Groupe de Recherche en Informatique, Image,
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Vade Mecum of Image Processing Objective Formulation

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Object of the document: This report provides a thorough guide to formulating image processing applications. A formulation has to clearly specify the objective of the application and to identify the range of available input data. Defining a "good" formulation is essential towards the goal of designing more robust and more reliable vision systems since it allows to fix the limits of the application, to favor reusability and to enhance evaluation.

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1.0	11/07/07	Initial published version
1.1	23/12/09	Revision of image class definition
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Table of Contents

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1 Prolegomena

1.1 Presentation

This report provides a thorough guide to formulating image processing applications. A formulation has to clearly specify the objective of the application and to identify the range of available input data. Defining a "good" formulation is essential towards the goal of designing more robust and more reliable vision systems since it allows to fix the limits of the application, to favor reusability and to enhance evaluation. A "good" formulation is understood as being:

- **compact**: it is reduced to essential information;
- **representative**: it keeps a strong correspondence to the real objects;
- **robust**: it has the ability to integrate all abnormalities and unusual cases;
- **discriminative**: it contains enough information to discriminate objects between them;
- **precise**: it allows a good identification of objects;
- **dense**: all foreseen objects and image primitives in the scene are modeled.

Unfortunately, formulating an image processing application is a problem of qualitative nature that relies on subjective choices. There does not exist an exhaustive or exact definition of the problem. Only an approximative characterization of the desired application behavior can be defined. Hence, it is the user responsibility to produce a good formulation.

The goal of this guide is to provide a formulation cycle together with models that go with the user to make the formulation more objective and less empirical and thus to help the user produce a rather good formulation.

This guide is intended to image processing specialist since the specification of the goal and the definition of the class of image requires skills.

1.2 Outline

The guide is organized as a reference document. First of all, the Section 2 defines precisely the image processing domain and describes the different elements of the methodology defined to formulate the application. Then, the section 3 describes the general process to perform the formulation according to the different points of view. Finally, the last sections contain all the reference tables which list the information category and the related vocabulary used at each part of the formulation process.

1.3 Definition of Image Processing

There is no general agreement on a clear-cut boundary of the image processing discipline. Hence, we adopt

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the following definition of image processing stated from an intentional viewpoint.

Definition 1. *Image processing encompasses all the images-to-images transformation objectives which result from combining the three basic operations – addition, modification and deletion – carry out on data in order to change signal values or to increase the intelligibility of information.*

Therefore, image processing is concerned with 6 co-dependent topics (Table 1):

- **Restoration**. The objective is to reconstruct the original image from its degraded version by adding signal information using a known degradation function.
- **Enhancement**. The objective is to improve the image quality by modifying signal information using only image data.
- **Compression**. The objective is to reduce the amount of memory needed to store a digital image by deleting "unnecessary" signal information.
- **Reconstruction**. The objective is to add symbol information from one or a set of input images such as depth, shape, or motion information. The result is an intrinsic image.
- **Detection**. The objective is to select a part of the input image that contains objects of interest and to discard all other information using shape or appearance models. The result is a positive mask.
- **Segmentation**. The objective is to structure pixels into symbols: region, contour and point of interest. The result is a segmented image.

Image is understood in its broader sense as any 2D, 3D or 4D multispectral representation of measured or calculated phenomena. This includes iconic images (eg., photo, scanning), statistical images (eg, IRM, TEP), intrinsic images (eg., depth map) and segmented images (eg., contour map, region map).

Input images are always considered at the signal level even if there are segmented or intrinsic images. In this case, the region label of the depth value is considered as a pixel value.

1.4 Definition of Image Processing Application

From a systemic viewpoint, an image processing application is analyzed as an intermediate system that consumes images from an image producer and generates images for a post-processing system (Fig. 1). It

Table 1. Image processing domain covers 6 objectives.

	Signal → Signal	**Signal → Information**
Add	Restoration	Reconstruction
Modifiy	Enhancement	Segmentation
Delete	Compression	Detection

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stresses both the dependence and the separation of the image processing application to the global application. It means that the image processing application can be considered as a separate unit (or suite of units) interacting with the remainder of the global application.

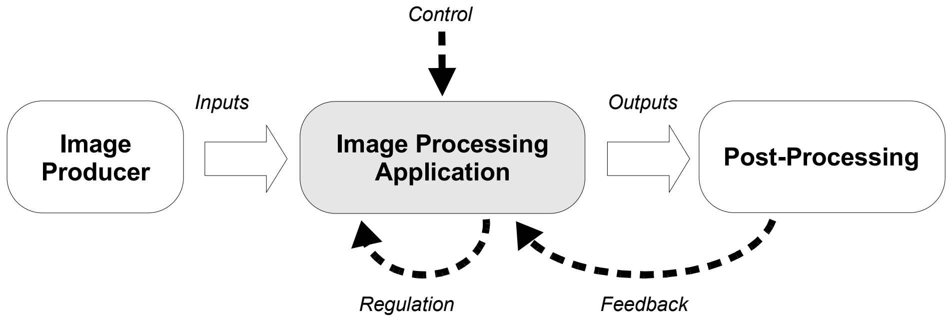

Fig. 1. An image processing application is a system that consumes image from an image producer system and generate new images to a post-processing system. Relationships with other systems, and with the execution environment are taken into account by the way of the control, the feedback and the regulation information.

The interactions with the global system are taken into account through the control mechanism, the interaction with the post-processing are taken into account through the feedback loop, and the variability of the input are taken into account through the regulation loop.

We adopt the following definition for image processing application stated from the software engineering viewpoint.

Definition 2. *An image processing application is a software specialized in the achievement of a given images-to-images transformation objective, which operates on images belonging to a given class.*

This definition has three consequences:

1. An application is clearly determined by an objective and a class of images. An objective refers to one of the six image processing objectives defined in Fig. 1. A class of images specifies a set of images that share the same list of invariant characteristics.
2. Any modification of the objective or the class of images leads to consider a new application. But it also implies that application must have self-capabilities to adjust its behavior in response to the inherent variability of images that belong to the class of images.
3. A global application generally encompasses several image processing applications that are chained sequentially, concurrently, or conditionally. The image producer can be an acquisition system or a synthetic image generator or a previous image processing application.

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1.5 Definition of Image Processing Application Formulation

Finally, the definition of the image processing application formulation is stated as:

Definition 3. *An image processing application formulation is composed on the one hand with the objective specification and on the other hand with class of images definition.*

An objective is specified by a task to perform on images. A class of images is defined by intension through a list of characteristics.

1.6 The objective specification

The objectives are expressed by mean of tasks to perform on images and constraints which restrict the scope of the tasks. Tasks translate processing intentions on images. This suggests a task-oriented specification of the objectives rather than a data-oriented specification.

1.6.1 Tasks to perform

The tasks are specializations of the processing objectives and hold on objects of interest or acquisition effects. They can formulate problems such as “enhance photometry”, “extract cars”, “segment image”.

1.6.2 The regulation constraints

The regulation process ensures the stability of the system with regard to the variability of the input images. It is expressed by one type of constraints **holding on the task** to perform:

- *Criteria to be optimized* identify elements on which the task should focus on. *e.g.*, since post-processing includes measures of area, then a criterion to be optimized is the localization of the nuclei boundary.
- *Acceptable errors* determine tolerances on each criterion to be optimized. They should decide compromises. *e.g.*, an acceptable error for the localization criterion is to prefer locating region boundary inside the nucleus to outside in order to avoid photometrical measure errors during the post-processing step.

1.6.3 The feedback constraints

The feedback loop translates the post-processing system requirements to the image processing system. It is expressed by one type of constraints **holding on the result** to produce:

- *Levels of detail* set the high and low limits of the scope of the task. *e.g.*, the low limit of the task “extract” can be to separate just-touching objects; the related high limit is to do not separate aggregates.

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- *Acceptable errors* determine tolerances on each level of detail. They should decide compromises. *e.g.*, an acceptable error for the separation level is to prefer aggregating just-touching nuclei than separatimg overlapping nuclei.

1.6.4 The control constraints

The control mechanism translates the global execution environment requirements. The control mechanism is expressed by two types of constraints **holding on the nature of the solution** to produce:

- *Performance criteria* express quantitative limitations on the resources to be used and on the processing time. *e.g.*, the processing time should be less than one second.
- *Quality criteria* express rather qualitative requirements on the ability of the system to face to foreseen and unforeseen situations. *e.g.*, the reliability is more important than the robustness (it means to prefer no solution to a wrong solution).

1.7 The Image Class Definition

An image class images is defined by a list of invariant descriptors at three levels (Fig. 2):

1. the physical level focuses on the characterization of the acquisition system effects on the images.
2. the perceptive level focuses on the description of the visual primitives (regions, lines, ...) without any reference to interest objects.
3. the semantic level focuses on the identification of the interest objects visualized in the images.

The definition of the class of image is based on the phenomenological hypothesis. This hypothesis states that a visual characterization of the images and the interest objects are sufficient to design image processing applications. Hence, we do not need a complete description of the scene but only a description of its visual manifestation. This includes the description of the effects of the acquisition process on the image contents, the characterization of the various interest objects from visual primitives and the spatial relationship between the objects.

1.7.1 Physical description

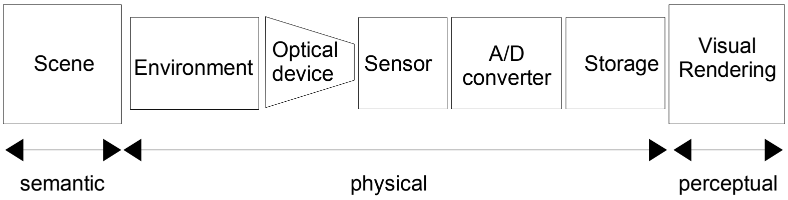

Fig. 2. The image acquisition process provides the three levels of description of the class of images.

The physical description details the effects of the acquisition process on the quality of the result images. Information is related to the various part of the acquisition system from the measure of the signal until the storage: environment conditions, optical device, sensor, digitalization and sampling, and storage techniques.

1.7.2 Perceptual description

Perceptual description accounts for the visual rendering of the image content from a global point of view without any reference to the real objects. The image content is described from the visual primitives: edge, region, point of interest, background or image area. Attributes detail geometrical, topological, spatial, texture, radiometric, and temporal characteristics of the visual primitives.

1.7.3 Semantic description

The semantic description reports the interest objects. It aims at identifying real objects or measured phenomena and at giving back lost or invisible information from the acquisition (*e.g.*, occlusion, loss of the third dimension). Attributes describe interest objects in terms of individual object properties (*e.g.*, minimal size, shape) and spatial distribution and temporal relationships.

2 The Formulation Cycle

The overall approach of the formulation of image processing application is composed of 6 steps.

2.1 Identification of the global objective

What is the global application domain and what is the objective of the global system? These information is mainly used to archive the application and to favor reusing.

1. Description of the global objective (in natural language)
2. Imaging category (cf. Table 2 Page 13)
3. Imaging sub-category (cf. Table 2 Page 13)
4. Application objective (cf. Table 2 Page 13)

2.2 Description of the post-processing

How the image processing results will be used in the post-processing?

5. Post-processing objective (cf. Table 3 Page15)
6. Input data (objects of interest) (cf. Table 3 Page15)
7. Operation to perform (cf. Table 3 Page15 and Table 4 Page 17)

2.3 Definition of the class of images

What are the invariant characteristics that define the images class?

8. Interest object tree (cf. Page 19). Build this tree if interest objects exist.
9. Physical description (cf. Table 5 Page 22)

Acquisition Effect	Descriptor	Value	Confidence

10. Semantic description (cf. Table 6 Page 23)
    - From the tree discriminate objects from each other.

Object	Visual Primitive	Feature	Descriptor	Value	Confidence

11. Perceptive level
    - Describe the visual primitives if objects are unknown or unpredictable.

Visual Primitive	Feature	Descriptor	Value	Confidence

2.4 Specification of the Image Processing objectives

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What are the intentions on images?

12. Image Processing tasks (cf. Table 7 Page 26)
13. Constraints:
    - Criteria to be optimized + acceptable errors (Table 8 Page 27).
    - Level of details + acceptable errors (Table 9 Page 28).

2.5 Control Constraints

What are the system control constraints?

14. Performance criteria + importance (cf. Table 11 Page 31)
15. Quality criteria + importance (cf. Table 11 Page 31)

2.6 Evaluation

How the result will be evaluated?

16. Evaluation protocol
17. Satisfaction rate

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3 Global objective

3.1 Categories

Table 2: Application domain categories (inspired from [Cloppet-96]).

Imaging Category	Application domain	Example
Strategic imaging	Surveillance	• License Plate Recognition • Surveillance camera
	Security	• Biometrics and forensic (face, iris, fingerprints recognition) • Drivers assistance / road monitoring • Avalanches detection
	Military defense	• Target tracking
Aerial and satellite imaging	Aerial	• Cartography • Ground object tracking • Environment
	Meteorology	• Infra red (IR) and thermal image analysis • Meteorology
	Astronomy	• Space • Celestial body tracking
Biomedical imaging	Biology (microscopic)	• Cytology • Histology • Virology
	Medical (macroscopic)	• Detection of organs • Brain analysis
Industrial imaging	Quality control	• Industrial inspection • Detection & Identification of flaws • Non contacts measures • Check for assembly integrity for completeness
	Robotic	• Robotic vision • Unmanned vehicle / autonomous vehicle
Commercial imaging	Document analysis	• Handwriting recognition • Signature and seal verification
	Gesture recognition	• Sign language interpretation • Gaze control
	Digitalization	• Digitalization of cultural heritage • Archival storage
Audiovisual and art imaging	Image and video indexing	• Content based Image or Video Retrieval • Video Semantic Indexing
	Communication	• Image compression

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Imaging Category	Application domain	Example
	High quality restitution	• Enhancement for visual rendering • Motion picture restoration
	Multimedia	• Virtual reality • Telepresence and telerobotics

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4 Post-Processing

4.1 Post-Processing Objectives

4.1.1 Definition

Objective	Definition
Scene reconstruction	The goal of 3D scene reconstruction is to provide a 3D model as complete and as accurate as possible, from a real world scene.
Archival storage	The goal of archival storage is to protect printed documents and photographs and to make them accessible to others now and in the future.
Art visualization	The goal of art visualization is to improve the image quality according to psychovisual criteria.
Detection / Tracking	Detection is the process of locating an object in the image and tracking is the process of following the object along the images.
Classification	Classification is a statistical procedure in which individual objects are placed into groups based on quantitative information on one or more characteristics inherent in the object.
Image comparison	Image comparison is the process of finding differences or similarities between two or more images.
Quantification	The goal of quantification is to score or grade images from quantitative measures extracted from the image contents.
Registration	Image registration is the process of transforming the different sets of data into one coordinate system.
Template matching	Template matching is a technique for finding small parts of an image which match a template image.
Transmission	Transmission encompasses data exchange through a network.
Visual inquiry	The goal of visual inquiry is to improve the quality of the image in order to put into light details that are not really visible to the human eyes.

4.1.2 Reference table

Table 3: Post-processing objectives with related possible input images and operations to perform on.

Objective	Input data	Operation to perform
Art Visualization	• Iconic image	• Display quality measurement • Print quality measurement
Visual Inquiry	• Iconic image • Segmented image (region, contour)	• Display quality measurement • Print quality measurement
Archival Storage	• Iconic Image • Statical image • Segmented image (region, contour)	• Compression measurement
Classification	• Segmented image (region, contour, point of interest)	• Morphology measurement • Orientation measurement • Radiometry measurement • Size measurement • Topology measurement

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Objective	Input data	Operation to perform
Image Comparison	• Segmented image (region, contour, point of interest) • Image	• Morphology measurement • Orientation measurement • Radiometry measurement • Size measurement • Topometry measurement
Detection Tracking	• Iconic image (mask) • Segmented image (region, point of interest)	• Morphology measurement • Spatio-temporal measurement • Topology measurement • Topometry measurement
Quantification (Grading, scoring)	• Segmented image (region, contour) • Statistical image • Iconic Image	• Morphology measurement • Orientation measurement • Radiometry measurement • Size measurement • Topology measurement • Counting
Registration	• Segmented image (region, point of interest, contour)	• Morphology measurement • Orientation measurement • Size measurement • Topometry measurement
Scene 3D Reconstruction	• Intrinsic image (depth image) • Segmented image (region, contour, graph, point of interest)	• Morphology measurement • Topology measurement • Topometry measurement
Template Matching (Pattern Recognition)	• Segmented image (region, point of interest, contour)	• Morphology measurement • Orientation measurement • Radiometry measurement • Size measurement • Topometry measurement • Topology measurement
Transmission Communication	• Iconic image • Statistical image • Segmented image (region, contour)	• Compression measurement

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4.2 Post-Processing Operations

4.2.1 Definition

Table 4: The list of measure categories and the related measures.

Category	Measure
Morphology	The value of a morphological parameter is obtained by a measure on the **shape.** Size and position are not important for these measurements.
	• Convexity • Elongation • Rectangularity • Sphericity • Compactness • Eccentricity • Curvature
Orientation	Orientation measures uses a reference frame attached to the image. They are invariant to translation and homothety.
	• Orientation
Topology	Topology measures characterize object shape and spatial arrangement of objects. They are invariant to rotation and translation.
	• Hole number • Number of components • Externally connected
Topometry	The value of a topometry parameter is obtained according to a **reference frame**.
	• Position • Distance
Size	The value of a size parameter is obtained from a **unit measure**.
	• Volume • Perimeter • Major Axis length, Minor Axis length
Radiometry	Radiometry measures are based on pixel values. They are invariant to translation, rotation and homothety.
	• Color • Texture • Contrast • Maximum, Minimum • Intensity • Entropy • Variance • Mean • Energy

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Category	Measure
	• Boundary contrast • Uniformity
Display Print	Measures are used to characterize the quality of images for print, or display.
	• Psychovisual test • Opinion score
Compression rate	Compression is characterized by rate and quality measures.
	• Rate (Number of bits per symbol (bps)) • Number of bits that are conveyed or processed per unit of time. • Peak Signal-to-Noise Ratio, Mean Square Error.
Spatio-temporal	Spatiotemporal measures are associated with one of the other measurements with respect to the time dimension.
	• Movement analysis: temporal + position/orientation • Deformation analysis: temporal + shape/size

5 Image Class Definition

5.1 Tree of Objects of Interest

5.1.1 The tree

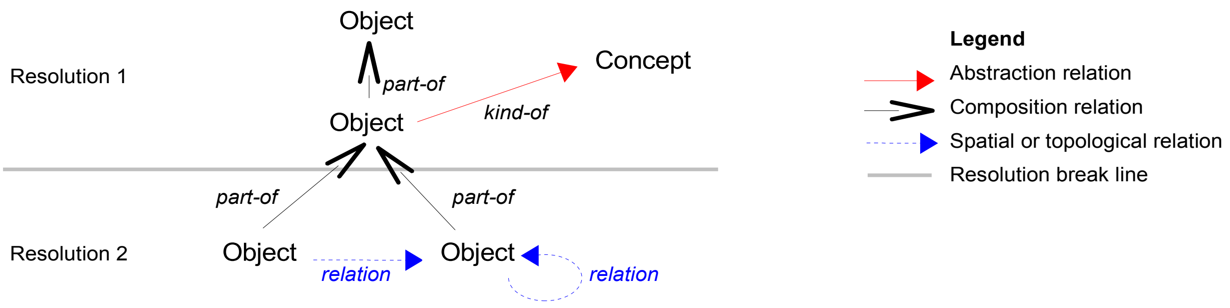

Fig. 3: The interest objects tree template.

The tree is mainly a **composition tree** (Fig. 3). It is made of nodes which are visible interest objects and edges which are meronymy relations. Then, the tree is decorated with other relations between objects such as hyperonymy (in red) or topological relations or spatial relations (in blue).

The tree is structured by resolution levels in case of multi-resolution An object is added in the tree at a specified resolution level only if it is visible at this level. If it is visible at several levels, a new object must be create at each level (and name differently) since its phenomenological description differs from on level to the other level.

5.1.2 Composition relation (meronymy / holonymy)

This relation translates a phenomenological composition of a compound object into composite objects.

Only the meronymy relation is used in the tree since the holonymy is the symmetrical relation.

- "**part-of**" define a composition relation. *X* is a meronym of *Y* and Y is a holonym of X if X is part of Y.

5.1.3 Abstraction relation (hyperonymy / hyponymy)

An abstraction relation defines the relationship between a concrete and a conceptual object. The conceptual object is defined to gather common characteristics of all its instance objects. Only the hyponymy relation is used in the tree since hyperonymy is the symmetrical relation.

- "**kind-of**" defines a hierarchy of concepts. B is a hyponym of A if B is a kind of A.

In this case, B inherits from all characteristics and relations from A. However, B can overload some characteristics.

5.1.4 Topological spatial relations

Topological spatial relations are relations which are invariant under topological transformations like rotation, translation etc. We use the RCC-8 topological relation model [Cohn, 1997] (Fig. 4). Only five of these relations are considered here since two of them are symmetrical:

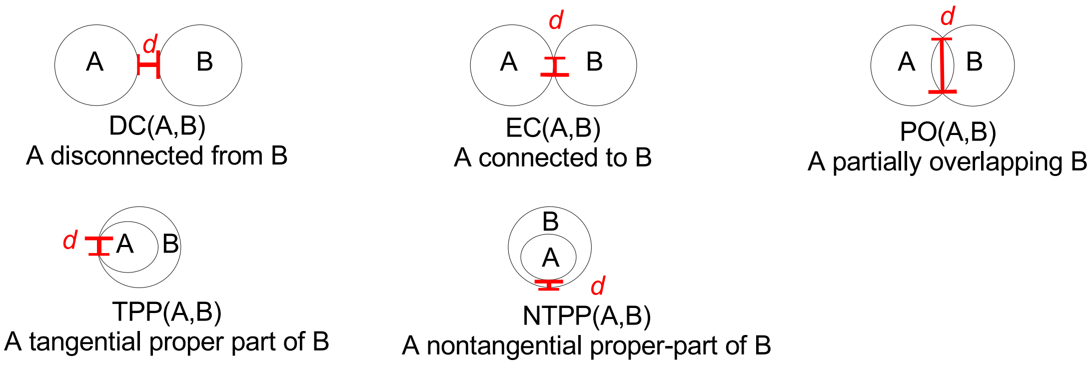

Fig. 4: The list of topological spatial relations.

A relation is described by a distance value (min-max interval). The sense of distance differs for each relation:

- DC: the distance between the two region boundaries;
- EC: the length of the overlapping;
- PO: the length of the overlapping;
- TPP: the length of the shared part;
- NTPP: the distance between the two region boundaries.

5.1.5 Extrinsic Spatial relations

Extrinsic spatial relations considers that the image define the reference and as such organized the relation between two objects. Each relation is characterized by a distance value (min-max interval).

In 2D, we consider the relations: Above, Below, On the left, On the right.

In 3D, we consider the relations: In front of, Behind, Above, Below, On the left, On the right.

5.1.6 Values

Values are of various types:

- Numeric: any single, set, or interval of values.
- Level: refers to the enumerated values: {null, very low, low, normal, high, very high, optimum}

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- Image: any kind of image included reference images (segmented, annotated, sketch, etc).
- Blob: a blob is the specification of an image area. The blob is associated with the related image.
- Text file: it is application dependent.

Comparison values: only superlative values are kept: the most and the less. We consider that relative comparison values, such as object1 hue is less than object 2 hue, are not useful for designing image processing applications.

5.2 Acquisition Effects

This class groups the different elements used to specify the acquisition system and its environment. Only the things that affect the resulted signal are considered.

Table 5: The list of acquisition effect descriptors.

Acquisition Effect	Descriptor	Value domain
Blur	Model	Image, Blob
	Direction	Numeric [degree]
	Length	Numeric [pixel]
	Strength	Numeric, Level
Image Colorimetry	Defect	{Bayer effect, Chromatic aberration}
	Model	Image, Blob
	Hue dynamics	Numeric, Level
	Saturation	Numeric, Level
Image Geometry	Defect	{astigmatism, geometric distortion, spherical aberration, coma}
	Model	Image, File
Image Movement	Direction	{vertical, horizontal, random}, Numeric [degree]
	Magnitude	Level, Numeric [pixel]
	Type	{jittering, traveling}
Image Photometry	Global contrast	Numeric, Level
	Dynamics	Numeric, Level
	Brightness	Numeric, Level
	Model	Image, Blob
Image Illumination	Illumination spatial condition	{heterogeneous, homogeneous}
	Illumination temporal condition	{stable, varying}
	Illumination defect type	{saturation, lag, shift, blooming, smearing, flicker}
	Dark image	*Image*
	Model	*Image, Blob*
Image Sampling	Defect	{aliasing, moiré, partial volume effect}
	Spatial x-resolution	Numeric
	Spatial y-resolution	Numeric
	Spatial z-resolution	Numeric
Image Quantization	Bit per pixel	Numeric
	Function	{linear, logarithmic}
Image Storage	Defect	{block effect}
	Width	Numeric
	Height	Numeric
	Depth	Numeric
	Type	{iconic, statistical, synthetic}
	Number of bands	Numeric
	Number of looks	Numeric
Noise	Model	Image, Blob
	Composition	{additive, multiplicative, mixed}
	Distribution	{exponential, Gauss, uniform, Poisson, Rayleigh, impulse}
	Power Spectral Density	{blue, brown, purple, white, colored, pink}
	Signal Noise Ratio	Level, Numeric
	Stationarity	{yes, no}
	First order	Numeric, Level
	Second order	Numeric, Level
	Third order	Numeric, Level
	Fourth order	Numeric, Level

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5.3 Visual Primitives

Table 6: The list of visual primitive descriptors.

Visual Primitive	Feature	Descriptor	Value domain
Edge	Model	Blob	
	Morphology	Contrast	Numeric, Level
		Sharpness	Numeric, Level
		Shape	{curve, set of straight line, straight line}
		Status	{open, close , loop}
		Profile	{inverse peak, roof, peak, valley, ramp, step}
		Straightness	[0..1], Level
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level
	Photometry	Brightness	Level, Image
		Contrast	Level, Image
	Position	Line position	{center, right, left, bottom, top,border touching}, coordinate
	Orientation	Line orientation	{vertical, horizontal}, Numeric [degree]
	Size	Length	Numeric, Level
		Thickness	Numeric, Level
	Motion	Velocity	Numeric, Level
		Direction	Numeric
		Persistence	Numeric, {true, false}
Region	Model	Blob	
	Boundary	Nature	{limit of texture, limit of homogeneous regions, edge, no boundary}
		Reference	Link to Edge description
	Photometry	Brightness	Level, Numeric
		Contrast	Level, Numeric
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level
	Texture	Direction	Numeric [degree], {horizontal, vertical, oblique}
		Scale	{macro, micro}
		Type	{no-texture, contour, dot, complex, periodic}
	Morphology	Shape	{rectangular, circle, ellipsoid, parallelepiped, square}
		Compactness	Numeric, Level
		Convexity	Numeric, Level
		Elongation	Numeric, Level
		Number of angles	Numeric
		Rectangularity	Numeric, Level
		Roundness	Numeric, Level
	Topology	Number of holes	Numeric
	Orientation	Orientation	Numeric, {vertical, horizontal}
	Position	Location	{center, right, bottom, top, border touching}
		Center of mass	Coordinate
	Size	Area	Numeric, Level
		Volume	Numeric, Level
		Bounding Box Width	Numeric, Level
		Bounding Box Height	Numeric, Level
		Bounding Box Depth	Numeric, Level
		Diameter	Numeric, Level
		Thickness	Numeric, Level
		Net perimeter	Numeric, Level
		Convex perimeter	Numeric, Level
	Motion	Velocity	Numeric, Level
		Direction	Numeric
		Persistence	Numeric, {true, false}

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Visual Primitive	Feature	Descriptor	Value domain
Background	Model	Blob	
	Texture	Direction	Numeric [degree], {horizontal, vertical, oblique}
		Scale	{macroscopic, microscopic
		Type	{no-texture, contour, dot, complex, periodic}
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level
	Photometry	Intensity	Numeric, Level
		Contrast	Numeric, Level
	Motion	Velocity	Level, Numeric
		Direction	Level
		Persistence	Numeric, {true, false}
Point of interest	Model	Blob	
	Photometry	Intensity	Level, Numeric
		Contrast	Numeric, Level
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level
	Morphology	Junction type	{L, T, X, Y}
	Motion	Velocity	Numeric, Level
		Direction	Level
		Persistence	Numeric, {true, false}
Points cloud	Model	Blob	
	Photometry	Intensity	Level, Numeric
		Contrast	Numeric. Level
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level
	Morphology	Shape	{rectangular, circle, ellipsoid, parallelepiped, square}
		Compactness	Numeric, Level
		Convexity	Numeric, Level
		Elongation	Numeric, Level
		Rectangularity	Numeric, Level
		Density	Numeric
	Orientation	Orientation	Numeric [degree], {vertical, horizontal}
	Position	Location	{center, right, left, bottom, top, border touching}
		Center of mass	Numeric
	Size	Area	Level, Numeric
		Volume	Level, Numeric
		Bounding box width	Level, Numeric
		Bounding box Height	Level, Numeric
		Bounding box Depth	Level, Numeric
	Motion	Persistence	Numeric, Level
		Velocity	Numeric, Level
		Direction	Numeric
	Temporal	Persistence	Numeric, {true, false}
Image area	Model	Blob	
	Position	Location	{center, right, left, bottom, top, border touching}
		Center of mass	Coordinate
	Orientation	Orientation	Numeric, {vertical ,horizontal}
	Size	Area	Numeric [pixel], Level
		Volume	Numeric [pixel], Level
		Width	Numeric [pixel], Level
		Height	Numeric [pixel], Level
		Depth	Numeric [pixel], Level
	Photometry	Intensity	Numeric, Level
		Contrast	Numeric, Level
	Colorimetry	Hue	Numeric, Level
		Saturation	Numeric, Level

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Visual Primitive	Feature	Descriptor	Value domain
	Morphology	Compactness	Numeric, Level
		Convexity	Numeric, Level
		Elongation	Numeric, Level
		Rectangularity	Numeric, Level
		Number of angles	Numeric
		Shape type	{rectangle, circle, ellipsoid, parallelepiped, square}
		Density	Numeric, Level
	Texture	Direction	Numeric [degree]
		Scale	{macroscopic, microscopic}
		Type	{no-texture, contour, dot, complex, periodic}
	Motion Temporal	Velocity	Numeric, Level
		Direction	Numeric
		Persistence	Numeric, {true, false}

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6 Image Processing Tasks

6.1 Tasks

Table 7: The list of defined tasks.

Goal	Task	Description
CompressionTask	ImageCompression	The goal is to reduce the amount of data needed to encode an image.
DetectionTask	ObjectDetection 'object'	The goal is to detect the presence and the location of a given object. Each occurrence of the object is denoted by a bounding box.
	ObjectExtraction 'object'	The goal is to locate precisely the boundary of the specified object in the image. The result contains only regions with the specified object.
	InterestPointDetection	The goal is to detect the presence and the location of points of interest.
	EdgeDetection	The goal is to detect the presence and the location of edges.
EnhancementTask	ContrastEnhancement	The goal is to enhance the global contrast and brightness. This task is useful in case of over-exposure or under-exposure or in case of low contrast.
	ColorEnhancement	The goal is to enhance colors of too washed or too saturated image.
	ImageSharpening	The goal is to highlight fine details in an image.
	EdgeSharpening	The goal is to reinforce the perception of the object borders and corresponds to unblurring and edge enhancement.
ReconstructionTask	ShapeReconstruction	The goal is to reconstruct the shape from pixel images.
	DepthReconstruction	The goal is to reconstruct the 3D scene from 2D.
	MotionReconstruction	The goal is to reconstruct the motion from still images.
RestorationTask	ImageDeblurring	The goal is to correct images corrupted by blur (eg. motion blur, defocusing).
	ImageDenoising	The goal is to reduce the noise level on images knowing the degradation model in order to increase the signal noise ratio.
	IlluminationCorrection	The goal is to correct illumination defects on images knowing a model of correct illumination.
	ColorCorrection	The goal is to correct color defects on images knowing a model of correct colorimetry.
	ImageDemosaicing	The goal is to reconstruct a full color image from the spatially undersampled color channels.
	GeometryCorrection	The goal is to correct geometrical defects on images knowing a model of distortion.
	ImageInpainting	The goal is to repair damaged images or remove unnecessary elements from images. The image area to inpaint is given as a mask.
SegmentationTask	ImagePartition	The goal is to partition the image into regions. In the result, each pixel of the image belongs to a region.

6.2 The criteria to be optimized

Table 8: The possible criteria to be optimized constraints for each task.

Task	Criterion to be Optimized	Acceptable error
ImageCompression	Maximize compression rate	
	Maximize image quality	
ObjectDetection	Maximize hits	Prefer miss to false alarm Prefer false alarm to miss
ObjectExtraction	Maximize hits	Prefer miss to false alarm Prefer false alarm to miss
	Maximize boundary localization	Prefer boundary inside Prefer boundary outside
InterestPointDetection	Maximize hits	Prefer miss to false alarm Prefer false alarm to miss
EdgedDetection	Maximize hits	Prefer miss to false alarm Prefer false alarm to miss
ContrastEnhancement		
ColorEnhancement		
ImageSharpening	Maximize fine detail visualization	
EdgeSharpening		
ShapeReconstruction		
DepthReconstruction		
MotionReconstruction		
ImageDeblurring		
ImageDenoising		
IlluminationCorrection		
ColorCorrection		
ImageDemosaicing		
GeometryCorrection		
ImageInpainting		
ImagePartition	Maximize segmentation precision	Prefer under-segmentation Prefer over-segmentation

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6.3 The level of detail

Table 9: The possible levels of detail constraints for each task.

Task	Level of Detail	Acceptable error
ImageCompression	Need compression rate <value>	
ObjectDetection	Need all pixels	Prefer more to less Prefer less to more
	Need n object occurrences <n>	
	Eliminate border-touching objects	
ObjectExtraction	Need all pixels	Prefer more to less Prefer less to more
	Need n object occurrences <n>	
	Do not separate just-touching and overlapping objects	Prefer no separation Prefer separation
	Do separate just-touching and overlapping objects	Prefer no separation Prefer separation
	Do separate only just-touching objects	Prefer no separation Prefer separation
	Regularize the boundary contours	
	Eliminate border-touching objects	
	Achieve sub-pixel precision localization	
	Put boundary inside	
	Put boundary outside	
InterestPointDetection		
EdgedDetection	Eliminate border-touching objects	
ContrastEnhancement	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel value	
	Do not affect edge profile	
	Do not affect region shape	
ColorEnhancement	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel values	
	Do not affect edge profile	
	Do not affect region shape	
ImageSharpening	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel values	
	Do not affect edge profile	

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Task	Level of Detail	Acceptable error
	Do not affect region shape	
EdgeSharpening	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel values	
	Do not affect edge profile	
	Do not affect region shape	
ShapeReconstruction		
DepthReconstruction		
MotionReconstruction		
ImageDeblurring		
ImageDenoising		
IlluminationCorrection	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel value	
ColorCorrection	Do not affect color rank	
	Do not affect color ratio	
	Do not add new pixel value	
ImageDemosaicing		
GeometryCorrection	Do not affect edge profile	
	Do not affect region shape	
ImageInpainting	Do not affect region shape	
ImagePartition	Do over-segmentation	
	Do under-segmentation	

6.4 Constraints from post-processing operations

It is possible to use post-processing requirements to identify relevant task constraints.

Table 10: Possible constraints from post-processing operations.

Operations	Level of detail	Criteria to be optimized
Morphology measurement	• Separate only just-touching objects • Do not separate just-touching and overlapping objects • Separate all	Regularize contours
Orientation measurement	• Separate only just-touching objects • Do not separate just-touching and overlapping objects • Separate all	
Topology measurement	• Separate just-touching objects • Do not separate aggregate • Separate all	Maximize hits (prefer miss to false alarm)
Topometry measurement	• Need all pixels • Separate only just-touching objects • Do not separate just-touching and overlapping objects • Separate all	Localize boundary
Size measurement	• Achieve sub-pixel localization precision • Separate just-touching objects • Do not separate • Do not separate just-touching and overlapping objects	Localize boundary
Radiometry measurement	• Separate just-touching objects • Do not separate just-touching and overlapping objects • Separate all	Localize boundary (prefer boundary inside the region)
Displaying	• Do not affect color rank • Do not affect color ratio	
Printing	• Do not affect the color rank • Do not affect original colors	
Compression	•	

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7 System Control Constraints

7.1 Constraints

The control constraints defines execution requirements on the expected application. It is expressed by two types of constraint: performance criteria and quality criteria

Table 11: Control constraints.

Constraint	Category	Qualifier
Performance criteria	Execution optimization	{runtime, real time, none}
Quality criteria	Ability	{reliability, robustness}

7.1.1 Performance criteria

The different choices for the optimization criterion are mutually exclusive:

- *runtime* for an optimization in time;
- *realtime* for real time processing;
- *none* means without optimization.

7.1.2 Quality criteria

Quality criteria express rather qualitative requirements on the ability of the system to perform its required function. The ability accepts three different values which are mutually exclusive:

- *Reliability* is the ability under specified environmental conditions during a given interval of time. In other words, it specifies that it would be better to do nothing rather than to produce bad results.
- that it would be better to do nothing rather than to introduce new defects;
- *Robustness* is the ability in case of environmental conditions which the system is not designed to tolerate. In other word, it specifies that it would be better to produce partial and even bad result rather than no result;
- *Best compromise* between reliability and robustness.

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