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# Controlled Mobile Robot for Tracking a Moving Objects

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**Abstract:** This study takes into explication the requirements to plan trajectories for taking a roving target and manipulating it with two arm's mobile robots with 7 degree-of-freedom provided by a Barrett hand and a gripper in an environment that takes the barrier problems on consideration. For the robots in charge, the algorithm has as function to determine the necessary trajectory to catch the object based on an observation: when the object starts moving, the algorithm uses also some variables like the start configuration, the object's speed and the robot's model and the scene. This algorithm is an expansion of RRT-JT which exploits the Jacobian-based gradient descent to coach a 7-DoF WAM robotic arm with a dynamic base and a robot gripper in sort to generate the shortest time path for the capture procedure while avoiding obstacles. Finally, we present empirical studies on tracking and capturing the strolling object with our mobile robot and we compare the results of two robots.

**Key words:** Mobile robot, trajectory, obstacles, moving tracking, planning, observation

## INTRODUCTION

Mobile robots have many application areas thanks to their high workability. Researchers have exhibited an interest in mobile robots. So, it's important to have mobile robots able to process moving targets. The problem of revealing and pursuing of roving objects using the volatile manipulator is a compound task (Cohen and Medioni, 1999). The issue of seizure a roving thing in the existence of holdbacks with an automatic manipulator was exposed by a lot of studies. Many studies have treated the handling navigation problem for a manipulator to avert collisions withobstacles (Pandey and Parhi, 2016; Bhagat *et al*., 2016). The capability of the robots to catch objects is substantial and the motion planning of prevailing the manipulator to size the items without clash has been thoughtful for an extended time. Rapidly-exploring Trees (RRTs) is one of the sampling-based of the planning algorithm (Kuffner and Valle, 2000) and Probability Roadmap (PRM) (Kavraki *et al*., 1996) algorithms are public in new years for the reason that of their capability of fast discovering the connection of high-dimensional configurated spaces. However, the aspire of the manipulator over human-robot interaction is not steady but dynamic. The movable robot had become an essential research topics. Most published research in control of movable manipulator behold its dynamics and kinematics (Siegwart *et al*., 2016).

To grasp dynamic moving targets (Gariepy *et al*., 2015; Bavithra *et al*., 2016) use the camera to evidence images of dynamic objects, after that they analysed their images to appreciate the placement to grasp it. This way is difficult necessitating an assortment of reckoning, picture processing and record images. The object localization is a very complex process in traditional algorithms. Moreover, the use of the predictive algorithms may cause different issues in the complexity of the algorithms that are based on many calculation and estimation. In this research, we propose an approach allowing to control two arms of a humanoid robot. The goal of our approach is to avoid obstacles while moving objects and grasping it without a camera. We propose an algorithm which is a stretching of RRT-JT to generate the shortest time path to apprehend the mobile object which avoiding obstacles. Finally, LQR method is employed for tracking purposes.

We present how to clutch a mobile target with a fixed manipulator the object shifts within a sphere which the diameter is the arm's length, therefore where the object moves fast and leave the sphere the robot can't grasp it anymore. To avoid that situation where the object proceeds fast, we utilize a mobile robot which is an assembly of two main components: a mobile base and a WAM arm.

**Literature review:** Each in previous research, researchers have divided the matter of moveable manipulation planning into four master techniques: navigation planning of the robot's base, path planning for a robot's arm, grasping and frameworks for generic manipulation

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planning. There are many researchers who are concerned in object discovery and tracking using mobile robot under unknown dynamic environments (Flacco *et al*., 2012; Almasri *et al*., 2015; Ali *et al*., 2016; Stilman *et al*., 2007; Hirano *et al*., 2005), approaching the motion planning problem was based on placing the end effector at pre-config locations, counted utilising the Inverse Kinematics (IK) used to some primary samples possessed from the goal region. These locations are consequently collected as an objective for a randomized planner, like an RRT or BiRRT (Damian, 2006). The solution offered by this way remains deficient because of the miss deem probabilistic aspect and the planner is obliged to utilize numbers priori chosen from the goal regions. As described by Bertram *et al*. (2006), the planning of the grasp can be tackled as follow:

- We explore, first, the robot's configuration using a research tree based on heuristics
- Then, we attempt to thrust the exploration across a goal region

Nevertheless, the aim regions and the heuristics given in the research (Drumwright and Hing, 2006) are highly problem particular to generalize and difficult to adjust. The approach introduced by Weghe *et al*. (2007) uses for a given workspace point an identical strategy extending toward an IK solution that is randomly generated. The researchers by Berenson propose the RRT-JT algorithm. They use a forward-searching tree to reconnoitre the Configuration space (C-space) and a gradient-descent heuristic. The gradient-descent heuristics anchored on the Jacobian-transpose to alignment the tree across a work-space target point. Two probabilistically full planner algorithms are introduced in Weghe. The first algorithm is a stretching of RRT-JT and the second one is a modern algorithm dubbed IKBiRRT. Both algorithms use the interleaving mechanism for exploring the robot's C-space with utilization of WGRs (Workspace Goal Regions). The prolonged RRT-JT is destined for robots that do not have this algorithms. It join the configuration space reconnoitring of RRTs with a workspace aim bias for producing direct paths in complex and highly efficient environments without the necessity of any inverse kinematics.

Serval research works are proposed in mobile manipulation. The approaches (Seraji, 1998) and (Yamamoto and Yun, 1994) study the mobile control issues while Nagatani and Yuta (1996) show a command way to the chore of door aperture. The method offered in (Jin, 2014) can be utilized for representing, tracking and human following by integrating multiple visions of distributed systems in robotic space. The swift road introduced by Liu *et al*. (2014) is able to rapidly organizing the arm griping and spotting manipulations for movable robot carrying systems in life science laboratories. The researchers by Thorat and Nagmode (2014) propose a scheme for detect the moving object. This scheme uses an adjust strategy based on the normalized cross correlation. It is clever to obtain, detect and pursue the object in frame sequence.

## MATERIALS AND METHODS

**System overview:** We utilize the OpenRAVE which is mostly used for storing the environment symbol of the manipulators, sensor situation, other scene pattern. We utilize the OpenRAVE Software to command the mobile robot whichprepared with Barrett hand, mobile base and WAM arm.

Our objective is to follow and pinch the travelling object which is our target while evading barriers in the environments. The approach in our paper uses an RRT-JT to determinate the target's position and to calculate the kinematics of the movable robot while avoiding obstacles.

The flow chart is in Fig. 1. Primary, we seek to locate the target and the obstacle, if it exist, we command the mobile robot to displace to the goal while avoiding the existing obstacle trajectory generation and object tracking/simulation should be done in parallel. At last, the robot seizes the target.

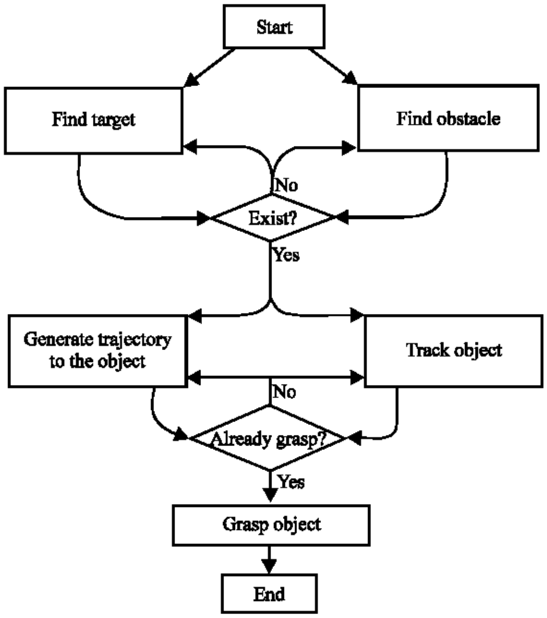

Fig. 1: Flow chart local motion planner

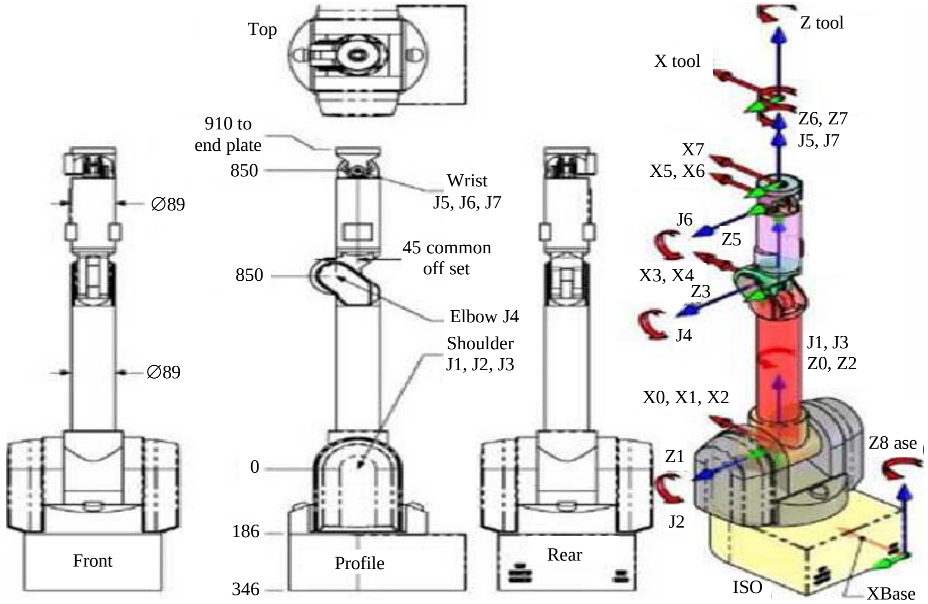

Fig. 2: WAM 7-DoF dimensions and D-H frames

**The WAM™ arm:** The WAM arm is a robotic back steerable manipulator. It has a steady joint-torque monitoring with a direct-drive capability. It offers a zero backslash and near zero friction to enhance the rendering of today's robots. It prepares good dynamic performance and torque sensing in its joints. It is so able of using all of its links to act force-controlled manipulation tasks. The three-fingered Barrett hand able to bend any of its three-link fingers separately.

It occurs with three main variants 4-DoF, 7-DoF both with human-like kinematics and 4-DoF with 3-DoF Gimbals. Its articulation ranks go beyond those for conventional robotic arms (Spong and Vidyasagar, 1989). Throughout this research, we will be using the WAM 7-DoF arm in the company of Barrett hand.

Figure 2 presents the full 7-DoF WAM system in the initial situation. An affirmative joint movement is on the right hand rule for every one axis. The following equation of homogeneous conversion in Eq. 1 is employed to fix the transformation between the axes K and K-1. D-H generalized transform matrix:

$$k\text{-}1Tk\begin{bmatrix} \cos\theta k & -\sin\theta k\cos\alpha k & \sin\theta k\sin\alpha k & \alpha k\cos\theta k \\ \sin\theta k & \cos\theta k\cos\alpha k & -\cos\theta k\sin\alpha k & \alpha k\sin\theta k \\ 0 & \sin\alpha k & \cos\alpha k & dk \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

- ak-1 = distance from Zk-1 to Zk measured over Xk-1
- dk = distance from Xk-1 to Xk measured along Zk

Table 1: 7-DoF WAM frame parameters

| K | ak | k | dk | θk |
|---|---|---|---|---|
| 1 | 0.000 | -π/2 | 0.00 | 1 |
| 2 | 0.000 | π/2 | 0.00 | 2 |
| 3 | 0.045 | -π/2 | 0.55 | 3 |
| 4 | -0.045 | π/2 | 0.00 | 4 |
| 5 | 0.000 | -π/2 | 0.30 | 5 |
| 6 | 0.000 | π/2 | 0.00 | 6 |
| 7 | 0.000 | 0 | 0.06 | 7 |
| T | 0.000 | 0 | 0.00 | - |

- αk-1 = angle between Zk-1 to Zk was roughly Xk-1
- θk = angle amidst Xk-1 and Xk was approximately Zk

Table 1 includes the parameters of the arm with 7-DoF. As with the prior example, we describe accurately the frame for our particular end effector. By multiplying all of the transforms up to and enclosing the final frame, we settle officially the toward kinematics for any frame on the robot. To regulate the end tip location and orientation, we utilize the following Eq. 2:

$${}^{0}T_{Tool} = {}^{0}T_{1}\,{}^{1}T_{2}\,{}^{2}T_{3}\,{}^{3}T_{4}\,{}^{4}T_{5}\,{}^{5}T_{6}\,{}^{6}T_{7}\,{}^{7}T_{Tool} \tag{2}$$

The transformation equations used to bring up the manipulator's joints until the interval between the movable object and the end effector almost equal to zero. Once the assignment of the contact is accomplished, the Barret hand shuts its fingers and grapples the object.

## Robot motion control

**Robot dynamics:** The Lagrange equations was utilized by the dynamic simulation to acquire the angular acceleration

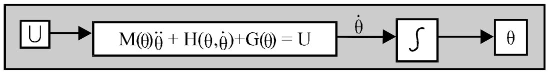

Fig. 3: Block graph of the open loop system

from the torque of every joint. Foremost, i computed the body Jacobian of every joint $j_i$ corresponding to $M_i$ where $M_i$ is the ith joint's inertia matrix. So, the manipulator inertia matrix $M(\theta)$ can be calculated as Fig. 3:

$$M(\theta) = \sum_{i=1}^{n} J_i^T(\theta)M_iJ_i(\theta) \tag{3}$$

Also, calculate potential part:

$$M(\theta) = \sum_{i=1}^{n} = 1J_i^T(\theta)M_iJ_i(\theta) \tag{4}$$

Second, I computed the torques of all joint using Lagrange equation which is:

$$\frac{d}{dt} = \left(\frac{\partial L}{\partial \dot{\theta}_i}\right) - \left(\frac{\partial L}{\partial \theta_i}\right) = U_i\,(i = 1, ..., 7) \tag{5}$$

where, the torque of the joint and:

$$L(\theta,\dot{\theta}) = \frac{1}{2}\dot{\theta}^T M(\theta)\dot{\theta} \text{-} P(\theta) \tag{6}$$

After expanding the components of Eq. 7 is as following:

$$M(\theta)\ddot{\theta} + H(\theta, \dot{\theta}) + G(\theta) = U(t) \tag{7}$$

Where:

$H(\theta, \theta) = B(\theta)\theta^2$ = The Coriolis and centrifugal force
$G(\theta)$ = The gravity term
$\theta$ = $[\theta_1, \theta_2, \theta_3, ..., \theta_7]$
$\dot{\theta}$ = $d\theta/dt,\ \ddot{\theta} d^2\theta/dt^2$

The potential energy $P_i$ of an element $C_i$ which mass $m_i$ of the robotic system compared to the base $R_0$ is written as:

$$P_i = -m_i g\,{}^0\overline{r_i} = -m_i g\left({}^0T_i\,{}^i\overline{r_i}\right) \tag{8}$$

The sum Potential energy P of our arm manipulator:

$$P_i = \sum_{i=1}^{7} P_i \sum_{i=1}^{7} -m_i g\left({}^0T_i\,{}^i\overline{r_i}\right) \tag{9}$$
$$i_{r_i} = [x_i, y_i, z_i, 1]^T$$

where, ${}^ir_i$ (the location vector of the material point) and the gravity vector:

$$g = [0 \quad 0 \quad -9.8032 \quad 0]^T \tag{10}$$

Given that the mobile base is strolling in a horizontal plane its Potential energy P = 0. Mappings between the joint coordinates and the robot end-effector coordinates $X_r$ are given as:

$$X_r = W(\theta) \tag{11}$$

$$\dot{X}_r = J(\theta)\dot{\theta} \tag{12}$$

$$\ddot{X}_r = j(\theta)\dot{\theta} + J(\theta)\ddot{\theta} \tag{13}$$

where, $w(\theta)$ describes the onward kinematic relation for the end-effector $J(\theta)$ and is the end-effector Jacobian matrix. By substituting Eq. 8-23 into Eq. 7, one can acquire the robot's dynamic equation in chore space:

$$MJ^{-1}\left\{\ddot{X}_r \text{-} jJ^{-1}\dot{X}_r\right\} + HJ^{-1}\dot{X}_r + G = U \tag{14}$$

By rearranging the terms, one can obtain the robot's dynamic equation of motion as:

$$MJ^{-1}\ddot{X}_r\left\{H\text{-}MJ^{-1}j\right\}j^{-1}\dot{X}_r + G = U \tag{15}$$

**Using the Jacobian:** We are concerned in reckoning an extension in configuration space from $q \in Q$ towards $xg \in X$, when the preferred end effector aim xg and the robot arm configuration q are given where X is the positions of the end of the robot arm R3. In spite of that the mapping from Q to X is frequently nonlinear and hence expensive to deduct its derivative the Jacobian is a linear map from the tangent space of Q to that of X that can be calculated easily ($Jq = x$ where $x \in X$ is the end effector location corresponding to q). Ideally, to urge the end effector to a wished configuration $xg(d\,xg/dt \approx 0$: object moves slowly) we could compute the error $e(t) = (xg\text{-}x)$ and hurry a controller of the shape $\dot{q} = KJ^{-1}e, K$ is a positive grow. This uncomplicated controller is able to get the target with no considering of any feasible barriers or articulation limits. Though this rotate inside a compound controller where the converse of the Jacobian should be done at every time step. To escape this expensive approach, we use alternatively the transpose of the Jacobian and the control law collapse into the form of $\dot{q} = KJ^{-1}e, K$. The controller expels the spacious overhead of computing the inverse by using the easy-to-compute Jacobian instead. The instantaneous action of the end effector is given via $\dot{x} = J\dot{q} = J(KJ^Te)$. The inner creation of this instantaneous motion with the fault vector is given by $e^T\dot{x} = ke^TJJ^Te \geq 0$. As this is forever positive, under our assumptions with obstacles, we may ensure that the controller will be clever to make onward progress towards the target (Damian, 2006).

**Target's velocity:** From the first position a($x_1$, $y_1$, $z_1$) to the second position b($x_2$, $y_2$, $z_2$) which $x_2 = x_1+\Delta_x$, $y_2 = y_1+\Delta_y$ and $z_2 = z_1+\Delta_z$ and $t\text{-}_{a-b}\ t_{sleep}+\varepsilon$ which $t_{sleep}$ is the time to rest en a and ε is the time from a to b:

$$V_x = \frac{\Delta_x}{t_{a\to b}}, V_y = \frac{\Delta_y}{t_{a\to b}} \text{and } V_z = \frac{\Delta_z}{t_{a\to b}} \tag{16}$$

So, the target's velocity:

$$V_T = V_x i+V_y j+V_z Z \tag{17}$$

**Optimal linear control:** The synthesized control U moves the system from an initial position to an equilibrium (constant characterized by acceleration and velocity joint equal zero $\dot{\theta}_{eq} = \ddot{\theta}_{eq} = 0$. This command is written like this:

$$U = U_{eq}+V \tag{18}$$

**Case study of balance:** When the robot reaches its equilibrium was then: $G(\theta_{eq}) = U_{es}$. Where $U_{eq}$ is the command required to preserve the robot to the position of static equilibrium $\theta_{eq}$.

**Linearization:** This linear order as the name suggests is based on the linearization of the equations of motion of the robotic system. To do this, the following definitions are provided: ϕ is the variation of relative to, $\phi = \theta\text{-}\theta_{eq}$. Taylor expansion to the first seek of a function f(θ) near $\theta_{eq}$ is as follows:

$$f(\theta) = f(\theta_{eq}+\phi) = f(\theta_{eq})+\left(\frac{\partial f}{\partial \theta}\right)_{\theta_{eq}} \phi \text{ with } |\phi| << 1 \tag{19}$$

By applying the development to the robotic system and employing the equations defined above, the dynamic equation of the robot becomes:

$$\begin{aligned}&\left(J(\theta_{eq})+\left(\frac{\partial J}{\partial \theta}\right)_{\theta_{eq}} \phi\right)\ddot{\phi}+\left(B(\theta_{eq})+\left(\frac{\partial B}{\partial \theta}\right)_{\theta_{eq}} \phi\right)\dot{\phi}^2+\\&\left(G(\theta_{eq})+\left(\frac{\partial G}{\partial \theta}\right)_{\theta_{eq}} \phi\right) = U_{eq}+V\end{aligned} \tag{20}$$

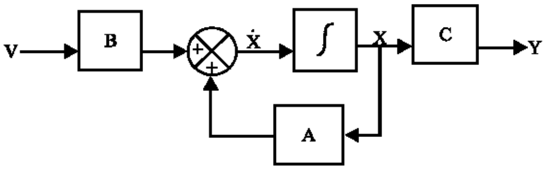

Fig. 4: Block diagram of the linearized system

After simplification and $G(\theta_{eq}) = U_{eq}$ equation of the linearized dynamics:

$$V = J(\theta_{eq})\ddot{\phi}+\left(\frac{\partial G}{\partial \theta}\right)_{\theta_{eq}} \phi \tag{21}$$

**State representation:** The linear system manifested by the above equation is a matrix representation translates following state (Fig. 4):

$$\dot{X} = AX+BV \text{ where } X = \begin{bmatrix}\phi\\ \dot{\phi}\end{bmatrix} \text{and } \dot{X} = \begin{bmatrix}\dot{\phi}\\ \ddot{\phi}\end{bmatrix} \tag{22}$$

**Calculation of the optimal control:** The optimality criterion to minimized, put under linear quadratic form is:

$$J(x,t) = \int_t^{tf} \left(X^TQX+V^TRV\right)d\tau \tag{23}$$

where, Q and R matrices are positive definite and the optimal control problem is called: problem LQR (Linear Quadratic Regulator). To locate a solution to this problem LQR, assume that the minimum cost standard is also quadratic form as:

$$J^*(X,t) = X^TSX \tag{24}$$

The S matrix is symmetric, positive and is a function of time as:

$$\begin{cases} S(t) = S(t)^T \\ \dfrac{\partial J^*}{\partial t} = X^T\dot{S}X \\ \dfrac{\partial}{\partial v}\left(\dfrac{\partial J^*}{\partial t}\right) = 0 \end{cases} \tag{25}$$

The aim, therefore is to search the optimal control V* that minimizes the cost criterion:

$$V^* = R^{-1}B^TSX \tag{26}$$

where, S is positive definite is the sole solution of the following Riccati algebraic equation:

$$Q+SA+A^TS+SBR^{-1}B^TS = 0 \tag{27}$$

## RESULTS AND DISCUSSION

We utilize the OpenRAVE simulator to control a robot WAM and a robot gripper for tracking, grasping and manipulating an object which float in the space. The objective is to pursue and hold a model mug while avoiding the existing obstacles. The object moves in the space with velocity range 4 cm/sec (for handicapped man by Husain the velocity is 21 cm/sec for a normal man). In order to stably follow and grip the target, so we can move it, the robot hand avoids collision in its way to attain the object than it closes its fingers. The end effector would budge right or left with the shorter distance. The chore is to shift a mobile object from some assumed beginning configuration to some given aim configuration. The matter can be splintered down into four sub-problems: move the item in the space, move the end effector from its beginning configuration to a configuration where it is approximate the target, seize the object, move the robot (holding the object) to some configuration which puts the object into its goal configuration.

### Grasping objects that move slowly in the space

#### Grasping objects in the environment without obstacles

**Grasping objects with robot WAM:** The robot was simulated by using the OpenRAVE as shown in Fig. 5. The initial positions of the end effector were (0.730, 0.140, 2.168 m) and those of the moving mug were (0.05, -0.13, 1.15 m). As mentioned in Fig. 5, the robot arm, first, picks up objects that are stored in Table 2. Second, it puts them on the dish rack. The robot hand remains a distance from the object, the Barret hand and the object as constant (Fig. 5a). The object can move with the velocity V = 4cm/sec and the robot moves to the object centroid position that corresponds to the center of the Barrett hand (Fig. 5b). The hand of Barrett center should coincide with the position on the object which is closest to the Barrett hand. In Fig. 5c, the robot is able to pick up the objects and place them in the desired position. In Fig. 5d, the robot puts the target object in the required position and opens its fingers.

Table 2 presents the outcomes of the time provided to grip the mobile target that moves with velocity V = 4 cm/sec (Tgrasp) and the time to shift the object to the preferred position (Tend). The robot usually tries to optimize a distance-based cost function and the time to seize between the two configurations. The

Table 2: Object movables with V = 4 cm/sec

| Objects (trial) | Tgrasp (sec) | Tend (sec) |
|---|---|---|
| 1 | 3.09 | 7.25 |
| 2 | 3.22 | 7.23 |
| 3 | 3.05 | 7.32 |
| 4 | 3.11 | 7.17 |
| 5 | 3.10 | 7.15 |
| 6 | 3.02 | 7.13 |

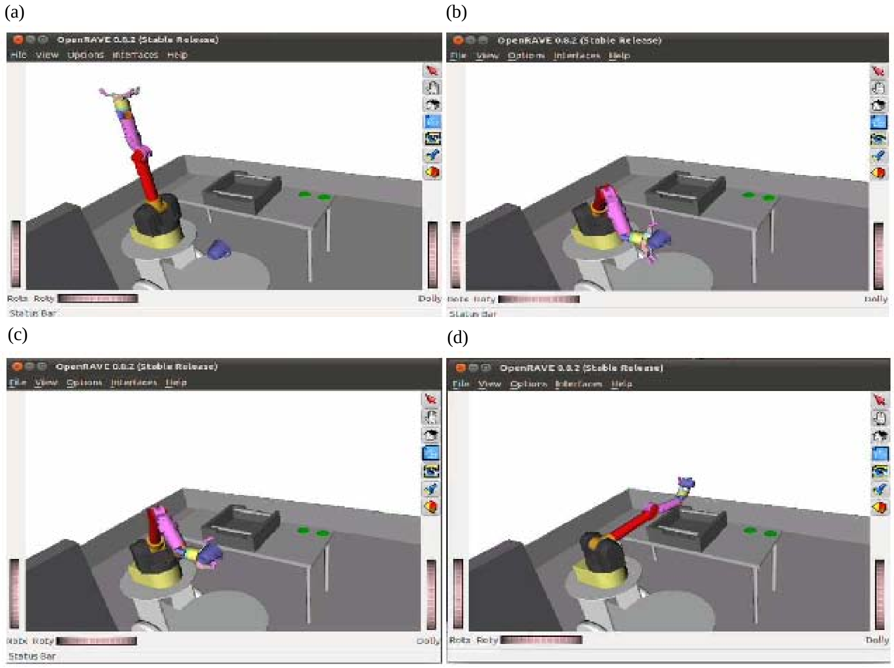

Fig. 5: Example of a successful case of capturing a moving object: a) T = 0; b) T = 2.57; c) T = 3.05 and d) T = 7 sec

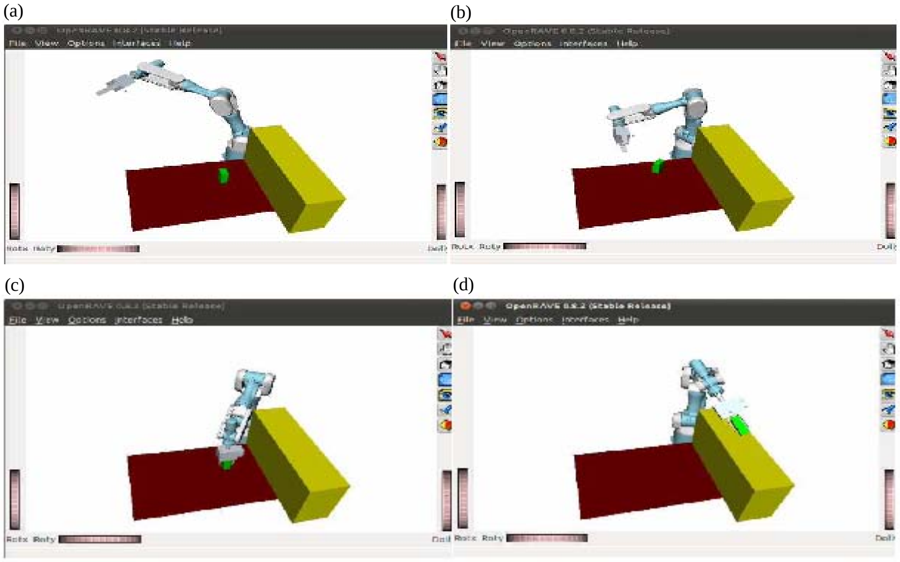

Fig. 6: Robot gripper captures the moving object: a) T = 1; b) T = 2; c) T = 3.05 and d) T = 7 sec

distance is travelled by the end effectors that should be controlled as the relation between their situations and the object's one.

As shown, they regulate the actual position of the roving object and pick the closest distance between the target and the end effector.

**Gripper grasps the objects:** The robot gripper was simulated via OpenRAVE as exposed in Fig. 6. The initial situation of the gripper in the space were (0.730, 0.140, 2.168) and those of the moving thing were (0.05, -0.13, 1.15). Figure 6 mention the stages of caught the moving thing by the robot gripper. Table 3 displays the results of the time when the gripper grasping the mobilized object.

### Grasping objects in the environment with obstacles

**Grasping objects with robot WAM:** In Fig. 7, we present the various stages for holding the object in question. Table 4 presents the upshots of the time provided to pinch the mobile mug. We note that the robot succeeded to evade the obstacles and take over control the object in all the trials. In Trial 3, we record two moments to clutching: the first grasping (Tgrasp1 = 3.60 sec) attempt fails and unstably grasp, so the robot opens its fingers and change its trajectory, it repeats a second grasp in Tgrasp2 = 7.43 sec and it succeeds.

Figure 8 illustrates the curves of the robot and the object: the mobile robot avoids obstacles and seizes the mug in time Tgrasp1 = 3.41sec which changes its position in the space with velocity V = 4 cm/sec. The robot puts the object in the preferred position in time Tend = 8.94 sec.

Table 3: Object stirs with V = 4 cm/sec

| Objects (trial) | Tgrasp (sec) | Tend (sec) |
|---|---|---|
| 1 | 2.90 | 7.13 |
| 2 | 2.92 | 7.18 |
| 3 | 3.02 | 7.11 |
| 4 | 2.87 | 7.12 |
| 5 | 3.01 | 7.09 |

Table 4: Object agitates with V = 4 cm/sec

| Objects (trial) | Tgrasp (sec) | Tend (sec) |
|---|---|---|
| 1 | 3.69 | 8.36 |
| 2 | 3.41 | 8.94 |
| 3 | 3.60-7.43 | 10.82 |
| 4 | 3.35 | 8.60 |
| 5 | 3.38 | 8.58 |
| 6 | 3.34 | 8.47 |

Our algorithm contemplates the mug in both its beginning and goal configurations as well as the location of the robot's base shown in Fig. 9.

**Grasping objects with gripper:** The algorithm uses the interface of the task manipulation using many features of OpenRAVE. It performs the following operations:

- Picking and validating the grasps and with the grasper planner
- Moving to the required grasp preshape and avoiding the occurred obstacles
- Safely moving the close to an obstacle by using a gradient descent methods based on Jacobian and RRT
- Catching the object and the verifying the collisions problems by using close fingers
- Holding and move objects to their destination using body grabbing

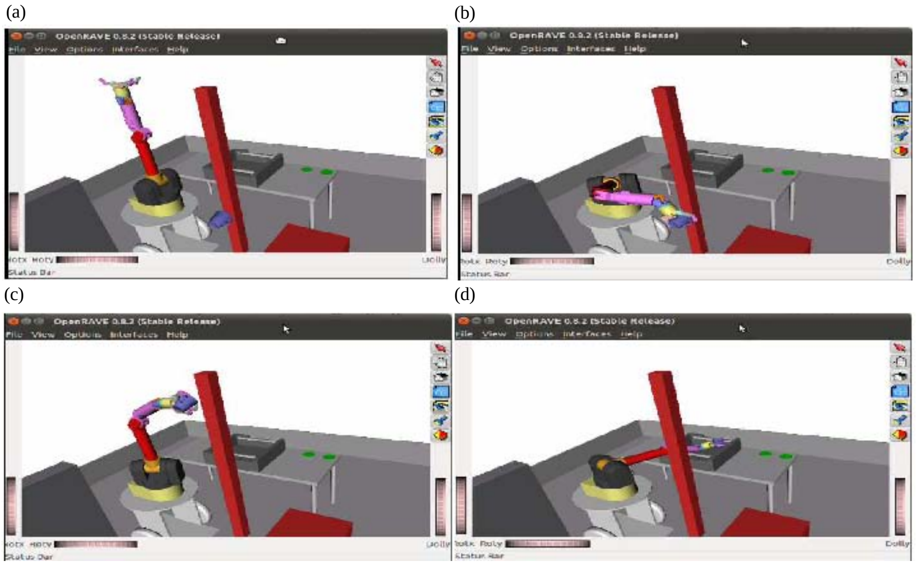

Fig. 7: The WAM grasps the moving mug while avoiding the obstacles: a) T = 1; b) T = 2; c) T = 3.05 and d) T = 7 sec

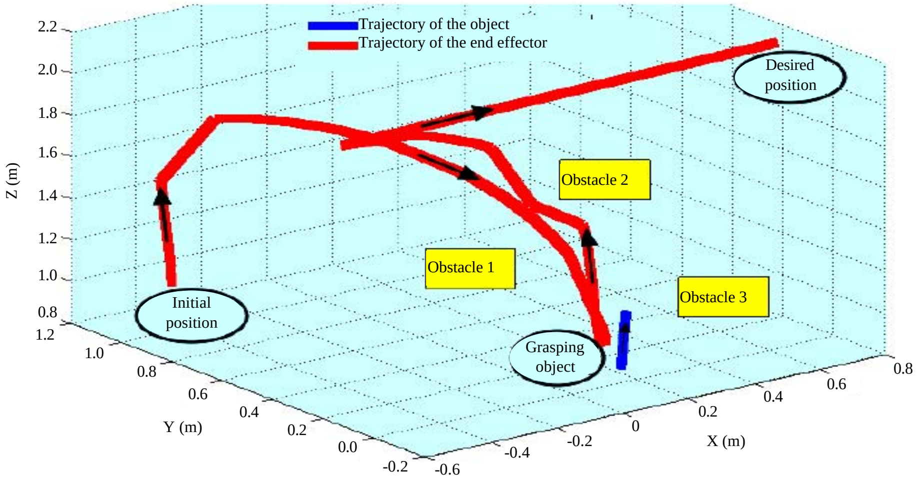

Fig. 8: The trajectory of the object and the end effector

- Lowering the object until collision and then release and move away from it

**Grasping objects that move fast in the space:** Figure 10 when the object moves fast with speed V = 20 cm/sec, the robot tries to follow the object but the last one flees (Fig. 11). The object moves fast with speed V = 20 cm/sec and the robot obviates barrier and assays to follow it.

**Grasping objects without obstacles:** To catch the target that moves quickly, we use a mobile robot equipped with mobile base. In order to make sure that the object doesn’t get out of the range of manupulator’s arm, a mobile base has been assembled with the the robots. The gripper pursues the motivate object witch moves with speed V = 20 cm/sec (Fig. 12).

**Grasping objects in the environment with obstacles**

**Grasping objects with gripper:** Figure 13 appears how the gripper ducks the obstacles and pinches the movable thing. Table 5 posters the summary time for selling the moving thing which proceeds with speed V = 20 cm/sec while shying obstacle.

**Robot WAM grasps objects:** We discuss an algorithm bestowed for tracking and grasping a moving thing while

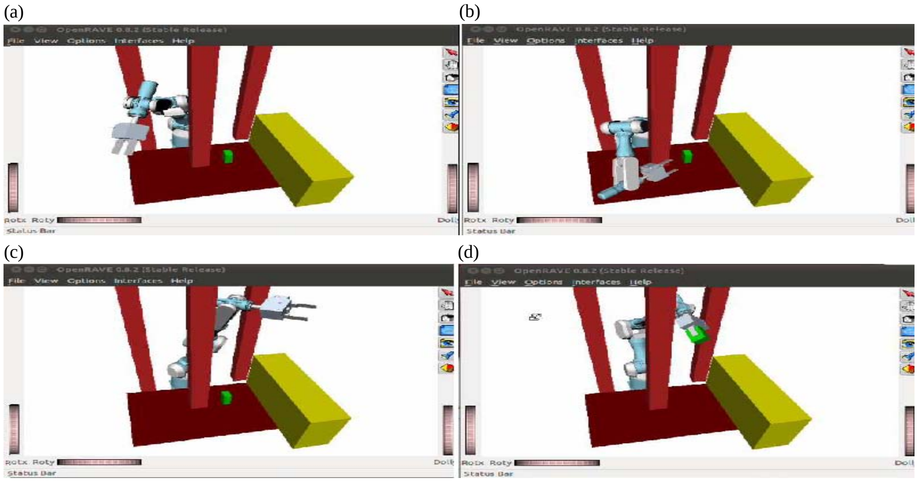

Fig. 9: The robot gripper averts barrier and touch the stirring object

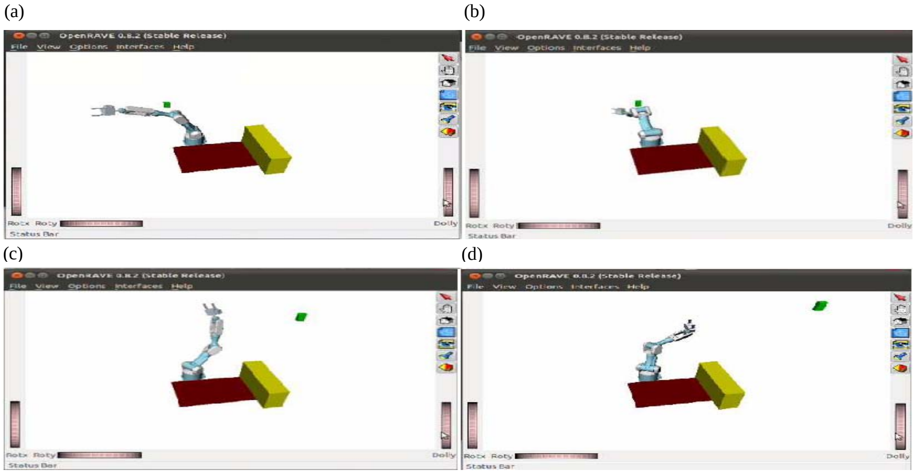

Fig. 10: The mobilized thing escapes from the robot gripper

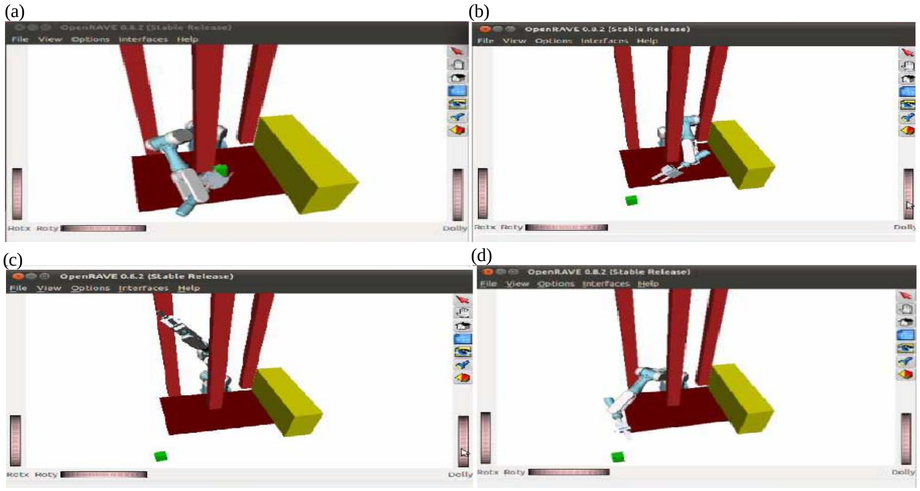

Fig. 11: The mobilized thing escapes from the robot gripper

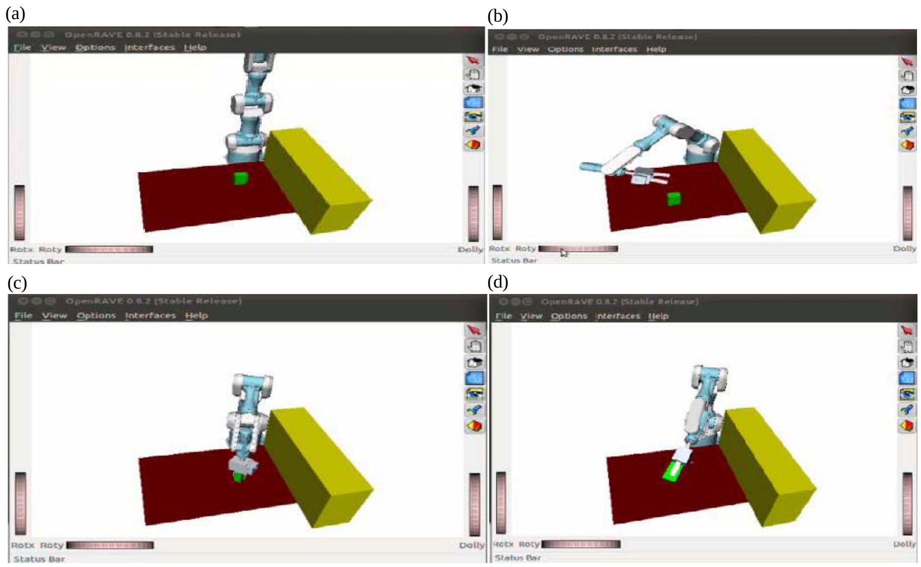

Fig. 12: The gripper constricts the movable object

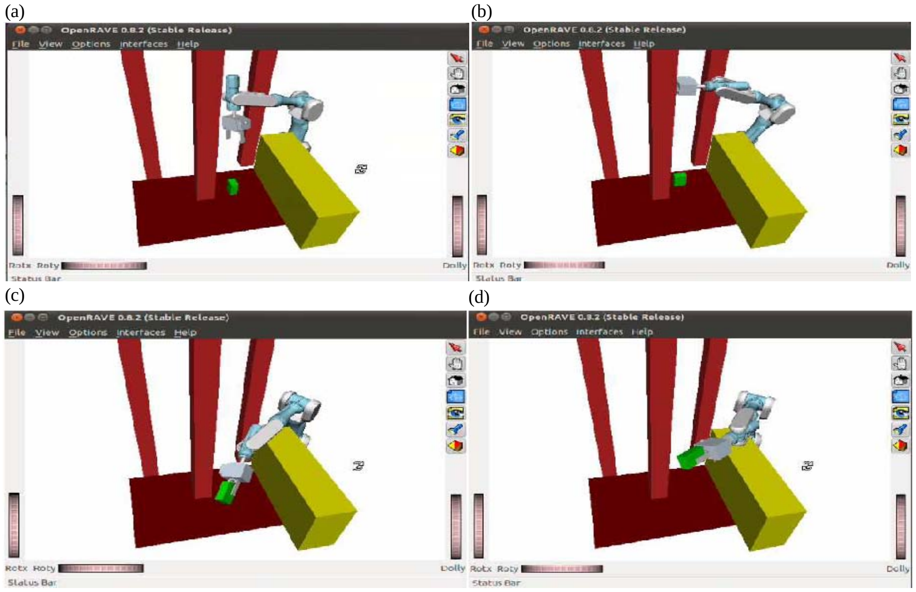

Fig. 13: The gripper evades obstacles and caught the object

seeking to escape th obstacles with a mobile robot. The tracking and grasping of a dynamic object in a full of obstacles area is what is revealed in Fig. 14, the mug has successfully captured, the mobile object escaping all of the obstacles in the trajectory. The first Fig. 14a exhibits the initial phase of the operation in which there is a distance between the end effector and the mug, the Barret hand and the object are immovable in the initial position, Fig. 14b illustrates the path of the moving mug which budges with speed V = 20 cm/sec and demonstrate that the mobile robot is trying to pursue the mug. Figure 14c, the robot tracks the strolling object and gets to the location of the centroid of the target where the center of the Barrett hand would coincide with the object, the robot locks its fingers and lastly grasps the object.

Table 6 presents the summary time for catching the moving object which shifts with velocity V = 20 cm/sec while avoiding obstacle. Figure 15, the robot avoids obstacles and tracks the movable object.

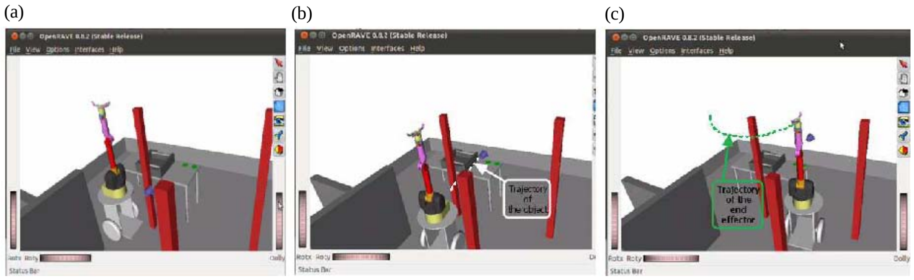

Fig. 14: Successful following and catching of a mobile mug: a) T = 0; b) T = 2.5 and T = 4.3 sec

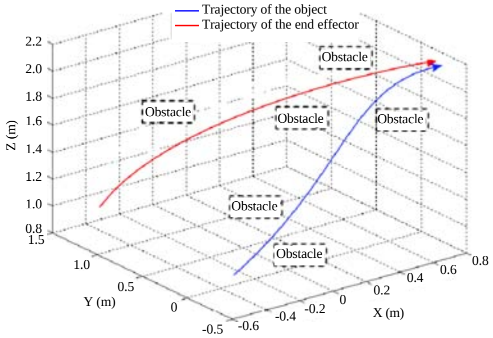

Fig. 15: Object and end-effector trajectories during hounding and grasping of a moving mug

Table 5: Object stirs with V = 20 cm/sec

| Objects (trial) | Tgrasp (sec) |
|---|---|
| 1 | 4.10 |
| 2 | 4.09 |
| 3 | 3.99 |
| 4 | 4.12 |
| 5 | 4.19 |
| 6 | 4.13 |

Table 6: Object moves with V = 20 cm/sec

| Objects (trial) | Tgrasp (sec) |
|---|---|
| 1 | 4.80 |
| 2 | 4.70 |
| 3 | 4.89 |
| 4 | 4.81 |
| 5 | 4.77 |
| 6 | 4.77 |

If we raise the object's velocity and the work's space, we notice that the results are convergent but slightly higher. Grasping the movable object is not an topic for the mobile robot because of it's moving base. Therefore, increasing object's speed acts in the grasping time. Hence, the mobile robot is perfectly able to confine the moving object in a rational amount of time.

The existence of the obstacle idling velocity of the robot and the augmenting of object's velocity complicates the grasping because of the time that it requires to reach the goal.

In all trials, the WAM arm and the gripper were competent to successfully chase the object using the tracking information and eventually grasp it in reasonnable time. The gripper takes the target in less time than the WAM. As a result, control a robot with three fingers is more complex than the gripper.

## CONCLUSION

In this manuscript, we studied the capability of grasping an object moving in real time. Moreover, we studied an algorithm grasping and tracking a moving entity while trying to shun the obstacles with two robots. We have performed a simulation of grasping a moving object which moves with different velocities and shift it to a desired position while shunning collisions using the robot gripper and the mobile robot which is an assembly of a 7-DoF robotic arm with the Barret hand and a mobile base in which we require the RRT algorithm. In fact, this algorithm permits us prevail the difficulty of the inverse kinematics by exploiting the Jacobian's nature as a transformation from a configuration space to workspace. Our algorithm is based on two main issues to mobile manipulation: choosing the best grasp and choosing the optimal positions for the mobile base. We fix forth separately the time of clutching the object which shifting with different velocity by taking into account of the obstacles and the time to put this object in a desired position. Firstly, it moves slowly with velocity V = 4 cm/sec. Second, it moves fast with velocity V = 20 cm/sec. The intended algorithm successfully holding the roving object in a rational time putting it in the aim station and the robots try to optimize the distance between two configurations and the time to seize the moving object. Times are nigh in the different trial. The existence of the obstacles increases the speed of catching the object. The gripper grasps the object in less time than the WAM, so control a gripper easier than the hand with three fingers.

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