Workshop on Contributions to Standards and Common Platforms in Robotics

Contributions to Standards and Common Platforms in Robotics: the Role of Color and Recommended Modalities

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1. **Introduction**
2. **The Role of Color**
3. **Recommended Modalities**
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Introduction 1 of 4

- **Robotics and AI: from research to applications**
- **Required functionalities of robots are varied and complex; standards should help**
- **Special areas of interest for us:**
  - **Cooperative robotics**
  - **Human interaction in domestic environment**
  - **AI, cognition, cognitics**
  - **Go quantitative ! Analogy: height of a wall to pass over**
- **Publications made, re. "MCS", a book; quantitative; in real world, Also re. SCPR'08 about standards.**

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- **Goal: cooperative robotics and human interaction for the domestic environment**
- **"Robocup", in particular "At-Home" : excellent environment for testing and validating**
- **More specifically here: "Colors", for perception and communication purpose. The latter are, basic and necessary capabilities of domestic service robots:**
- **Validation tests: "Follow and Guide", "Go and Get it", "Lost and Found", "Who is Who?", etc.**

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- **+ Vision has been studied in humans;**
- **+ Numerous chromatic standards developed (e.g. Pantone, ISO, Windows and HTML - W&H)**
- **+ Classic CIE Color chart well established and billions of variations are now measurable**
- **- Yet a mere 16-color standard (W&H) is already challenging for usual 30 bit/s human cognitive channel :** e.g. "Teal", "Lime", "Silver", "Aqua" and "Olive"? And intensity-based color differences: Yellow/Olive, Blue/Navy, Lime/Green, Red/Maroon?
- **- RGB semantically poor; e.g. Color if R=0.75? Maybe red, but maybe also light-gray, orange, purple or even a low-saturated cyan instead!**

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- **> classical RGB->ISH (or HSI) mapping**
- **> NEW: Saturation-based differentiation and recognition processes,**
  - **for 9-colors (**Like for the Boolean, digital representation, the coarse representation here is extremely good in terms of noise margin it allows**)**
    - **3 grays, incl. B & W**
    - **2 x 3 primary colors (additive - subtractive)**
  - **and for more! (**For internal, machine-based reasoning**)**
    - **Hue *or* intensity based**
    - **SbWCD: saturation-based weighted hue *and* intensity color difference**
  - **spatial neighborhood features**

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2.1 The role of vision, and more specifically, of color perception, in humans

2.2 The potential of color perception, for robots

2. The Role of Color 2 of 14

2.1 Color for humans

 

- **Black and white images are useful**
- **for example, the above person can be recognized**
- **Yet, in practice, intensity may strongly vary in the image for similar intrinsic albedo values, such as in the forehead or the nose.**

2. The Role of Color 3 of 14

2.1 Color for humans

Humans perceive their environment, with five different senses:
- **to adapt to circumstances,**
- **to move efficiently,**
- **to gather or produce food, and**
- **in general to proceed with all aspects of life.**

In particular, vision
- **rapid acquisition (about 0.2 s)**
- **huge amount of information (about 2^{10^7} bit)**
- **large range of distances (0.01 m to millions of km (Moon, Sun))**
- **large aperture angle (up to 180 degrees).**

2. The Role of Color 4 of 14

2.1 Color for humans

A particular domain of vision relates to **color** sensing, and we now focus on that domain. Color perception for humans is addressed here in three steps:

- what is the **goal** of color perception,
- what are the specific **advantages** and
- what are the **drawbacks** of this approach?

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2.1 Color for humans

Goal.

- Early evolutionary stages : visible band of the electromagnetic spectrum.
- Equivalent to the early capabilities of black-and-white TV.
- Color perception implies the ability to **perceive several light bands** and to **differentiate** between them.
- Experience shows that color-based perception has **increased benefits** when compared to black-and-white perception.

2. The Role of Color 6 of 14

2.1 Color for humans

***Advantages*.**

- **Several channels instead of a single one does not ensure more information; a monochromatic channel could acquire more information with a larger spatial resolution, a better signal to noise ratio (SNR), or a larger bandwidth.**
- **For the human eye, the amount of acquired information remains quantitatively very similar in mono, polychromatic and stereo modes; in color perception: 3 channels, but spatial resolution two to four times smaller!**
- **The key advantage of color perception, is the ability, in most circumstances, to acquire intensity-independent visual features.**

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2.1 Color for humans

In practice, color gives useful additional information (e.g., objects on the ground.)

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2.1 Color for humans

***Drawbacks of color perception*.**

- **higher system complexity**
- **requirement for relatively high light levels (human eyes do not attempt to detect colors in night vision).**
- **"useless" in cases where all color channels receive a similar power (low saturation)**

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2.1 The role of vision, and more specifically, of color perception, in humans

2.2 The potential of color perception, for robots

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2.2 Color for robots

Contrast: Early robots (re. manufacturing environments) did not heavily rely on perception channels. Yet, machines have huge capabilities in terms of data acquisition (from nuclear magnetic resonance tomography to billion-year-old light wave acquisition in space with Hubble)

In particular, vision can be very effective in perceptive applications. Here, with focus on vision and color sensing.

Three steps: goal, advantages and drawbacks

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2.2 Color for robots

***Goal*. Three main alternatives should be considered:**

- **to emulate humans**
- **to improve the ability of robots to operate on their own in a manner functionally similar to the one of humans**
- **to enable the best possible cooperation between humans and robots**

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2.2 Color for robots

- ***G1, to emulate humans.*** **May sound attractive, but ultimately cannot succeed, as machines will never be humans.**
- ***G2, to improve the ability of robots to operate*** **on their own in a manner functionally similar. Thus many more tools and techniques can be used, including distance scanners and infrared cameras. The use colors, should in principle yield results similar to those achieved by humans and that are adequate.**
- **G3 to enable the best possible cooperation between humans and robots. In addition, to G2, matches the needs of communication, for human-robot dialogue and cooperation.**

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2.2 Color for robots

Advantages.

- **Similar to its use in humans: color perception, therefore defining its role, is its ability, in most circumstances, to acquire intensity-independent visual features**
- **Additionally, for robots, this approach matches with the communication needs, which are required for dialogue and cooperation between robots and humans.**

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2.2 Color for robots

***Drawbacks*.**

- As in humans, the drawbacks of color perception include higher system complexity
- Cost is higher for color perception here than for monochromatic system
- Sensitivity is "doubly" reduced (versus monoband):
  - practical silicon-based systems have half of their bandwidth in the infrared range, which must now be filtered out;
  - and furthermore, for appropriate white balance, the sensitivity of the red channel must be squeezed down to the one of the blue channel (10 to 100 times lower)

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3. Recommended Modalities

3.1 Light properties and other principles.

3.2 Preferred modalities

3. Recommended Modalities 1 of 7

3.1 Light properties

- **Depending on application, light is focused, diffused, filtered in specific frequency bands, monochromatic, and possibly, in the latter case, monophasic.**
- **A very common approach: black-and-white (BW), reflecting the natural sensitivity of silicon: visible band + the near-infrared.**
- **Most common approach : 3 overlapping bands, red, green, and bue (R,G,B), filtering out the infrared range of native silicon sensors.**

3. Recommended Modalities 2 of 7

3.1 Light properties

- **Electromagnetic signals can be much more than BW and RGB: some satellites feature up to 14 different channels (e.g., microwaves, very effective through clouds and ice; and X-rays, through many materials that absorb or reflect visible light).**
- **Other principles may be used, such as active light triangulation or ultrasonic or light-based time of flight measurements.**
- **The human red channel includes a sensitive range across a short wavelength domain, usually not replicated in machine**

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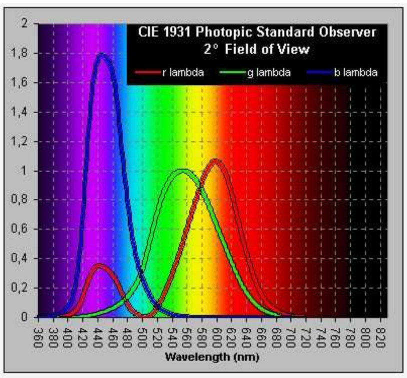
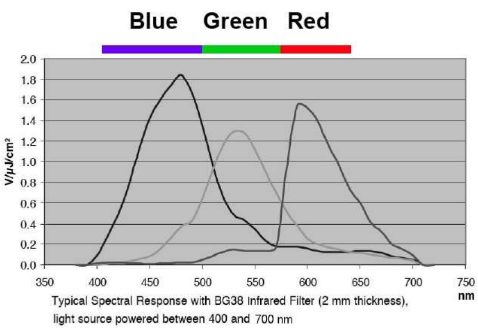
3.1 Light properties





- **Notice in particular the red channel in humans (left, CIE chart) and machines (right, Atmel)**

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3.1 Light properties

- **A common, but strange, definition of intelligence implies that AI is impossible: intelligence is a property exclusively implemented in humans. People who subscribe to this view likely have a similar opinion regarding vision: anything that can be achieved by machines is by definition a trick or minor solution, but can never really be considered AI or vision.**
- **Vision can schematically be split into three phases:**
  1. **Image acquisition : the proper mapping of features from the real, physical world to a table of numbers in memory, a 2-D image.**
  2. **2D image processing, e.g., smoothing, edge-extraction, or blob labeling.**
  3. **Scene analysis: extracting specific features from 2D images, allowing for relevant image analysis, e.g., the size and location of an object.**

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3.2 Preferred modalities

- **Vision is often a very complex faculty. Successful color-based vision typically requires taking into account the following elements :**
  - **Focus on selected applications and goals (e.g., 11-pixel-based banknote recognition).**
  - **Special attention to primary features and precursors ("pre-color features" e.g., fluorescence, reflectance, shadow casting, surface orientation, and index of refraction of the transparent-media lens effect) and not only on common secondary features (e.g. blob area)**

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3.2 Preferred modalities

- Careful exploration of most **discriminating** features and spaces.
- **Intensity-saturation-hue** (ISH) mapping: intensity often of a small value compared to hue; nevertheless when saturation low, hue gets too noisy.
- Possible orthogonality with human perception: IR use.
- **Best use of the intensity versus hue duality***: use of the SbWCD function defined below.
- Pattern processing* (e.g., matched filters, Haar transforms and correlation)

* re. §Implementation)

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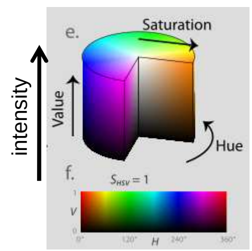
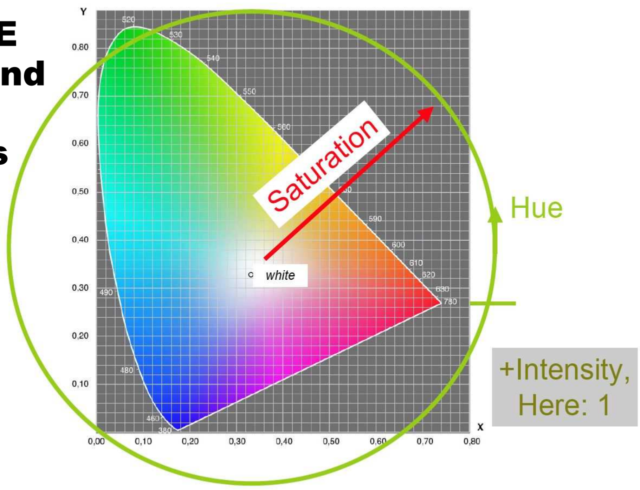
3.2 Preferred modalities

- Standard CIE color map and ISH components



Doc. Wikipédia



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4. Implementation

4.1 Image acquisition
4.2 2D-processing
4.3 Scene analysis
4.4 From RGB to ISH representation
4.5 Nine color mode
4.6 Saturation-based Weighted Color Difference (SbWCD)
4.7 Correlation with SbWCD

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4.1 Image Acquisition

- Image acquisition is a necessary stage that is of critical value
- Laymen tend to overlook this stage
- Experts take great care in
  - searching for the most discriminating physical parameters,
  - mapping them to light phenomena, and finally
  - acquiring images with high contrast (SNR)
  - using the smallest possible amounts of information (dynamic ranges and resolutions in time, space, intensity and spectral range)

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4.2 2D-Processing

- The 2D processing of images is usually very limited in its scope
- The individual processing of each pixel is most easily performed (re. tables or palettes)
- The potential of kernel-based processing (ordinary filtering) is limited:
  - kernels must be small (re. resolution)
  - consequently little variety is possible (a Gaussian function and a triangle are exactly the same "curves" in 3 samples).
- Blobs are connected regions of pixels with identical values. Of high interest: labeling

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4.3 Scene Analysis

- Scene analysis is most often done on the basis of very simple image components such as selected pixels or one or a few line segments.
- When regions are considered, typically as blobs, they are typically characterized by their colors, sizes and locations.
- Semantically, either the individual components are relevant, or more globally, the specific structures may turn out to be useful clues in considered scenes

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4.4 From RGB to ISH representation

- The transformation RGB to ISH yields semantically rich features
- Performed at the pixel level, it is classical
- In our Piaget environment, RGB and ISH components are 8-bit (0-255) numbers
- *Intensity* is the average of RGB components.
- Rearrange RGB components (Max, Med, Min).
- *Saturation* : S=(Max-Min)/(Min+1)*255.
- *Hue* is estimated in several steps.
  1. H=f(Max); R=>H=0; G=>H=83; B= >H=167);
  2. Correction C in the direction of the second-largest component: C = ((diffmax-diffmin) /(diffmax+1))*42 with diffmax =Max-Min, and diffmin=Med-Min); H=H + or - C; mod 255;

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4.5 Nine-Color Mode

- The **nine-color mode** is useful to segment color images into uniform regions, => rich semantic content, (e.g. various objects or environmental components)
- The first parameter analyzed : **saturation**
- if saturation high => reliable hue analysis...
  - Hue considerations
    - => one of the 3 **primary colors** in additive synthesis: red, green or blue; or
    - => one of the 3 intermediary hue values: yellow, cyan or magenta
  - ... else intensity is processed instead=> one of three levels: **white, gray, or black**.

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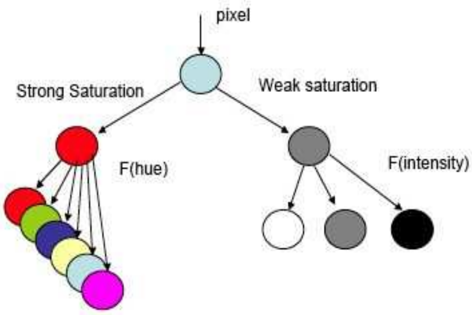
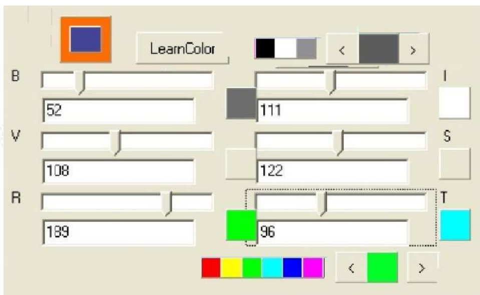
4.5 Nine-Color Mode





- Nine-color mapping on an ISH basis. Saturation value dictates whether hue or intensity is relevant. Hue and intensity intervals **can be adjusted**

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4.5 Nine-Color Mode

- **nine values for colors => good tradeoff**
  - **number of different colors used to distinguish regions**
  - **uniformity in a domain where noise levels have little influence.**
- **For most cases in Piaget, however, all thresholds can be dynamically modified: e.g.,**
  - **a saturation limit between the intensity and hue domains,**
  - **a black-to-gray intensity limit, and**
  - **a red-to-yellow hue limit.**
  - **In fact, five hue intervals can be very narrowly defined, so as to distinguish, for example, five different kinds of “red”**

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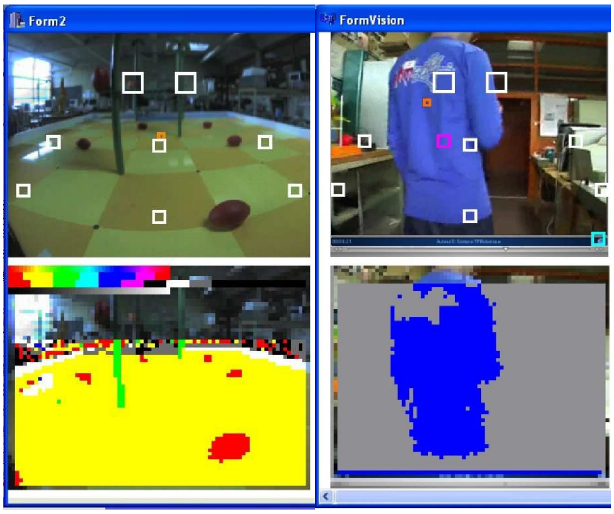
4.5 Nine-Color Mode

Nine-color mapping on ISH basis, in a large section of each picture. The nine colors are very robust (left, for Eurobot). One out of nine possible colors (here, blue) allows for robot guidance, e.g., in the case of the Bremen Robocup-at-Home competition (right).”



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4.6 Saturation-based Weighted Color Difference (SbWCD)

- **For more demanding cases, nine colors are not enough, and there is more pressure to cope with unwanted variations and disturbances (noise).**
- **The major limiting factor appeared to be the two-level quantification of the saturation value**
- **Re. fuzzy logic systems:**
  - **Boolean values are replaced by finely-varying membership functions.**
  - **Well-identified cases get ad hoc solutions and decisions evolve continuously in between**
- **Similarly here, two thresholds for saturation value are defined, and between them, the results stemming from hue and intensity considerations are combined with weights depending on pixel saturation.**

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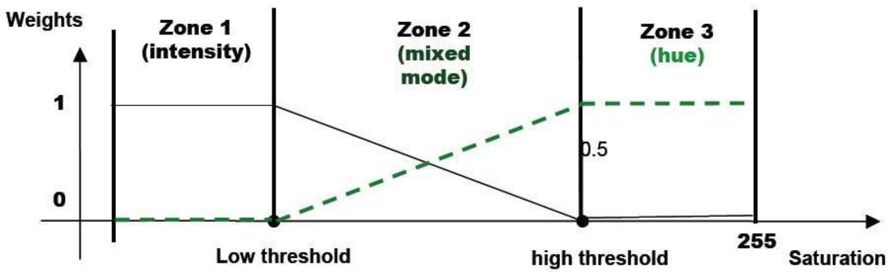
4.6 Saturation-based Weighted Color Difference (SbWCD)



As in fuzzy logic, a weight function is associated with intensity or hue processing, which finely depends on saturation level

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4.6 Saturation-based Weighted Color Difference (SbWCD)

- **Algebraically, the difference between two pixels, pix_1 and pix_2, includes the following, elementary term (In principle; hue is cyclic though) :**

$$SbWCD_e = \frac{w_{hue}(sat)\cdot(h1-h2)+w_{\text{int}}(sat)\cdot(\text{int}1-\text{int}2)}{w_{hue}+w_{\text{int}}}$$

- **Saturation itself is a meaningful feature of colors :**

$$SbWCD = w_{contrast}\cdot dContrast + SbWCD_e$$

- **Other variations may integrate some statistical values in selected regions (average and standard deviation of intensity, most-common hue value in color histograms, etc.).**

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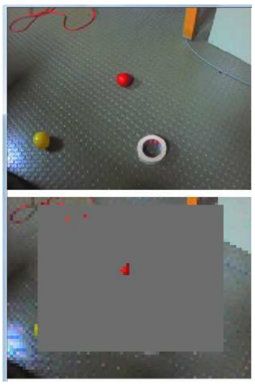
4.6 Saturation-based Weighted Color Difference (SbWCD)

-The first learned color is a kind of red, from a darker region of the ball
- Similarly, many other colors (L2-L19) have been learned simply by clicking on the picture
- Then the ball and some elements of a wire are recognized (lower image).
- On the right, previously learned colors are reproduced, along with their differences (re. SbWCD) with respect to the currently-selected red



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4.7 Correlation with SbWCD

- **The colors described above relate to individual pixels**
- **Yet, for more complex cases, a limit arises where patterns in image sub-regions must be considered**
- **In this paragraph, the joint use of a sliding kernel mechanism similar to classical correlation processes and of the semantically very robust SbWCD differences just introduced is presented.**

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4.7 Correlation with SbWCD

- **The basic correlation function is the following, whereby a template, y(j) is compared to another function, x(m):**

$$R(k) = \sum_{i=1}^{n} x(i+k) \cdot y(i)$$

A maximum value of R typically denotes the maximum similarity of the two functions, and k specifies for which function shift this best result occurs.

In 2D (A denotes the sub-region to detect):

$$R(row,column) = \sum_{l=1}^{n} \sum_{c=1}^{n} I(l+row, c+column) \cdot A(l,c)$$

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4.7 Correlation with SbWCD

- **Alternative: absolute differences.**
  Best match <=> minimal difference :

$$D(row,column)=\sum_{l=1}^{n}\sum_{c=1}^{n}\left|I(l+row,c+column)-A(l,c)\right|$$

- **Colors requires adaptation of the subtraction operator:**

$$D_{SbWCD}(row,column)=\sum_{l=1}^{n}\sum_{c=1}^{n}SbWCD\big(I(l+row,c+column),A(l,c)\big)$$

- **Very powerful indicator. Improves previously-used effective approaches such as matched filters for bin picking or Haar transforms for facial recognition (both classically rely only on gray level representation)**

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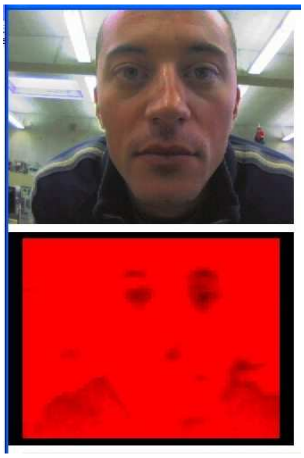
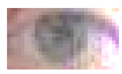
4.7 Correlation with SbWCD

- **A small region (left eye) selected in the top left image (shown without change, and enlarged below, with a lighter intensity and a stronger contrast)**
- **The lower left show the "correlation" results (with regards to D_{SbWCD}); high similarities are displayed as dark shades**
- **Not surprisingly, the best similarity is found at the location of the trained left eye.**





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4.7 Correlation with SbWCD

- The proposed approach is very robust
- For example, some tests made:
  - the same reference gives the correct result on both images of Fig. 1 (color versions)
  - on various objects in Fig. 8, and
  - for torso recognition of the guide in the Robocup-at-Home 2010 “Follow-me” task
- The problem is difficult. For example, the white part of the eye should ideally have a maximal intensity (255 in our context), and yet it is measured as 87 in these circumstances.
- If required, further improvements are possible by normalization of the comparison.

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4.7 Correlation with SbWCD

Some views of the RH5-Y team and robots in Singapore during Robocup 2010 Congress and Competition (league “at-Home”). Color-based vision is critical in several of the tests.

5. Conclusion 1 of 4

- For humans, vision is important for detecting objects at a distance.
  - Gray level is simple and appropriate for scenes with very low optical power
  - Otherwise, color brings specific benefits in terms of scene element discrimination and robustness to intensity variations
- For robots, many additional perception possibilities exist, but color awareness has an advantage for cooperation with humans.

5. Conclusion 2 of 4

- Image acquisition requires proper engineering techniques
- ISH (intensity-saturation-hue) representation is an advantage for the subsequent use of light information
  - In particular, saturation is crucial for selecting color properties based on hue versus selection based on intensity.
  - In the low level saturation domain, hue is random, and intensity is more significative
  - in high saturation, hues are usually much more reliable than intensities.

5. Conclusion 3 of 4

- While a nine-color approach is an effective solution which combines simplicity and immunity to noise in a manner similar to that used with Boolean signals, more discrimination power is often required. For this purpose, a Saturation-based Weighted Color Difference approach is proposed (SbWCD), both at the pixel level, and, for more demanding cases in which patterns are the key, for a specific difference estimation of correlation type.

5. Conclusion 4 of 4

- In the SbWCD approach, weights are associated to hue and intensity differences to mix them differently as functions of saturation; in a manner similar to fuzzy logic
- Relevant equations are given in the paper, along with some examples in the context of Robocup and domestic applications with cooperating robots.
- Acknowledgements: past RH-Y team members, as well as HESSO and HEIG-VD support

Thanks for your attention!

More information... 1 of 3

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Program

(The order of presentation is modified. (2010/11/12))

Opening Remark [08:40-08:45]

Session 1: Common Platform [08:45-10:00]

1. **Christoph Brauers, Marcel Dombrowski, Hartmut Surmann, Rainer Worst, Thorsten Linder, and Jochen Winzer:**
   "The RescueBot - A new variant of the VolksBot"
2. **Heinrich Mellmann, Yuan Xu, Thomas Krause, and Florian Holzhauer:**
   "NaoTH Software Architecture for an Autonomous Agent"
3. **Itsuki Noda, Shuichi Nishio, Takeshi Tsubouchi, Takeshi Sakamoto, and Satoshi Tadokoro:**
   "Mathematicsl Framework for Localization Information Coordinate Reference System for Robotics"

(Coffee Break) [10:00-10:20]

SCPR 2010

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Program

(The order of presentation is modified. (2010/11/12))

Invited Talk [10:20-10:45]

- **Noriaki Ando**
  "Standardization Activity on Robotics in OMG" (tentative)

Session 2: Standards [10:45-12:00]

1. **Ulrich Karras and Martin Riedmiller:**
   "Simulation of Logistics in RoboCup Competition"
2. **Jean-Daniel Dessimoz and Pierre-Francois Gauthey:**
   "Contributions to Standards and Common Platforms in Robotics; The Role of Color and Recommended Modalities"
3. **Laurent Rioux and Charles R. Robinson:**
   "A Standards Based Architecture Using JAUS and RTC"

November 15-18, 2010 - Darmstadt, Germany

2nd International Conference on SIMULATION, MODELING, and PROGRAMMING for AUTONOMOUS ROBOTS

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Novel robotics applications driven by research, industry and society call for the development of systems of ever increasing complexity: systems with sliding autonomy; humanoid robots; distributed robots; mobile sensor networks, and so on. But unfortunately, steady improvements in robot hardware have not been matched by corresponding advancements in robot software. Besides fundamental open problems still waiting for sound answers, the development of new robotics applications still suffers from the lack of widely used tools, libraries, and algorithms ready to be incorporated into new projects. Simulation environments are playing a main role in reducing development time and cost of large scale systems. But their use is still regarded by many with skepticism. Seamless migration of code from general purpose simulators to real world systems is still a rare circumstance, due to the complexity of robot, world, sensors, and actuators modeling.

These challenges drive the quest for next generation of methodologies and tools for robot development. The objective of the International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR) is to offer a unique forum for these topics and to bring together researchers from academia and industry to identify and solve the key issues necessary to ease the development of increasingly complex robot software, and to boost a smooth shifting of results from simulated to real applications.

Topics of interest include, but are not limited to:

- 3D robot simulation and mathematical modeling of robots
- Reliability, scalability and validation of robot simulation
- Simulated sensors and actuators
- Offline simulation of robot design
- Online simulation with realtime constraints
- Simulation with software/hardware in the loop
- Middleware for robotics
- Modeling framework for robots and environments
- Testing and validation of robot software
- Standardization for robotic services
- Communication infrastructures in distributed robotics
- Interaction between sensor networks and robots
- Human robot interaction and collaboration
- Multirobot systems

News

Wednesday, November 03, 2010
Detailed program of the oral presentations is online!

Wednesday, November 03, 2010
Workshop schedules available on workshop websites.

Tuesday, October 07, 2010
Hotel reservation deadlines are approaching!

E-Mail Forward

General Chair	gc@simpar.org
Local Chair	lc@simpar.org
Program Chairs	pc@simpar.org
Exhibition Chair	ec@simpar.org
Tutorial Chair	tu@simpar.org
Workshop Chair	wo@simpar.org

Upcoming Important Dates

Submission of slides for the poster spotlight gong show

- November 10

Download complete **iCalendar**

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Sunday November 14

18.00	Sunday evening welcome tour	

Monday November 15

09.00-10.30	Workshop sessions	
WS1	International Workshop on Dynamic languages for RObotic and Sensors systems (DYROS)	3.06
WS2	Simulation Technologies in the Robot Development Process	3.07
WS3	Domestic Service Robots in the Real World	3.03
WS5	Teaching robotics, teaching with robotics	3.02
WS7	Biomechanical Simulation of Humans and Bio-Inspired Humanoids (BH)² Workshop	3.05
10.30-11.00	Coffee break	3.11
11.00-12.30	Workshop sessions	
WS1	International Workshop on Dynamic languages for RObotic and Sensors systems (DYROS)	3.06
WS2	Simulation Technologies in the Robot Development Process	3.07
WS3	Domestic Service Robots in the Real World	3.03
WS5	Teaching robotics, teaching with robotics	3.02
WS7	Biomechanical Simulation of Humans and Bio-Inspired Humanoids (BH)² Workshop	3.05
12.30-14.00	Lunch break	
14.00-15.30	Workshop/Tutorial sessions	
TU1	Model-Driven Software Development in Robotics	3.06
WS2	Simulation Technologies in the Robot Development Process	3.07
WS5	Teaching robotics, teaching with robotics	3.02
WS7	Biomechanical Simulation of Humans and Bio-Inspired Humanoids (BH)² Workshop	3.05
15.30-16.00	Coffee break	3.11
16.00-17.30	Workshop/Tutorial sessions	
TU1	Model-Driven Software Development in Robotics	3.06
WS2	Simulation Technologies in the Robot Development Process	3.07
WS5	Teaching robotics, teaching with robotics	3.02
WS7	Biomechanical Simulation of Humans and Bio-Inspired Humanoids (BH)² Workshop	3.05
17.30	Workshop reception	3.11

Tuesday November 16

08.30-10.00	Workshop/Tutorial sessions	
WS4	Brain Computer Interface	3.06
WS6	Standards and Common Platforms for Robotics (SCPR 2010)	3.07
TU2	An Introduction to the OpenSim API	3.05
10.00-10.30	Coffee break	3.11
10.30-12.00	Workshop/Tutorial sessions	
WS4	Brain Computer Interface	3.06
WS6	Standards and Common Platforms for Robotics (SCPR 2010)	3.07
TU2	An Introduction to the OpenSim API	3.05
13.00-13.30	Lunch break	