degrees of overlap. Previously, the resolution of the original range images was reduced by
interpolation. Thus, the algorithm was evaluated starting from low resolution with the aim of obtaining
an alignment with rotation and translation errors of less than 5° and 5mm respectively. If the algorithm
were not capable of finding a good alignment, the resolution is increased successively having the
original resolution as a limit. The number of points of the reduced range image (before removing parts)
necessary for a good alignment is shown in Table 2 for twelve range images corresponding to four
different objects. These results show that the proposed algorithm and similarity measure have a good
performance when both density and overlap are low, which is not possible with algorithms that use 2D
or 3D descriptors [34], since they need a sufficient quantity of points in order to construct the
descriptors.

Moreover, as is shown in Figure 11, the alignment algorithm can also be used to determine the pose
of an object in a cluttered scene (problem that arises in bin-picking tasks). In this case, point cloud 1
represents the scene and point cloud 2 represents the object model. Thus, the radius of the point-of-
interest environment must be limited to the maximum radius that can be obtained for the object (in
Figure 11 this limit was fixed at 120 mm).

**Figure 11.** 3D alignment in cluttered scenes (point-of-interest environment radius equal to 120 mm).
(a) Range images: scene (left) and object model (right). (b) Corresponding points (normal vector in
magenta) which obtained the maximum similarity value. (c) CIRCON images associated with those
points. (d) Alignment: reduced cloud (left) and 3D rendering using the original point clouds (right).