2.2. Descriptor Construction

In order to obtain the descriptor associated with a particular point-of-interest in the cloud (let \( ^w p_q \) be this point), it is necessary to express the cloud points in a local coordinate system centered on \( ^w p_q \) and whose \( Z_q \)-axis is its normal vector. The \( X_q \)-axis is chosen so that it is perpendicular to both the \( Y_w \)-axis of the reference coordinate system and the normal vector at the point-of-interest. Thus the \( Y_q \)-axis is determined by the cross product of unit vectors along the \( X_q \) and \( Z_q \) axes. This criterion establishes a unique reference for the angles of rotation about the \( Z_q \)-axis (i.e. above normal \( \overline{n}_q \)), which will subsequently facilitate the calculation of the Euclidean transformation associated with that correspondence.

**Figure 1.** Construction of a CIRCON descriptor. Green shows cell division in sector i and red indicates the contour formed by the points of the cells with the greatest z coordinate.

![Diagram of CIRCON descriptor](image)

Once the cloud points are transformed to the local frame, the environment of the point-of-interest is considered to be divided into \( n_s \) sectors (whose angle is \( \rho_\theta \) radians), which are further divided radially into cells with length \( \rho_r \) mm (excluding the cell closest to the centre, “cell 0”, which will be a sector with a radius \( 0.5 \cdot \rho_r \) mm). The sectors are numbered clockwise starting with the sector that is centred on the \( X_q \)-axis (\( \theta_i = 0 \)). Figure 1 shows, around the \( Z_q \)-axis, this sense of numbering and the nature of the cells for the i-th sector.

Taking into account this division of the point cloud into sectors and cells, a transformation based on cylindrical coordinates is applied in order to obtain, for any point \( p_d \) with coordinates \((x_d,y_d,z_d)\) in the coordinate system with origin at \( ^w p_q \), the \( i \) index corresponding to the number of sector to which it belongs, the \( j \) index indicating the cell within that sector, and the height value associated with its coordinate \( z_d \).

\[
i = \left\lfloor \frac{\tan^{-1} \left( \frac{y_d}{x_d} \right)}{\rho_\theta} \right\rfloor \mod n_s + 1
\]

(1)