Using Symmetry Evaluation to Improve Robotic Manipulation Performance

P. J. Sanz, R. Marín and S. Dabić
Department of Computer Science & Engineering. Univ. Jaume I. Campus Riu Sec (12071-Castellón)

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1. Introduction

Presently, the robotics domain is increasing its performance possibilities mainly by using all kind of recent sensor based technology, jointly with very efficient software and hardware to process the information in a suitable manner. In particular, new robotic applications in service context are starting to be available now (e.g. space and underwater activities, telesurgery, etc.), as can be observed in all the most important conferences around the world and in the real life scenarios. These emergent activities in robotics, outside the well structured and predictable industrial domains, would be impossible without the appropriate use of sensory information.

In our case, after some years of previous research in the robotic manipulation area, by using computer vision to guide the grasping actions of 2D objects [Sanz et al., 98], we have discovered the importance of implement some algorithms that make easier the underlying geometric reasoning necessary to improve the final robotic manipulation performance. In particular, the knowledge about symmetry of planar shapes (i.e. 2D images of the objects are available) has been successfully used by the authors [Sanz et al., 99], and some other researchers before [Blake, 95], within the grasping determination domain.

2. Problem Description and Previous Results

As it has been commented beforehand, in previous works the geometric reasoning necessary to determine suitable regions of one object, in order to be grasped, was supported by the symmetry knowledge associated to the contour of this object. With the aim to quantify this symmetry degree a new concept was introduced by the authors [Sanz et al., 99] the .normalized global symmetric deficiency.. In the following we clarify this concept. For a planar shape two privileged directions exist related to its mass distribution (inertia), these directions are I_{min} and I_{max}, and they represent the eigenvectors of the moment of inertia covariance matrix. If mirror symmetry exists, these directions are the first candidates for that. As a result of that the next objective is evaluate the symmetry degree associated with these two directions. From the curvature description K_{ki}, the symmetry degree is computed with respect to the I_{min} associated with the contour, using the intersection points $\{ \mathbf{C} \bigcap I_{min} \}$, computing Δ_i, such as:

$$\Delta_i = K_{k,P_3-i} - K_{k,P_3+i};\ i = 1, K,\ \tfrac{N}{2},$$

where $P_3 \in \{\mathbf{C} \bigcap I_{min}\}$ traversing the contour clockwise from the initial point, PI, between P_1^0 and P_2^0. That is to say, Δ_i is computed as indicated, for each couple of points equidistant to P_3, covering all the contour. Using these quantities, we define the normalized global symmetric deficiency as:

$$\Phi = \tfrac{1}{N} \textstyle\sum_{i=1}^{i=\frac{N}{2}} \Delta_i$$

where N is the total number of points in the contour. The same process is utilized to compute Φ for the Imax direction, but now, instead of P_3, we compute Δ_i with $P_1^0 \in \{ \mathbf{C} \bigcap I_{max} \}$, as introduced above. Note that $\Phi = 0$, i.e. perfect mirror symmetry with respect to the considered axis, exists only for an ideal mirror symmetric object. Some results in relation with the usefulness of Φ are shown in

	I_{min}		I_{max}	
Shape	μ_Φ	σ_Φ	μ_Φ	σ_Φ
Nut	1.86	0.74	1.99	0.69
Screwdriver	1.58	0.82	4.25	0.57
Scissors	1.59	0.92	4.85	0.32
Pliers	2.68	0.54	4.67	0.83
Pincers	4.42	0.61	5.60	0.87
Allen wrench	6.38	0.58	5.46	0.78

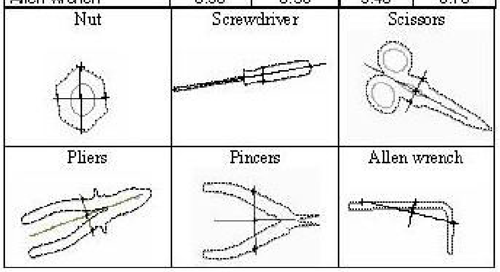

Table 1
Normalized global symmetric deficiency Φ computed for different images in both directions I_{min} and I_{max}. It shows the mean,ν_Φ, and the standard deviation, ρ_Φ, for each one.

Table 1.

The data shown in Table 1 are the mean and standard deviation computed from four digitizations for each object at different locations (position and orientation) over the work area. From that table some empirical results can be observed:

I_{min} direction. Looking at the table a gap between "pliers" and "pincers" is observed, $\Phi = \leq 3$. After many trials we have followed a mirror symmetry approach for those images that present $\Phi < 5$, named $\Phi_c = 5$ to this critical value.

I_{max} direction. In this case the gap appear just between "nut" and the rest of shapes. So a value $\Phi_c = 3$ represents a good critical value.

A primary classification of the objects present in Table 1 would be the following: "mirror symmetry for I_{min} and I_{max} directions" {nut}; "mirror symmetry in I_{min} direction" {nut..pincers}; and "without symmetry" {Allen wrench}. Note that only "nut" has mirror symmetry in both directions in correspondence with its inherent radial symmetry.

These results were applied successfully to the grasping determination domain [Sanz et al., 99], where the input were contours extracted from 2D images.

Nevertheless, as it has been remarked above, a problem was detected with some shapes, for instance, the pincers. The differences observed between the hopped (i.e. mirror symmetry along the Imin direction) and real results has been the starting point for the present research contribution. To clarify this situation is convenient to observe the Fig 1, in which an image of pincers is processed. When the curvature-symmetry fusion [Sanz et al., 99] diagram is used to analyze the performance, we found that the intersection between one of the extremes of the I_{min} axis, and the external contour (i.e.P_3), is not well situated (i.e. see the circle in this Fig.1). And when the computation to evaluate Φ is carried out, the final result is that shown in Table1, namely a higher value that the theoretically hopped for this kind of shape, that as we can observe it is symmetric in that direction.

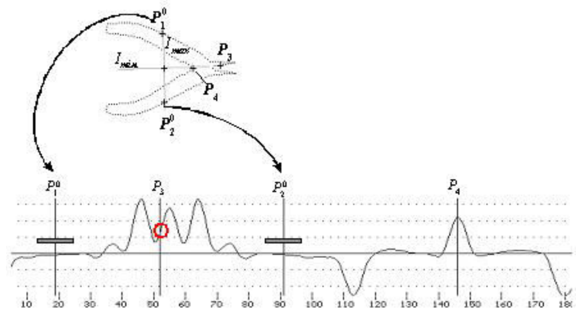

Fig. 1. The performance analysis in the case of pincers. Marked with a circle is observed the bad situation between the I_{min} axis and the external contour of this shape (i.e. P_3).

3. How to solve this problem?

Well, looking at literature we find the Leyton's Theorem [Leyton, 87], about "symmetry-curvature duality", were a local correspondence between a symmetry axis and a curvature point contour is established. Thus, if a symmetry axis exists in a shape, this axis intersect the shape always in a local extreme of curvature. Our present contribution has been to implement this Theorem in our algorithms in order to solve the initial problems found.

And, as work in progress, we are now testing the use of this new Φ, incorporating the Leyton.s Theorem, as a new descriptor in automatic object recognition.

Finally, it is noticeable that with this improvement we have got a very robust solution to evaluate the symmetry degree associated to a planar shape in a predefined direction, and in a very fast way, making feasible real applications in the robotics domain.

References

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