Image Segmentation by Spherical Coordinates

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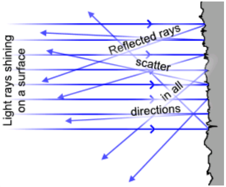
Introduction

- In this work we present a Image Segmentation algorithm.
- It is grounded in the dichromatic reflection model through a spherical interpretation of the RGB color space.
- The proposed approach takes advantage from strong robustness regarding highlights and spots and doesn't need preprocessing.

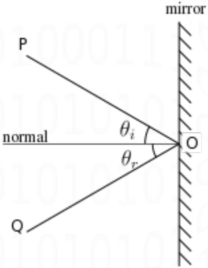
Introduction

- Inspired from the human-like vision, the described segmentation algorithm is based on hybrid distance evaluation.
- It uses a neighborhood in labeling the segment, engaging only the four "West-Nord" neighbors.
- This low computation time consuming method can be applied for real time applications as those dealing with robots' visual control.

Diffuse and Specular reflections



(a)



(b)

(c)

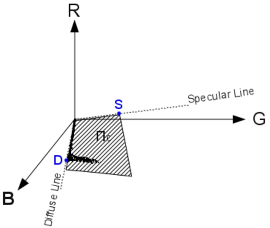
Figure: Diffuse reflection(a), specular reflection(b), natural image(c)

DRM

- The Dichromatic Reflectance Model (DRM) explains the formation of the image of the observed surface as the addition of a diffuse component D and an specular component S.
- Algebraically, the DRM is

$$I(x) = m_d(x)D + m_s(x)S$$

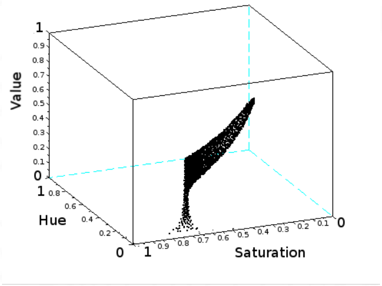
where m_d and m_s the diffuse and specular component weights respectively.



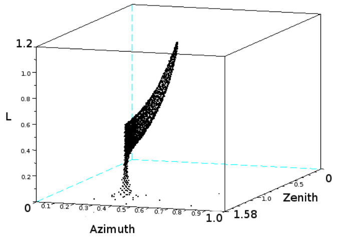
Color Space

- The DRM is defined as a vectorial sum in an euclidean space. This linearity exist in RGB however do not exist in other spaces like in the HSx family.
- When working with color images is very interesting to separate color in its components; intensity, chromaticity, hue and saturation specially when we are looking for photometric invariants.
- We can get it expressing the RGB color space by spherical coordinates, where a pixel $p_{euclidean} = \{r, g, b\}$ can be expressed equivalently in spherical coordinates by $p_{spheric} = \{\theta, \phi, l\}$ where θ, ϕ are the angular parameters and l is the vector magnitude.

Color Space



(a)



(b)

Figure: Distribution of the ball image in the HSV color space (a) and in the spherical interpretation of the RGB color space (b)

Color Space

- Previous figure shows the distribution of the image pixels in a $\theta - \phi - l$ space.
- As we can see the pixels distribution in this space is very close to the HSV space.
- But by difference with HSV, the spherical interpretation of the RGB color space let us express the DRM in spherical coordinates as:

$$\mathbf{I}(\mathbf{x}) = (\theta_{\mathbf{D}}(\mathbf{x}), \phi_{\mathbf{D}}(\mathbf{x}), l_{\mathbf{D}}(\mathbf{x})) + (\theta_{\mathbf{S}}, \phi_{\mathbf{S}}, l_{\mathbf{S}}(\mathbf{x}))$$

where the first one is the diffuse component and the second one the specular component.

Segmentation

- If P() is a homogeneity predicate defined on groups of connected pixels, then segmentation is a partition of the set F into connected subsets or regions $(S_1, S_2, ..., S_n)$ such that $\bigcup_{i=1}^{n} S_i = F$ with $\forall i \neq j, S_i \cap S_j = \varnothing$
- In out method a set is identified by a label

Distance

- The kernel of all edge detector id a distance applied in a neighborhood
- Empiliral experiments say ud that:
  - Intensity gradient is a bad chromatic edge detector
  - Chromatic gradients are very noised in dark regions
- We'll propose a hybrid distance solving this problems

Hybrid distance

- The function $\alpha(x)$ depends of the image intensity.

$$\alpha(x) = \begin{cases} 0 & x \leq a \\ \frac{c}{2} + \cos\left(\frac{(x-a)\cdot\pi}{b-a} + \pi\right) & a < x < b \\ c & x \geq b \end{cases} \quad (1)$$

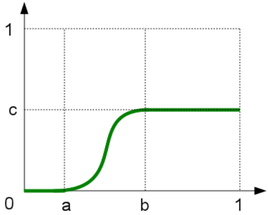


Figure: Chromatic activation function $\alpha(x)$

Hybrid distance

Now we can formulate an hybrid distance between whatever two pixels p,q as follows:

$$Hd(p,q) = \overline{\alpha}(p,q) \cdot Id(p,q) + \alpha(p,q) \cdot Cd(p,q) \tag{2}$$

where the relationship between $\alpha(x)$ and $\alpha(p,q)$ is done by $x = \frac{|l_p - l_q|}{2}$ where l_p, l_q

- Id is an intensity distance as $Id(p,q) = |l_p - l_q|$ and
- Cd is a chromatic distance as $Cd(p,q) = \sqrt{(\theta_q - \theta_p)^2 + (\phi_q - \phi_p)^2}$

Main aspects

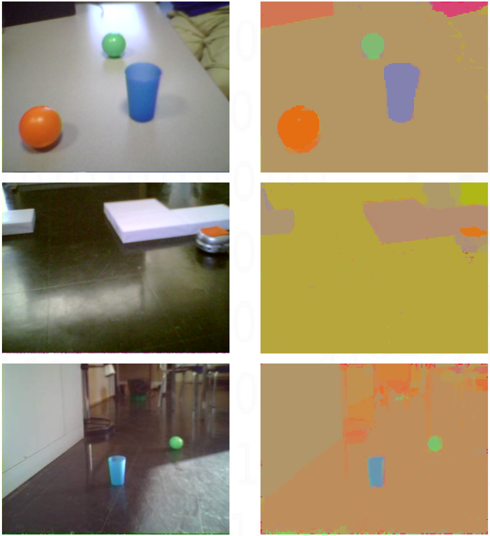
- This algorithm returns a bi-dimensional integer matrix where each label is a integer.
- Computing this algorithm we need also a structure that relate each label with a chromaticity and the amount of pixels labeled with it.
- That is necessary because each time that we assign a new pixel to a label we must actualize the chromaticity of this label, the chromaticity of a label is the mean chromaticity of all pixels labeled with it.
- The most important parameter for this algorithm is the chromatic threshold δ.

```
Set the threshold δ, and values a,b,c
for each x ∈ Ω loop
    look the neighborhood labels
    If there is only a label
        dm ← min(Hd(x,y)) ∀y ∈ N_4(x))
        If dm < δ (this neighbor is close)
            Assing this label to the current pixel
            Update label chromaticity
        else
            Create a new label
            Assign it, to the current pixel
    else
        D ← Hd(L_1,L_2)∀L_1,L_2 ∈ NL|L_1 ≠ L_2
        If min(D) < δ
            Assign label to the current pixel
            Update label chromaticity
            "Region merging"
        Else (all labels are different each others)
            dm ← min(Hd(x,y)) ∀y ∈ N_4(x))
            If dm < δ
                assign nearest label
                update label chromaticity
            Else (actual pixel is different of the neighbors)
                create a new label
                Assign it
end loop
```

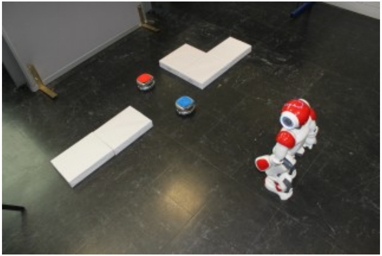
Experimental results

- We have developed the previous described algorithm for robotic applications involving real time computing time.
- This segmentation method is using in a NAO robot.
- The main features of the images taken by robots are, firstly the noise, due to the poor quality of this cameras and secondly the shine due to the real environment where the robot is.
- For a good visual supervision, the output images are drawn using the label's chromaticity with a uniform intensity ($l = 0.7$).
- The used parameters was: $Thr = 0.02$, $a = 0.2$, $b = 0.4$ and $c = 0.5$.

Experimental results



Experimental results



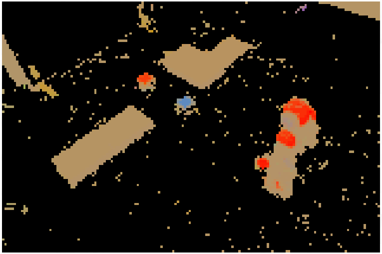


Figure: Segmentation of image of NAO environment

In this work we have presented a segmentation method, with the following features:

- It is fast method and can be applied in real time.
- It doesn't need preprocessing for edge detection contrary to some other approaches.
- It is grounded in the dichromatic reflection model and therefore it has physical support.
- It use a hybrid distance inspired in the human vision and through its parameters can be adapted to different conditions.
- It has a good behavior, avoiding shine problems and detecting correctly color edges.

Thanks so much for your attention :)