# Movement Speed Models of Natural Grasp and Release Used for an Industrial Robot Equipped with a Gripper

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**Abstract.** In this paper, movement speed models of a robotic manipulator are presented according to the mode of operation of the human hand, when it wants to grasp and release an object. In order to develop the models, measurements on a human agent were required regarding the movement coordinates of his hand. The movement patterns have been approximated on the intervals, using first and second degree functions. The speeds were obtained by deriving these functions. The models obtained are generally presented; for their implementation in models applied for a certain robot, specific changes from case to case have to be made.

**Keywords:** Speed, Models, Robot, Grasp, Gripper

## 1 Introduction

Robots became more powerful and more intelligent in the last decade and they are developing in the direction of services. Being used by people without technical knowledge, it's important for them to be easily operated using a flexible programming system. A great importance, concerning the robotics, is the way the robots catch and manipulate objects. The research is in the direction of the development of models for natural grasp of objects, like the human model.

In its functioning, the human hand has a completely natural movement with the sensorial ability for a subtle manipulation. Biological subtleties can be ignored since they contribute little to natural hand modeling [2, 9]. In [11] van Nierop et al. a model of the human hand is presented, which has natural movement and constraints due to the biomechanical joints of the skeleton and the skin of the hand. They present their research in modeling and provide a description of anatomic nomenclature. For the evaluation of the model, they realize the taxonomy of elementary tasks which describe the movements of the hands into a 2-dimensional parametric space.

Many papers have focused on the construction of a firm grasp [4]. In [1] R. Abu-Zitar and A.M. Al-Fahed Nuseirat present a heuristic technique used for solving the linear complementary problems (LCP). Their research consists in the determination of minimal force required for the grasp an object with a multi-finger gripper. The contact is assumed to be frictionless. A numerical algorithm, Lemke, can be used for solving the problem. Lemke is a direct method, deterministic, used for finding precise solutions using a few constraints. The authors propose the neural network technique for obtaining the largest number of precise solutions, in positions that can be solved and good solutions for position in which Lemke method fails. Using inequality theory, the problem is composed like a LCP. The research of the authors had to convert the problem into a heuristic search problem, using the architecture and learning capabilities of a single two layered neural network.

In their research, Alexandra Constantin et al. present a method for quality assessment in terms of arm movement imitation. They propose a segmentation and comparison algorithm based on the angle rotation of the joint [3]. Here, they describe an empirical study designed to validate the algorithm, comparing it with human assessment of imitation. The results show that automatic metric evaluation does not differ significantly from the human evaluation.

The work on automatic grasp synthesis and planning is a relevant idea [6, 7, 8]. In [10] is presented a method for automatic grasp based on shape primitives of an object, using a programming by demonstration platform. Initially, the system recognizes the grasp from a demonstrator and then generates the grasping strategies for the robot. The authors of this paper began by presenting how the grasp is modeled and learned and how it is mapped at the robot hand. They continued with the accomplishment of a dynamic simulation of the grasp execution, with focus on objects that must be grabbed whose position is not completely known.

Humanoid robotic requires new programming tools. The programming by demonstration method is good for simple movements, but until now the adaption for subtle moves is very difficult for it. The mathematical models have been realized only for simple hands or objects. In [5] Michele Folgheraiter et al. tried to use the information obtained directly by a human teacher. They have developed a glove which they used for collecting the information from the different experiments and generalized it into a neuronal network.

In this paper several elements derived from a research regarding natural grasp of an object by man, will be presented. In our research, we made some measurements on a human agent regarding the movement coordination of the hand and his finger when he wants to grasp and release an object. The basic idea was to translate these measurements into a model of movement speeds which can be used by an industrial robot equipped with a gripper.

## 2 Contribution to Technological Innovation

Humanoid and mobile robots development is heading in the direction of imitating the human behavior attempt. The objects grasp and manipulation is a significant domain even in the industrial robots field. In nowadays, industrial robots work with constant speeds when they have to grasp and release objects. This paper presents theoretical models of movement speed of an industrial robot manipulator simulating the human hand model. The usage of the proposed models for the movement speed of an industrial robot gripper improves the grasping quality, respectively the releasing quality of an object and minimizes the accomplishment time. Currently, the gripper of an industrial robot passes through three distinctive steps when a grasp or a release has to be done: the first step in which the gripper is positioned in the grasp point, respectively the release point; the second step in which the gripper closes, respectively it opens; and the third step in which the robots continues his movement with or without object. The proposed models determine that the three steps above defined to intertwine: thus they improve the quality of grasping and releasing and the time in which these are accomplished is minimized. Both the gripper speed movement model and the closing/opening speed model have relatively large periods of time for opening and closing of the gripper. This shows that the models approach to human hand model and reduce the force shocks, caused by the inertial force, as it happens when the industrial robots currently used manipulate objects.

Therefore, in this paper speed models of an industrial robot gripper are proposed, in order to improve the object grasping and releasing, using human hand model simulation.

## 3 Measurement Procedures

The measurements have been made using the OptiTrack system, using the camera displacement like in Fig. 1 a). For improving the precision, the work volume was reduced to approximately 1 cubic meter.


a) b)

**Fig. 1.** a) The displacement of the camera; b) The object used to accomplish the measurements.

The measurements were made on the object presented in Fig. 1 b). On this object there were attached four markers, which were selected for achieving a „rigid body", named „body" using the ARENA software.

The object is placed in the XOZ plane, like in Fig. 1 b). In this figure, the object is placed on worktable. If the object is lifted from the table, then OY coordinate of the four markers will increase; if it will be put down then it will decrease. In the measurement made the object is considered to be dot-like, being represented only by the coordinates of the rightmost marker.

The measurement operation consisted in capturing the human hand and the object coordinates when a human agent grasps an object from the workbench, lifts this object to a certain height, puts down the object on the workbench and releases it, lifts once again the hand without the object (open hand), than puts down the hand to grab again the object and starts again a new cycle.

For tracking the human hand those three markers disposed like in Fig. 2 were used. The markers are attached to a rigid support, as is it shown in the below picture.

a) b)

**Fig. 2** Markers arrangement on the human agent.

The arrangement of the markers on the hand surface has been tried. Due to the fact the four fingers do not constitute a rigid body a problem was encountered in which the software did not recognize the three markers as "rigid body", this is the reason for using the rigid support. As in the case of the object, the hand is considered dot-like by the coordinate's point of view. The coordinates of the hand are represented by the right-bottom marker coordinates in the Fig. 2.a. According to figures 1.b) and 2 when the hand opens, the distance on the OZ coordinate between the hand and the object will increase, and when it closes this will be reduced.

## 4 Obtained Results

In the figure 3 the coordinates of the human agent's hand and of the object on the OY direction, in a complete grab-release object cycle, are represented with green (A, B).

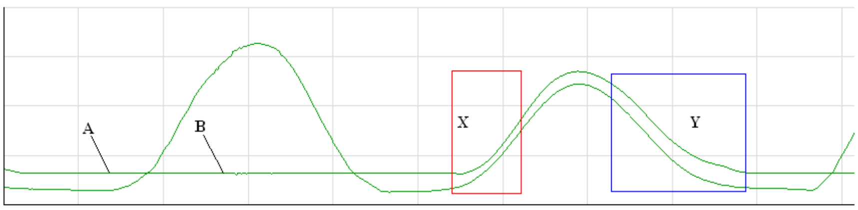


**Fig. 3.** The difference between the grip and the release of the object.

The area where the object is lifted from the workbench is enclosed in a red rectangle (X), and the area where it is standing still on the workbench is enclosed in a blue rectangle (Y). It can be observed that the time which is needed in order to lift the object from workbench is smaller than the time which is needed for it to be still. The human agent, in the phase of placing the object back on the workbench, is more careful and the motion has a much higher precision.

The green lines (A, B) represent the coordinates at equal moments in time. The slope of the lines in every point is the speed in the corresponding point.

It can be observed that the speed of rise and descent isn't constant in either cases, not for the free hand and neither for the hand with an object. With other words the human agent's hand doesn't moves with a constant speed, which is usually the case in robotics, but according to a curve like the one presented in figure 3.

In figure 4 the blue lines (A, B) represent the OZ coordinates of the human hand, and also the object which has to be handled (coordinates through which the grabbing and releasing motions can be highlighted). The green ones (C) represent the OY coordinates of the hand and of the object.

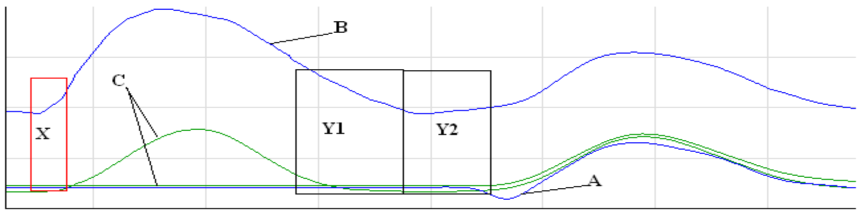


**Fig.4.** The OZ and OY coordinates of the hand and object for an entire cycle.

Just like it was the case with the horizontal movement, in the case of the closing and opening motion of the hand of the human agent, we have to deal with a motion which has a variable speed. The area inside the red rectangle (X) represents the release zone of the object. The area inside the black rectangles (Y1, Y2) represents the grabbing zone of the object. As it can be observed the time for grabbing the object is longer than time needed for releasing it.

Its grabbing starts in a moment before the moment in which the hand is at the level of the workbench. In the first black rectangle (Y1) the proper grasp of the object is presented. The second rectangle of the same color (Y2) follows an area of post-grabbing, an area where the human agents tests the grip. In this moment he checks whether the grip is stable and he ensures that it's the correct one. Only after realizing this, he begins to lift the object.

## 5 The Established Models

The results obtained in the previous chapter are used for constructing models of the movement speed on the vertical axis (in the direction of grabbing the object) and of the speed of closing-opening of the industrial robot's gripper. These models are obtained based on the actions of the human hand.

In the graphics from the previous figure the coordinates for vertical movement and for the closing-opening of the human hand are presented, at equal moments in time.

By deriving these curves the movement speeds for the corresponding directions can be obtained.

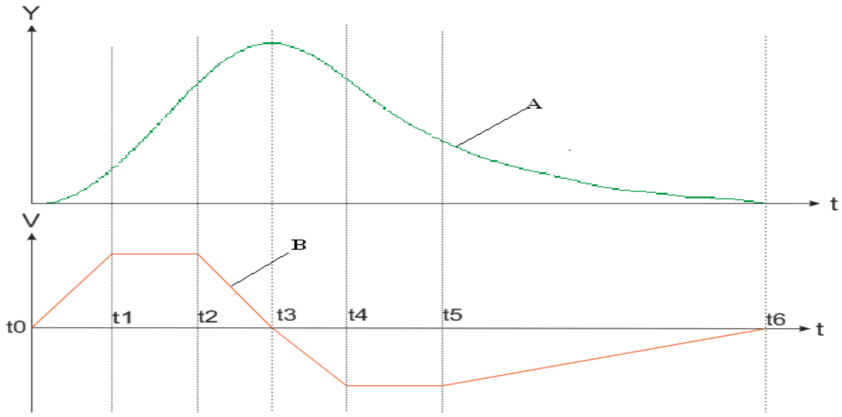


**Fig. 5.** Modeling of the vertical speed (in the direction of grabbing the object) of the gripper.

In figure 5, on the upper graph, the vertical coordinate of the human agent’s hand (A) is presented, when he lifts and lowers the object. In the interval t0 – t1 the curve can be approximated with a 2nd grade curve. By deriving the 2nd grade function a 1st grade function is obtained, thus the speed on this section can be approximated by a straight line segment. In the interval t1 – t2 the curve can be approximated with a straight line segment. For this reason the speed in this interval is constant. In the same way the other intervals are analyzed and in the end the speed’s graph is obtained which is presented in the lower part of figure 5.

The graph at the lower part of figure 5 can represent an approximately model of the movement speed on the vertical (in the direction of the grabbing) of the gripper of an industrial robot. In this model the intervals t0-t1, t2-t3 and t3-t4 can be considered equal to T. In the t5-t6 interval (the interval for placing the object back to the workbench) is big. It can be considered as being equal to 3T. The intervals t1-t2 and t4-t5 depend on the distance between the coordinates in which the robot has to act.
In conclusion the model presented above can be used on another scale, in a real system, considering the shape and some proportions of the speed-graph.

In figure 6, on the top graph the coordinates of the human hand and of the object are presented, when the object is released, the hand is raised without the object, the hand is lowered and the object is grabbed. The area in the yellow frame (X) is not used for establishing this model. When the object is released, the hand can have a relative motion on the OZ direction towards the object and because of this the coordinate difference on the OZ between hand and object is not the same as when the hand was opened. In the interval t4-t5 it is considered that the opening of the hand is constant. In the vicinity of the moment when the hand begins to rise and the moment in which it reaches the surface of the workbench, the difference on the direction OZ between the hand and the object, is approximately equal to the displacement of the thumb towards the other four fingers of the human hand (the opening of the hand).

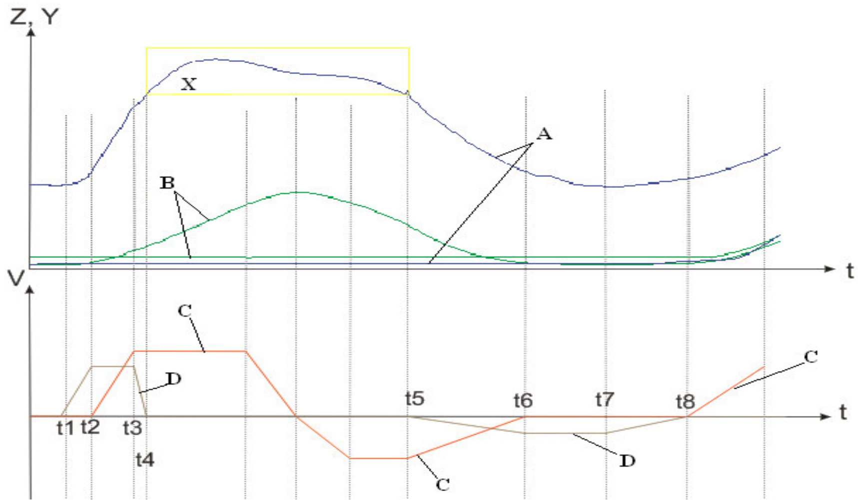


**Fig. 6.** Modeling the vertical speed of the robot's gripper and the closing-opening speed of the gripper.

The vertical movement coordinates are presented in green (B), while the movement coordinates in the direction of the opening of the hand are blue (A). In the lower graph, the approximate model of the vertical movement speed of the robot's gripper is represented in red (C). The brown line (D) is the model which is used for closing and opening the gripper of the robot. These models were used in the same way as the one in figure 5. The interval t1-t4 is the interval in which the object is released. The robot's gripper opens with a growing speed until the moment t2. In this moment the robot begins to move the gripper on the vertical. For a brief period of time, t2-t3 the gripper opens with a constant speed, and in a very short time-period the gripper's speed reaches 0. In the periods of time: t1-t2 and t2-t3, in order to establish the model they can be considered to be T1. The deceleration period t3-t4 can be considered to be T1/3. The interval t5-t8 is the interval in which the object is grabbed. The gripper begins to close with an accelerating speed before it moves the proper grabbing position of the object. When it reaches the corresponding position, it closes with a constant velocity, and after a while the speed begins to drop until it reaches 0. This last phase is the period in which the robot tests whether the grip is stable.

An exact relationship between the intervals t5-t6, t6-t7 and t7-t8 can't be established, but they can be considered approximately equal to 2-3 times T1.

## 6 Conclusions

The obtained models are only approximations. They are not general, but they can be used for specific type of actions. In the shown models, the magnitude of acting speeds is intuitively chosen; it is important in which way this can be modeled. The speeds have been modeled with line segments: oblique and horizontal. Linear models have been used for simulating the human hand model in order to obtain simple and easy to use models. Others functions and techniques of measured data synthesis for the models improvement might be used, but those involve larger processing time.

In the models that have been presented only proportions between the time interval in which the speed is described by an oblique line segment, and in the time intervals with constant speed the time depends on distance between the point's coordinates in which the manipulator has to act are established.

These models have been realized for a two finger gripper, but they can be used also for manipulators with more than two fingers. In the future we want to implement and test these models on an industrial robot equipped with a three finger gripper.

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## References

1. Abu-Zitar, R., Al-Fahed Nuseirat, A. M.: A Neural Network Approach to the Frictionless Grasping Problem. In: Journal of Intelligent and Robotic Systems, vol. 29, pp. 27-45, Kluwer Academic Publisher (2000)
2. Bando, Y., Kuratate, T., Nishita, T.: A simple method for modeling wrinkles on human skin, In: Proceedings of the 10th Pacific Conference on Computer Graphics and Applications, pp. 166-175, IEEE Computer Society, Washington (2002)
3. Constantin, A., Hall, B.: Evaluating Arm Movement Imitatio, In: American Journal Of Undergraduate Research, vol. 4, No. 4 (2006)
4. Faverjon, B., Ponce, J.: On computing two-finger force-closure grasps of curved 2D objects, In: Proceedings of the IEEE International Conference on Robotics and Automation, pp. 2290-2295, Nice, France (1991)
5. Folgheraiter , M., Baragiola, I., Gini, G.: Teaching Grasping to a Humanoid Hand as a Generalization of Human Grasping Data, In: Knowledge Exploration in life Science Informatics, vol. 3303-2004, pp. 139-150, Springer Berlin (2005)
6. Miller, A.T., Knoop, S., Allen, P.K., Christensen, H.I.: Automatic grasp planning using shape primitives, In: Proceedings of the IEEE International Conference on Robotics and Automation, pp. 1824--1829 (2003)
7. Morales, A., Chinellato, E., Fagg, A.H., del Pobil, A.: Using Experience for assessing grasp reliability, In: International Journal of Humanoid Robots, vol. 1(4), pp. 671--691 (2004)
8. Platt, R., Fagg, A.H., Grupen, R.A.: Extending fingertip grasping to whole body grasping, In: Proceedings of The International Conference on Robotics and Automation (2003)
9. Rhee, T., Neumann, U., Lewis, J.P.: Human hand modeling from surface anatomy, In: Proceedings of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, pp. 27--34, ACM Press, New York (2006)
10. Tegin ,J., Ekval, S., Kragic, D., Wikander, J., Iliev, B.: Demonstration-based learning and control for automatic grasping. In: Intel Serv Robotics, vol. 2, pp. 23--30 (2009)
11. Van Nierop, O. A., van der Helm, A., Overbeeke, K.J., Djajadiningrat, T. P. J.: A natural human hand model, In: The Visual Computer, Vol. 24 (1), pp. 31--44 (2008)