities of the robot are decoupled;**

Complex movements - Rectilinear



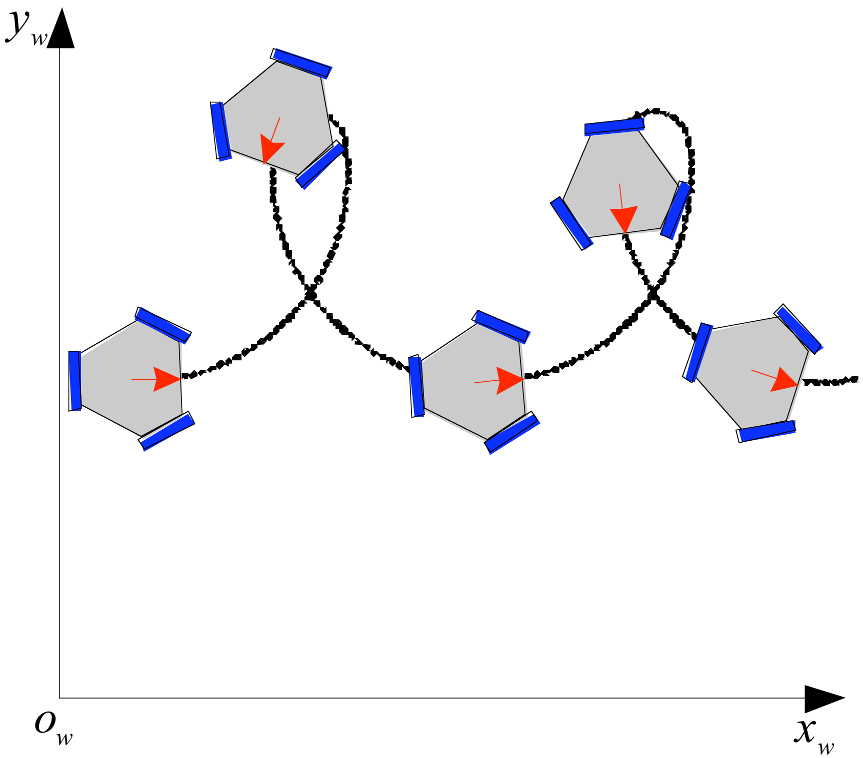
- This rectilinear movement which is just a particular case of complex movement is particularly useful for e.g. passing behavior,
- Can be easily achieved with world to model velocity transformation and inverse kinematics,
- Interpolation is the key;

Complex movements - Circular



- **This movement can be described with:**
  - **$V = \omega . r$, r being the radius of the circle;**
  - **V w.r.t the trajectory can be decoupled in Vx and Vy w.r.t the world frame:**
    - **$X = r.\cos(\omega t)$;**
    - **$Y = r.\sin(\omega t)$;**
    - **$Vx = - \omega . r.\sin(\omega t)$;**
    - **$Vy = \omega . r.\cos(\omega t)$;**
- **Use the inverse kinematics and we get the desired trajectory;**

Complex movements – Any other



- Using the basic movements we can follow any trajectories that can be decomposed in known trajectories;
- This particularly is the composition of a straight line and a circular motion;
- Once again, interpolation is the key;
- For all derived velocities generated for the circular motion add the linear velocity;

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- **Kinematics**
- **Frames**
- **Movements**
- **Potential Fields**

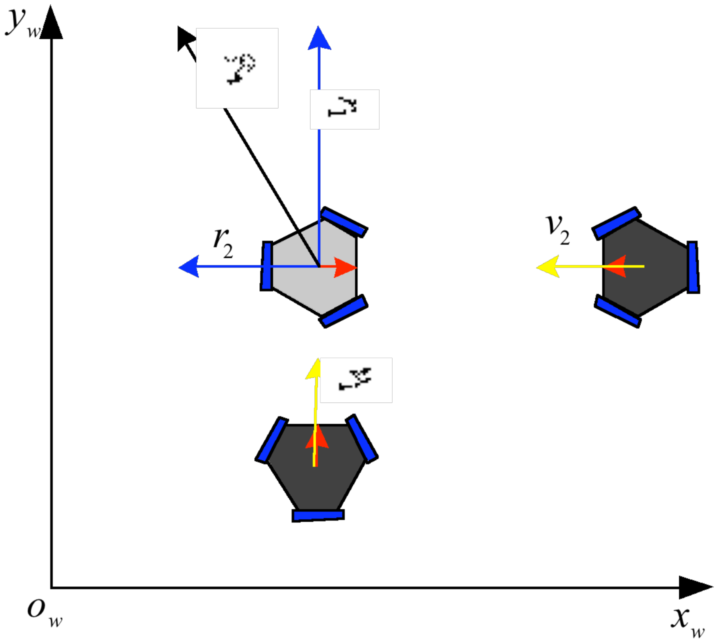
Potential Fields

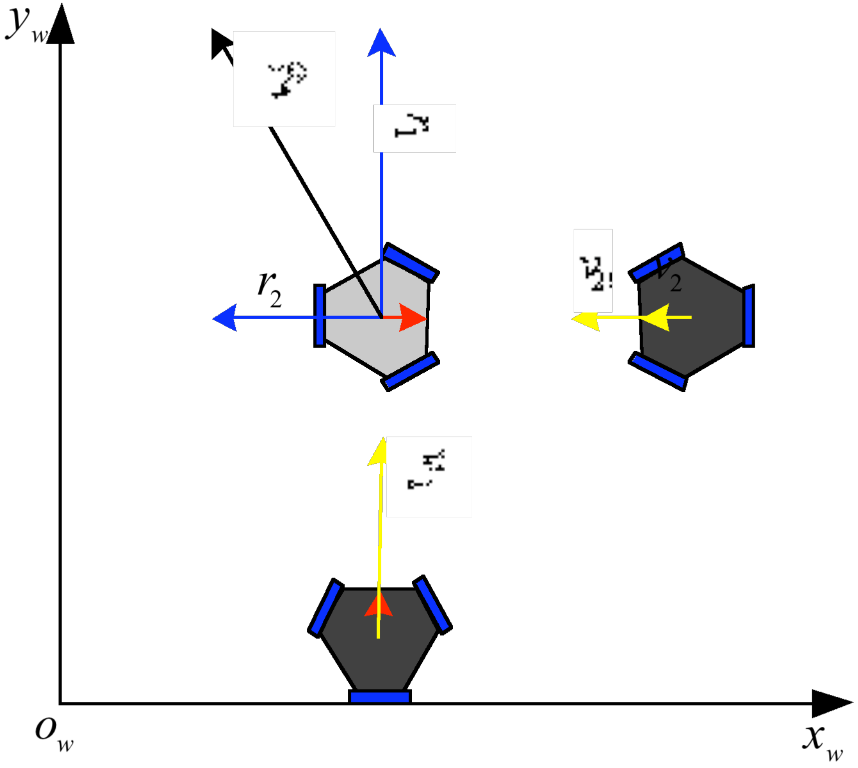
- **Rigid bodies are treated as particles;**
- **Repulsive and attractive forces exist between them;**
- **Did not take into account particles approaching velocities;**
- **Modification: Generalized Potential Fields, which takes into account particles approaching velocities;**

Potential Fields

- **Repulsive force is inverse-proportional to distance between particles and proportional to increase of approaching velocities between them;**
- **The attractive force will be restricted to particle (rigid body) motion characteristics;**
- **Very elegant as attractive forces and repulsive forces can be derived independently;**
- **The resulting force is a linear combination of the two derived forces;**

Potential Fields





- **Kinematics**
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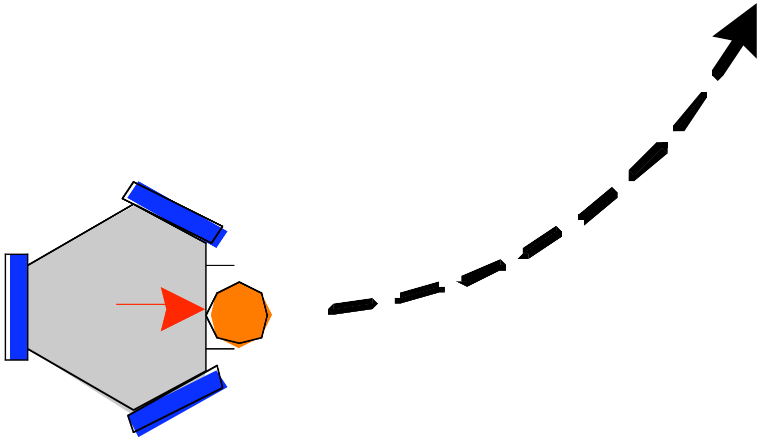
- **Potential Fields**
- **Dribbling**

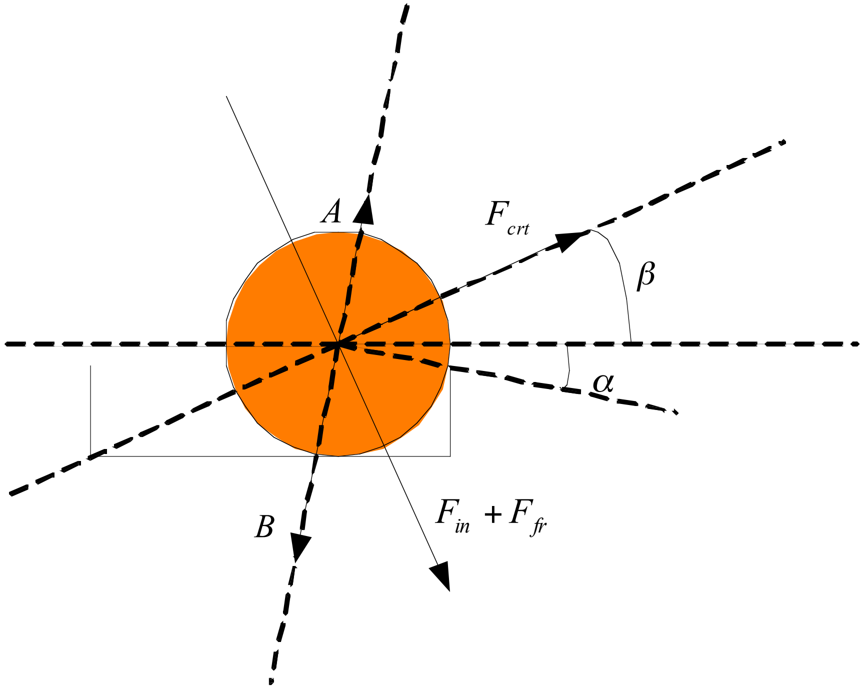
Dribbling

- Dribbling is mechanism through which the robot navigates in a obstacles environment without losing it and taking it to it's goal;
- The robot has flippers, the mechanism used to dribble the ball;

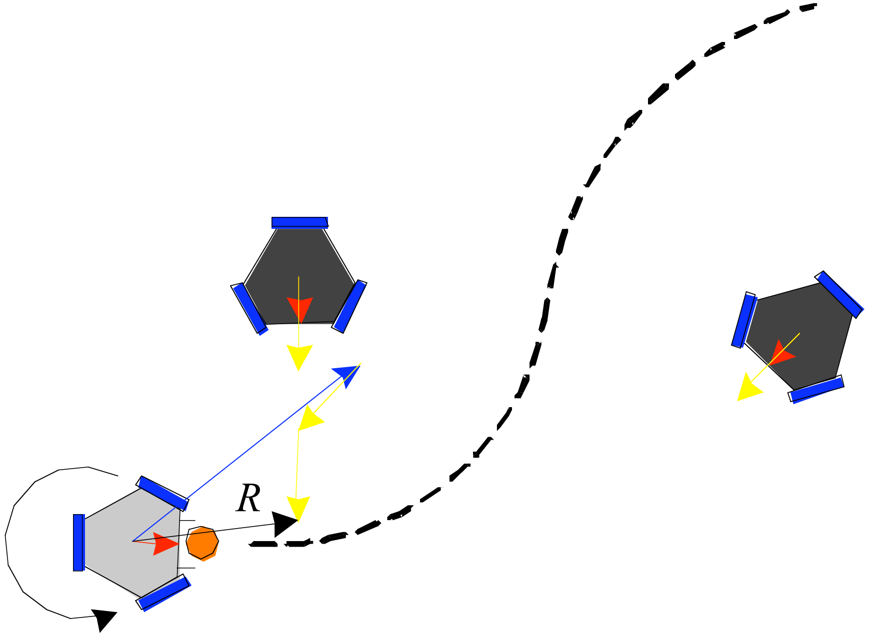


Dribbling

- To navigate through obstacles the inertial and friction forces exerted on the ball must overcome the torque originated by the centrifugal force;
- Forces exerted on the ball:
  - Inertial force;
  - Frictional force;
  - Centrifugal force;
- Intuitively, as long as B's absolute value is bigger then A the ball is kept with the robot;

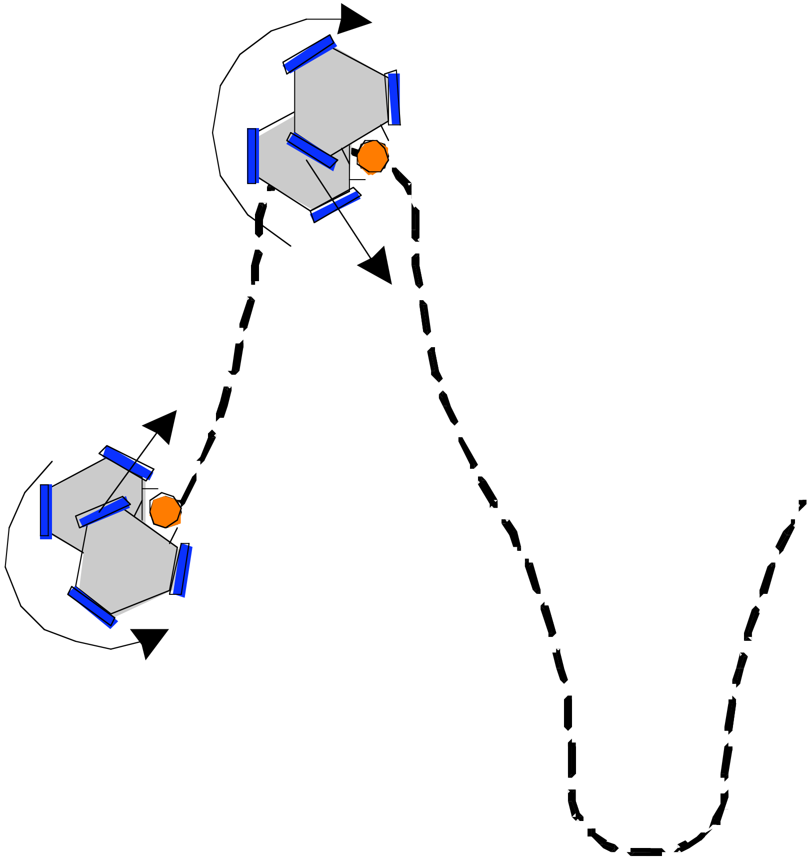


Dribbling



- Dribble is applied to the result force;
- Potential field algorithm is applied and the resulting force is calculated;
- Then the orientation of the robot can be modified in order to maintain the force equilibrium exerted on the ball;

Dribbling



- Using the set of movements implemented we can keep the ball in between the robot and the goal point, while always respecting the force equilibrium;
- This implementation is still intuitive and no tests have been made to see it working yet, it is currently under work;

- **Kinematics**
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- **Potential Fields**
- **Dribbling**
- **Conclusion**
- **Q & A**

Conclusion

- Basic set of movements are very useful;
- Complex behaviors can be easily implemented on the top of existing basic movements and other features;
- Dribbling is yet intuitively implemented;
- Later, will have strong mathematical foundation;
- No results at the moment;

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Q & A