

# The Message in the Shadow: Noise or Knowledge?

Edited by

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## Abstract

Computer vision, besides being a key area in Computer Science, is present in various industrial applications, such as traffic sign recognition (including car license plates), face and gesture recognition, content-based image retrieval, remote sensing, cartography, radar sensing, and robot mapping. However, most computer vision systems disregard the cognitive aspects of human perception, thus limiting their applicability in natural environments, whereby small changes in the light conditions cause negative effects on the system's accuracy. This seminar brought together contributions from Computer Vision, Cognitive Psychology, Philosophy and History of Art in order to discuss the information content in cast shadows which, although currently recognised by psychologists as providing important cues about depth perception, is considered as noise in the computer vision literature.

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## 1 Executive Summary

*Roberto Casati*

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The seminar “The Message in the Shadow: Noise or Knowledge?” brought together researchers from the various disciplines involved in investigating the problem of understanding the perception of shadows (both in biological and in artificial systems) as well as art historians and artists involved in the study or in the manipulation of shadows in art pieces. The nationalities of the seminar participants were as varied as the disciplines involved its central theme; from the 20 attendees there were 4 that came from Brazil, 4 from Germany, 1 from the Emirates, 2 from France, 2 from the UK, 1 from Canada, 3 from the US, 1 from the Netherlands and 2 from Japan.

The small size of the seminar helped to create a friendly atmosphere, in which every participant had time and space to engage in discussions with every other, and every one had an equal amount of time to present his/her ideas, independently of the career stage the participant was in.



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The dynamics of the seminar was as follows: every participant that had an interest in presenting a talk was allocated a 20 minute slot, followed by a 10 min discussion period, during the mornings (from 9 to 11am). The talks were distributed into 4 tracks, one for each day of the week: Psychology (Monday), Artificial Intelligence and Computer Vision (Tuesday), Art and Rendering (Wednesday), Architecture and Spatial Reasoning (Thursday). The titles of the talks given, per track, are cited as follows (the related abstracts are listed in the next section):

### **Psychology**

- Patrick Cavanagh, What does vision know about shadows?
- John Kennedy, Shape-from-shadow polarity
- John O'Dea, Do shadows make surfaces look dark?
- Marteen Wijntjes, Perception of shadows in paintings

### **Artificial Intelligence and Computer Vision**

- Hannah M. Dee, Why does computer vision find shadows so problematic?
- Paulo E. Santos, Shadows in AI and Robotics
- Frederick Fol Leymarie, On medialness-based shape representation: recent developments and food for thought
- Ann Marie Raynal, Leveraging the Information in the Shadows of Synthetic Aperture Radar

### **Art and Rendering**

- Koichi Toyama, The systematic introduction of Chiaroscuro in 15th century Florence and the symbolic shadow in Sienese Painting
- William Sharpe, Shadow Messages in the arts
- Marcos Danhoni, Shadows on the moon and the sun by Cigoli and Galileo: The Copernican planetarium inside the Paolina's Chapel of Santa Maria Maggiore
- Roberto Casati, X-From-Shadow: There is still room at the bottom
- Koichi Toyama, Un-naturalistic painting and the lack of shadow: History of shadow in 18th- 19th century Japanese paintings and woodblock prints

### **Architecture and Spatial Reasoning**

- Barbara Tversky, Can uses of shadows in language and art inform perception of shadows?
- Juliano Beraldo, Daylight metrics for building design
- Christian Freksa, Shadow and friends illuminate space
- Mehul Bhatt, Carl Schultz and Jakob Suchan, Grasping Objectified Shadows

### **Working Groups**

At the end of the morning sessions, discussions were conducted in which the ideas presented during the talks served as inspiration for the conception of research statements. Some of these statements were selected to be discussed during the break out session that occurred during the Monday and Tuesday afternoons. The main questions discussed are presented below:

- Information about the light-source contained in shadows: there is a number of features from the light source that is present in the shadow of an object (for instance: the number of sources, the localisation, the shape) but much of this information is not used by the perceptual system. The question of the evolutionary advantages of this selective use of the information content of shadows was discussed and also the possibilities for a computer system to explore it fully;
- Mooney Faces and Shadows: To test people's vision, Craig Mooney devised two-tone pictures of faces. In Mooney faces, some parts are strongly illuminated, others are in deep shadow. His pictures were static. Motion helps vision find the faces. Mooney faces in negatives are hard to make out. Proper facial expression is lost. In outline, they are equally uninterpretable. Adding a dark line to the border of a positive Mooney face can drop recognition to the level of a negative. Motion helps, but still leaves the face looking cartoonish and flat. Often the line is taken as part of a profile. A light line border of a negative also leaves it cartoonish.
- Cross-disciplinary terminology for shadows: there is currently a non-consensual use of terms to refer to shadow issues (for instance, a caster is sometimes referred to as 'obtruder' or 'occluder'). This group proposed a tentative terminology that was later discussed with the other participants.
- Throwing away information. Shadows are used by the visual system to retrieve various spatial features of the scene, then discarded. The group discussed cognitive/computational mechanisms that may throw away shadows.
- Mereotopological formalisation of Eclipses. The group created a formalized version of the terminology used in describing the different phases of an Eclipse of the Sun. An amendment of the existing taxonomy was proposed.

At the end of the Monday session, artist Francesca Bizzarri showed some aspects of the art of shadow performance.

On Thursday afternoon the participants were directed to discuss possible collaborations, project proposals, and to devise conclusions (even if partial) to the various questions discussed during the previous days. Some of the results obtained in this session are listed below:

- Collaboration between S. Paulo and Bremen
- Online, real-time, Mooney face generator – A computer generated video by Dee, Kennedy and Casati, on the impairment of depth perception through the display of lines on moving Mooney faces, has been created and is visible at:  
<https://www.youtube.com/watch?v=IuDNUz9RSuw>
- Collaboration between Tokyo and New York (on art history)
- The foundation of a work group on terminology
- The projected publication of the mereotopological formalisation of Eclipses (Paris-Bremen-S. Paulo)
- Video displaying the phenomenon of the polarization of shadow (Casati and Cavanagh)

Finally, we discussed the future submission of a proposal for a special issue of the Journal Spatial Cognition and Computation (<http://www.tandfonline.com/toc/hsc20/current>) with the themes of the seminar and the organisation of a follow-up event in 2017 related to these ideas. Our proposal for a special issue of the Journal Spatial Cognition and Computation was accepted by the journal editors in June, 2015 (the *call for papers* will be advertised in the second half of this year).

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### 3 Overview of Talks

#### 3.1 Daylight metrics for building design

*Juliano Beraldo (University São Paulo, BR)*

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**Main reference** International Commission on Illumination (CIE) – <http://www.cie.co.at>, Sessions of the CIE, Expert Symposium

**Main reference** D. DiLaura, K. Houser, R. Mistrick, G. Steffy (eds.), “The Lighting Handbook,” 10th Edition, Illuminating Engineering Society of North America (IESNA).

**Main reference** T. Muneer, C. Gueymard, H. Kambezidis, “Solar Radiation and Daylight Models,” 2nd edition, Elsevier Butterworth-Heinemann, 2004.

**Main reference** J. Summerson, “The Classical Language of Architecture,” ISBN: 9780262690126, MIT Press, 1966.

This presentation covers the findings of the research that is still ongoing and shows the daylighting traditional project approach and new daylight performance metrics. Also discuss the interaction between architectural and daylighting project aspects and finish with a reflective discussion about the project approach in which the shadow is understood not only as a variation on intensity of light but also as a variation in the light quality.

The boom in the construction of energy efficient buildings promoted the use of solar architectural features to maximize the exploitation of daylight. Nowadays, recent policies regarding energy performance of buildings have led to vigorous standardisation activities. Rating systems, such as LEED, BREEAM, DGNB, are now a key driver of building design. However, daylighting is a building performance strategy, which is difficult to evaluate due to the fact that embraces several different dynamic interaction factors from building, climate and surroundings.

The current design and evaluation of daylighting approaches revealed to be unsatisfactory faced with the new designers evaluation requirements of a more complete approach. As a result, during the last decade, there has been several researches related to daylighting and new empirical models have been developed.

In the last years the use of dynamic daylight performance measures was promoted by CIE (Commission Internationale de l’Eclairage) as capable to lead to superior daylighting designs. Nevertheless, recent discussions in CIE sessions pointed to the need of verifying the many dimensions of daylighting performances has revealed that the current evaluation methods and metrics in many occasions proved to be deficient or inadequate to assess daylighting in a holistic way.

The changes in the methods do not change the traditional principles of good daylighting practice that are focus in three main points: light levels, indoors light distribution and avoid glare. However, an overall point of view is essential, according to latest scientific debates, to achieve the high-quality building environment. It is possible that a small change in the daylighting project approach, based on geometric proportions and integrated with an architectural perspective, could reach a more appropriate daylighting results.

### 3.2 Declarative Reasoning about Spatio-Temporal Things

Mehul Bhatt (*Universität Bremen, DE*)

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**Joint work of** Bhatt, Mehul; Schultz, Carl; Suchan, Jakob

**Main reference** M. Bhatt, “Between Sense and Sensibility: Declarative narrativisation of mental models as a basis and benchmark for visuo-spatial cognition and computation focussed collaborative cognitive systems,” arXiv:1307.3040v2 [cs.AI], 2104.

**URL** <http://arxiv.org/abs/1307.3040v2>

We pursue declarative reasoning about *visuo-spatial dynamics* from the viewpoint of the research areas of *artificial intelligence*, *commonsense reasoning*, and *spatial cognition and computation*.

*Declarative spatial reasoning* ([3]) is the ability to (declaratively) specify and solve real-world problems related to geometric and qualitative visuo-spatial representation and reasoning pertaining to spatial, temporal, and spatio-temporal things, be it abstract regions of space or time, material spatial objects, or spatial artefacts such as shadows or affordances cast by material objects ([2, 4, 10]). The problems that we address in this context encompass both specialist and everyday instances identifiable in a range of *cognitive technologies* and *spatial assistance systems* where spatio-linguistic conceptualisation & background knowledge focussed visuo-spatial cognition and computation are central ([5]).

As a systematic development of the declarative spatial reasoning method, we have initiated formalisations of *space* and *spatial reasoning* within constraint logic programming ([3, 8, 9]), and most recently, non-monotonic reasoning about spatio-temporal dynamics within answer set programming ([12]). We have developed **CLP(QS)**, a *declarative spatial reasoning system* capable of modelling and reasoning about qualitative spatial relations pertaining to multiple spatial domains, i.e., one or more aspects of space such as topology, and intrinsic and extrinsic orientation, size, distance etc. With CLP(QS), users and application developers may freely mix object domains (i.e., points, line-segments, and regions) with the available spatial domains. CLP(QS) also offers mixed geometric-qualitative spatial reasoning capabilities, and in its current form, basic quantification support offering the means to go back from qualitative relations to the domain of precise quantitative information.

The emphasis in CLP(QS) is on the seamless integration of declarative visuospatial (computational) problem-solving capabilities within large-scale hybrid AI systems, and cognitive (interaction) technologies. Currently, integration is achieved via the medium of *logic programming* – specifications in the form of (domain) *facts* and *rules* consisting of mix of, for instance, background semantic or conceptual knowledge, spatio-temporal knowledge, and knowledge about action and dynamics. The general concept of declarative spatial reasoning lends itself to re-interpretations and extensions with other perspectives such as diagrammatic representations. CLP(QS) marks a clear departure from other (relational-algebraically based) spatial reasoning methods / tools by its use of the constraint logic programming framework for formalising the semantics of mixed geometric and qualitative spatial representation and reasoning. The approach has demonstrated applicability in several domains, most recent examples being *architectural design cognition* ([7]), *cognitive vision* ([6, 11]), *geospatial information systems* [1].

The CLP(QS) system is also being designed and used as a pedagogical tool to be used as part of university based courses at the interface of Artificial Intelligence, Knowledge Representation and Reasoning, Cognitive Systems, and Spatial Informatics.

**CLP(QS):** A Declarative Spatial Reasoning System. <http://www.spatial-reasoning.com>.


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### 3.3 Ideas on shadow theatre

*Francesca Bizzarri (Associazione Ca' Luogo D'Arte – Gattatico, IT)*

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In theatre: pretense is more real than reality and sometimes the shadow in theatre helps the pleasure of imagining; shadow is ambiguous, we complete the emotion. In theatre, as a condensation of time, space and emotion, the use of shadow engage audience to fill in shadow blanks and supports some technical possibilities, not always doable in real: Alice in Wonderland grows and shrinks easily. Usually an actor has to adjust action speed to shadow speed; style and angle of gesture are important; feel the light in order to know you are projecting a profile; know where your body is vis à vis the light; an actor has to imagine what the audience is seeing/imagining. In some shadow theatre we do not see features, so the body and gesture are important; but in regular theatre the lighting technician has to cancel distracting shadows; as actors we have to “grab the light”, we spend one day to pointing the light on all the scenes.

In Noh Theatre the changing shadow on a mask gives different emotions and expressions. Moving shadows convey action, gender, the exact person if you know him/her. When in theatre halogen lamp came out every shadow became sharp, clean, readable. Transformations, creating illusions depends on shadows because you only get the outline, you lose body and individuality; creation of airplanes or flowers; modern shadow theatre companies use whole troupe to make shapes, objects, setting, not just human figures and they rely on the astonishment of the audience, the surprise to seeing people represent complete different figures even inanimate ones. When we see shadows on screen do we see them as flat, as figures in a flat world, or as three dimensional? Do we fill in a third dimension, do we imagine colors, materials?

### 3.4 X-from-Shadows: There is still room at the bottom

*Roberto Casati (ENS – Paris, FR)*

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I shall present a number of ecological observations and pictorial examples to indicate that there is still room at the bottom for research in shadow perception. Shadows are minor entities, both ontologically and perceptually, and the examples presented here are thus marginal cases of a minor entity. Not all the information present in shadows appears to be retrieved by the visual system (although this should be confirmed by empirical research); the information is however available and artificial vision can conceivably find an use to it.

### 3.5 What does vision know about shadows?

*Patrick Cavanagh (Paris Descartes University, FR)*

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How does the visual system identify and use shadow information in a scene? Shadow edges can irretrievably mislead the interpretation of a scene if they are taken to be object contours rather than shadow contours. So they need to be identified reliably and rapidly. Aside from their nuisance value, shadows also provide useful information about relative locations of objects. So how does vision identify shadows? It cannot be based on their shape as this is determined by several factors simultaneously: the direction of the light source, the shape of the object casting the shadow, and the surface relief on which it falls, as well as the relative positions of the light source, object, and receiving surface. In most cases this problem is intractable and clearly the visual system must have some set of rules for rapidly identifying a shadow based on simple local properties. We will look at first the rules that artists have discovered in depicting convincing shadows and the rules of physics that artists know they can break. Then we will look at experimental evidence concerning the rules for shadows.

### 3.6 Shadows on the Moon and the Sun by Cigoli and Galilei: The Copernican planetarium inside Paolina's Chapel of Santa Maria Maggiore.

*Marcos Cesar Danhoni Neves (State University of Maringá, BR)*

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**Joint work of** Danhoni Neves, Marcos Cesar; da Silva, Josie Agatha Parrilha

The Sidereus nuncius of Galileo Galilei irrefutably confirms the great revolution of the new astronomy initiated by Copernicus, Tycho, Kepler, Digges and Bruno. The presence of craters on the lunar surface showed, almost unequivocally, a marriage between heaven and earth, destroying the Aristotelian conception of the universe. However, this revolutionary idea of a Copernican universe was conquered not only by the acceptance of a new instrument, the telescope but, above all, by the construction frames of reference, the laws of linear and anamorphic perspective, and, especially, by the intense relationship between art-science, as can be seen by the friendship between Cigoli, Coccapani and Passignano with Galileo Galilei, on direct observation of the sun and its representations, including the famous moon cratered under the feet of the Madonna Assunta in the Paolina Chapel of Santa Maria Maggiore in Rome. But the shadow of the Inquisition condemns Galileo and erase the craters of the Madonna's Paolina, making it "Aristotelian", leading, also (as for the the nature of sunspots) to an arid intellectual debate, refusing the nature revealed by the perspective. However, a contemporary reinterpretation, and the rediscovery of the Cigoli's craters in twentieth century, allow a reconstruction of the new Galilean. This reconstruction allows us to discover a kind of a secret code inserted in the Cigoli's fresco. So, after the Church's censorship is removed, it is unveiled inside the Paolina dome a true Copernican planetarium, pushing back the shadows of the ecclesiastical censure since the condemnation of Galileo Galilei.

### 3.7 Why does computer vision find shadows so problematic?

*Hannah M. Dee (Aberystwyth University, GB)*

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**Joint work of** Dee, Hannah; Santos, Paulo E.

**Main reference** H. Dee, P. E. Santos, “The perception and content of cast shadows: an interdisciplinary review,” *Spatial Cognition and Computation*, 11(3):226–253, 2011.

**URL** <http://dx.doi.org/10.1080/13875868.2011.565396>

This talk provides a brief review of the state of the art in shadow detection within computer vision. This considers image acquisition issues (single image, video from a static camera, video from a moving camera, video from a robot...), image processing issues (whether to work in the colour or texture domain), and issues of level of modelling (do we need to know the shape of the shadow caster? do we need to know where the light source is?). The talk will go on to emphasise issues and approaches for the evaluation of shadow detection algorithms, and will also show some datasets for shadow detection from a moving platform (wheeled, humanoid and UAV) which can be shared with workshop participants. Much progress has been made, particularly in the realm of shadow detection from a static camera in situations where statistical background models can be derived. However there remain many unsolved problems, and the issue of robotic shadow detection is largely unaddressed.

### 3.8 Shadows, Shape, Medialness

*Frederic Fol Leymarie (University of London/Goldsmiths, GB)*

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We explore the shape of shadows in static and dynamic situations, via a representation based on medialness. Medialness is an extension of the classic medial graphs of Harry Blum and others. An image with contours, possibly fragmented, incomplete, is mapped to a medialness field under a gauge figure in the form of an annulus with width epsilon (a parameter alike a scaling factor). Ridge features extracted from this medialness field, such as peaks, saddles, ridge ends, provide a representation for the shape of the trace of objects, such as shadows.

We illustrate the retrieval of medial “hot” spots and significant convexities and concavities of shadow borders for static scenes as well as in videos (such as when observing a shadow theatre performance). The approach is inspired by recent results in perception, vision science and computational models. Differences between a shadow caster (3D) and its shadow (2D) are illustrated (e.g. with shadowgraphs). A careful study of the relation between the 3D nature of a physical object and the 2D nature of associated shadows remains an open and interesting avenue to explore, in static and dynamic situations.

### 3.9 Shadow and friends illuminate space

*Christian Freksa (Universität Bremen, DE)*

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**Joint work of** Freksa, Christian; Schultheis, Holger

**Main reference** C. Freksa, H. Schultheis, “Three Ways of Using Space,” in: D. R. Montello, K. E. Grossner, D. G. Janelle (eds.), “Space in mind: Concepts for spatial learning and education,” ISBN: 9780262028295, MIT Press 2014, pp. 31–48.

**URL** <https://mitpress.mit.edu/books/space-mind>

Cognitively relevant spatial parameters such as orientation, distance, and topological relationships are geometrically and physically determined by relative positions and orientations of objects in three-dimensional coordinate systems. Physically induced features such as visual illumination, occlusion, shadowing, reflection, mirroring; sound emanation and echo; surface texture and shape increase the complexity of sensory input to be processed by cognitive systems compared to scenes that are free of such features. However, as the geometric structures of these features are severely constrained by the structure of space and the physical laws of optics, acoustics, and haptics, respectively, they convey rich information about the space: they modulate the perceptibility of spatial configurations and environments and substantially enhance our abilities to disambiguate and make sense of perceptual stimulus patterns. Features such as shadows have been treated as noise that needs to be removed before spatial structures can be recognized; in contrast, we are interested in identifying ways in which these features can support recognition of spatial structures and spatial problem solving on the level of perceptual representation.

### 3.10 Shape-from-shadow polarity applies to 11 borders – 8 real, 3 pictorial

*John Kennedy (University of Toronto, CA)*

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**A.** Ecological optics offers spectral and luminance borders. These can be static, and projected to a single vantage point. These are monocular borders. Optics also provides borders given by two vantage points. These are binocular (stereovision) and kinetic (accretion and deletion) borders. The total is  $2 \times 2 \times 2 = 8$ . These are real borders, I suggest. However, besides the 8 real borders, in outline pictures there are an additional 3 kinds of borders. Outline drawings have continuous lines, dotted lines and subjective-contour lines. Can all 11 trigger shape-from-shadow perception? Consider an observation of shadows and stains by Hering, and Cavanagh & Leclerc’s polarity hypothesis. For all 11 borders, shape-from-shadow would need low luminance on the shadow side, higher luminance on the illuminated side.

**B.** Lines can have two borders, one with correct polarity and one with reversed polarity. Countermanding the correct polarity, the reversed polarity border can block shape-from-shadow perception.

**C.** Shape-from-shadow vision should be successful even if the shadow borders have moving fringes (a demo from Bai).


**D.** P.S. 1. In a picture from Whuczko, shadows cast on a plain and converging to a point on the horizon provide information that they are parallel. Does perception erroneously take the shadows as actually converging?

**E.** P.S. 2. In a picture from Hammad, shadows cast from a cube offer depicted angles and depicted angles. Are the depicting angles seen correctly, or biased towards the depicted angles?

**F.** P.S. 3. In a lunar eclipse, shadows cast on the moon by the Earth are information for the size of the Earth, as Kennedy and Casati have noted. They also indicate the size and distance of the sun. Can vision detect the sun’s size and distance?

### 3.11 Do Shadows Make Surfaces look Dark?

*John O’Dea (University of Tokyo, JP)*

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Does a shadowed white area have a “appearance” like a non-shadowed grey area? Many say: In one sense “yes”, and in a other sense “no”. The “yes” sense is a problem, since it suggests that this aspect of perceptual experience is not representing things, or not representing straight- forwardly. The obvious solution is that we simply see the way things are illuminated in addition to the quality of the surface. In this talk, I focus on a particular way of modelling the experiential connection between surface colour and illumination quality: a multi-dimensional quality space. I am interested in one particular problem – that illumination and surface colour seem to be both integral and separable dimensions of the space.

### 3.12 Leveraging the Information in the Shadows of Synthetic Aperture Radar

*Ann Marie Raynal (Sandia National Labs – Albuquerque, US)*

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Radar sensors have existed for nearly a century. However, radar data is not as intuitive as optical data for humans to interpret and glean important intelligence, surveillance, and reconnaissance information without extensive training or significant algorithm development and data post-processing to distill critical information. Well-designed radars, tools for their operation, training materials, and sensor data presentation or exploitation, can make immense impact on a mission’s execution by radar operators and analysts, whom are often overtasked and overwhelmed despite being incredibly capable. Radar shadows are the most optical-like features for human interpretation of radar data. Research from cross-disciplinary fields suggests shadows are innately preferred by our visual perception system for the interpretation of our spatial environment over other qualities. Preliminary research has shown shadows in radar imagery to be useful in determining stationary or moving target characteristics such as orientation, height, 3D shape, and location, which offer 3D imaging, detection, location, tracking, and identification possibilities. Unfortunately, shadows are inherently noisy and can disappear due to surrounding signals of even slightly higher energy that can overwhelm the

shadow. Furthermore, foibles of the human visual perception system can lead to erroneous assertions about objects and their spatial qualities. Shadow characteristics depend on many factors of the radar, platform, object, and scene. Algorithm development and requirements are needed for more automated analysis of shadows to overcome human flaws and shadow degradation. The utility of radar shadows and how best to leverage their information for radar applications is investigated in this talk.

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### 3.13 Shadows in Robotics and Artificial Intelligence

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**Joint work of** Santos, Paulo E.; Dee, Hannah M.; Fenelon, Valquiria

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Recent research in psychology suggests that the human perceptual system gives preferential treatment to information from shadows when inferring motion in depth and perceiving 3D scene layout. Much work in computer vision and robotics, however, starts from the premise that shadows are sources of noise rather than information. Indeed, due to high contrast in the image, shadows are among the most salient visual items, and a source of distraction from objects and locations.

The purpose of this talk is to bring together contributing ideas from the various disciplines involved in the investigation of the knowledge content in cast shadows in artificial systems. This talk starts with a short survey of the use of the information content of shadows in the fields of AI and Robotics and finishes with a proposal of a probabilistic algorithm for robot self-localisation that is based on a topological map constructed from the observation of cast shadows. Distinct locations on the map are defined by means of a classical formalism for qualitative spatial reasoning.

### 3.14 Grasping Objectified Shadows

*Carl Schultz (Universität Münster, DE)*

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Architects have long recognised that it is useful to treat shadows as real, physical, “first-class” objects, at a similar ontological level as objects with a material extension (furniture, walls, and so on). It is useful in the sense that the spatial patterns of light and shadow that people perceive have a powerful influence on their subjective impressions of the environment; as architects are ultimately concerned with designing experiences, identifying salient light-shadow patterns produced by the interaction of shadow objects with the environment is of central importance. I am interested in how we can formally model these rules about experience and patterns within artificial intelligence representation and reasoning frameworks. The aim is to provide cognitively- driven design analysis support in a high-level, qualitative and declarative manner.

### 3.15 Shadow Messages in the Arts

*William Sharpe (Columbia University, US)*

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In the arts, obvious “messages” are frowned upon; didactic work has been largely out of favor for over a century. And looking back over earlier periods, scholars, critics, and artists

themselves generally prefer works that seem to demand interpretation, or that seem to propose a number of plausible “readings”. For artist and writers, then, the challenge is to make their shadow “messages” intriguing, without saying too much or too little. Sometimes the desire is to minimize shadow “noise”, but other times the aim is to increase that “noise” into the central statement of the artwork. In a forthcoming book I argue that in literature and the visual arts there are basically four kinds of shadow, which can be distinguished by their use (on the creative end) and by their reception (on the audience’s end). Painters, writers, photographers, and filmmakers employ a spectrum of realistic shadows, from nearly imperceptible shadows to strongly defined dramatic ones, to provide information about the light, volume, and location of objects and people within a given scene. Often they seek to accomplish this without distracting the reader/viewer’s attention from the main features of the narrative or scene. But they may also desire to activate these shadow functions (light, location, volume) via the use of shadows that add special emotional and semantic features—moody, menacing, vibrant, grotesque shadows. We regularly meet with what I call “Look Elsewhere” and “Vital” shadows, shadows that either redirect the attention “elsewhere” to their casting objects, or shadows that seem expressively to call attention to themselves (what Roberto Casati has called “reflexive shadows”). But sometimes even further semantic information is added, to the detriment or transcending of informational aims. Separating shadows from their casters, the shadow-makers foreground human emotional investment in shadows. “Completing” shadows reveal the void that is felt when objects or people are bereft of shadows that signal full participation in life; and “Independent” shadows, becoming permanently detached from their “owners”, take on an autonomous existence as dark impulses and rebellious figures seeking to revolutionize the artistic landscape. In artistic expression, the more “noise” that is created by a noticeable shadow, the stronger is the message of the shadow. But what that message is depends on our culturally determined understanding of shadows, particularly what we perceive as their troublingly wayward behavior. Information of a concrete sort may be hard to come by; like shadows, shadow- messages in word or image are a challenge to grasp. At the least, however, we can sort out what kind of shadow we are encountering, and (roughly) what the range of meanings is that can be assigned to it.

### 3.16 Declarative Methods for Cognitive Vision

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**Main reference** J. Suchan, M. Bhatt, P. E. Santos, “Perceptual Narratives of Space and Motion for Semantic Interpretation of Visual Data,” in Proc. of the Computer Vision – ECCV 2014 Workshops – Part II, LNCS, Vol. 8926, pp. 339–354, Springer, 2015.

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The cognitive interpretation of interactions of humans in their everyday surroundings requires systems to perceive their operational environment, recognise activities performed, and reason about the observed information. This includes the detection of low-level perceptual information about the individuals and objects in the scene, motion, shape, relative configuration, and the computational capability to interpret these in terms of high-level human interactions performed towards the goal of an activity.

Our research focuses on developing declarative models of human interactions that are grounded in their low-level / quantitative perceptual input. The aim is to allow systems to perform integrated reasoning about space, actions, and change at a commonsense level. The



implemented model is such that primitives of the theory, e.g., pertaining to space and motion, are available as first-class objects with deep semantics suited for inference and query. As applications for this research, we focus on the cognitive interpretation of human interactions in areas such as smart environments, human behaviour in indoor space (e.g., for wayfinding analysis), and cognitive studies pertaining to the embodied perception and interpretation of films.

### 3.17 The systematic introduction of Chiaroscuro in 15th century Florence and the symbolic shadow in Sienese Painting and Un-naturalistic painting

*Koichi Toyama (Keio University, JP)*

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Illusionism in painting using cast shadows was first introduced by Masaccio in the mid-1420s at the Santa Maria del Carmine, Florence. There, the painter depicted naturalistic cast shadows in scenes such as the The Tribute Money, The Expulsion from the Garden of Eden, and St. Peter Healing the Sick with His Shadow, as if the shadows were projected by light penetrating from the rear window of the Brancacci Chapel. It is clear that this system of shadow was added to the system of shading introduced by Giotto at the Scrovegni Chapel, Padua, almost one century before. I will take several examples from contemporary Sienese religious paintings in which painters such as Sassetta, Giovanni di Paolo, and Pietro di Giovanni d'Ambrogio depicted cast shadows only once or twice during their lifetimes, supposedly for specific symbolic reasons. Then I will discuss examples of incongruous shadows found even in “realistic” Florentine painting.

### 3.18 Un-naturalistic painting and the lack of shadow: History of shadow in 18th-19th century Japanese paintings and woodblock prints

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Historically speaking, no culture was able to depict cast shadows systematically without contact with Western painting from after the Renaissance. Japan was no exception. During the national isolation of the Edo period (1603-1868), only after the import of Dutch books was permitted in the mid-18th century did a few Japanese intellectuals and artists attempt to learn Western illusionistic techniques such as linear perspective and chiaroscuro. Afterwards, certain painters who created designs for woodblock prints attempted to adopt cast shadows only for specific scenes. I would like to illustrate the reception of chiaroscuro in Japan using the works of Hokusai and Hiroshige (Night View of Saruwaka-cho).

### 3.19 Shadow Play

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Shadow and shadows have many meanings, and are used deliberately by speakers, photographers, filmmakers, cartoonists, and artists to create meaning. Can these creations inform perception? I present a loose collection of uses of shadows in language, film, photography, and art that illustrate some of the subtle meanings shadows convey.

### 3.20 Perception of Shadow and Shading in Paintings and Photographs

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Our study starts with the observation that painters often do not comply to the rules of linear perspective when it comes to cast shadows. Cast shadows are relatively rare in paintings (although they seem to receive more popularity from the 19th century onwards), especially cast shadows that go beyond the a blurry, formless blob. Canaletto (1697–1768) was certainly not avoiding cast shadows in his “vedute” of Venice. Furthermore, it appears that he was aware of potential problems with perspective since he (and many other painters) often orients the sunlight parallel to the projection plane. Therefore, the cast shadows are also parallel to the projection plane and do not have to converge to a vanishing point in the picture plane. In some cases Canaletto does use an oblique illumination and the problems arise quite evidently: whereas the architectural content complies perfectly to the rules of perspective, the cast shadows do not vanish in a single vanishing point.

This observation made us look a bit closer at the shadow casting persons in these paintings. It occurred to us that in quite a number of cases, the shading direction did not match the shadow direction. Whereas shadows often indicated that the light came from exactly left or right, the shading suggested more oblique angles, often more from the front. When the light comes somewhat from the front, the humans are better visible and may look better. Therefore, we hypothesised that Canaletto (and possibly other painters) uses two different motivations for the rendering of shading and shadowing: aesthetical and practical.

This finding made us question how sensitive humans are for possible discrepancies between shading and shadowing. We performed a light direction estimation experiment in which small fragments of Canaletto paintings are presented flanked by an interactive light probe. The light direction on this probe could be adjusted to match the illumination on the fragment. Three conditions were used: shadow only (persons were black silhouettes), shading only, and combined. We found that for the shadow only and shading only conditions light direction is estimated markedly different. In the combined condition we found that some observers rely purely on the shadow cue, whereas others combine the cues. In a follow up we also used photographs. This data is still being analysed but should be ready at the Dagstuhl seminar.

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