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Switching Partners: Dancing with the Ontological Engineers

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A certain measured, cadenced step, commonly called a “dancing step”, which keeps time with, and as it were beats the measure of, the Music which accompanies and directs it, is the essential characteristic which distinguishes a dance from every other sort of motion.

Adam Smith (1980 [1795])

“Ontology” is a term increasingly used in all areas of computer and information science to denote, roughly, a hierarchically organized classification system associated with a controlled, structured vocabulary that is designed to serve the retrieval and integration of data. An ontology under this view is an artifact whose purpose is to ensure that information about entities in some domain is communicated successfully from one context to another, and this despite differences in opinions about what is the case in that domain or differences in the terminology used by the authors to describe the entities it contains.

Ontologies are today being applied in almost every field where research and administration depend upon the alignment of data of distributed provenance. They are used, for example, by biologists to classify genes, toxins, and

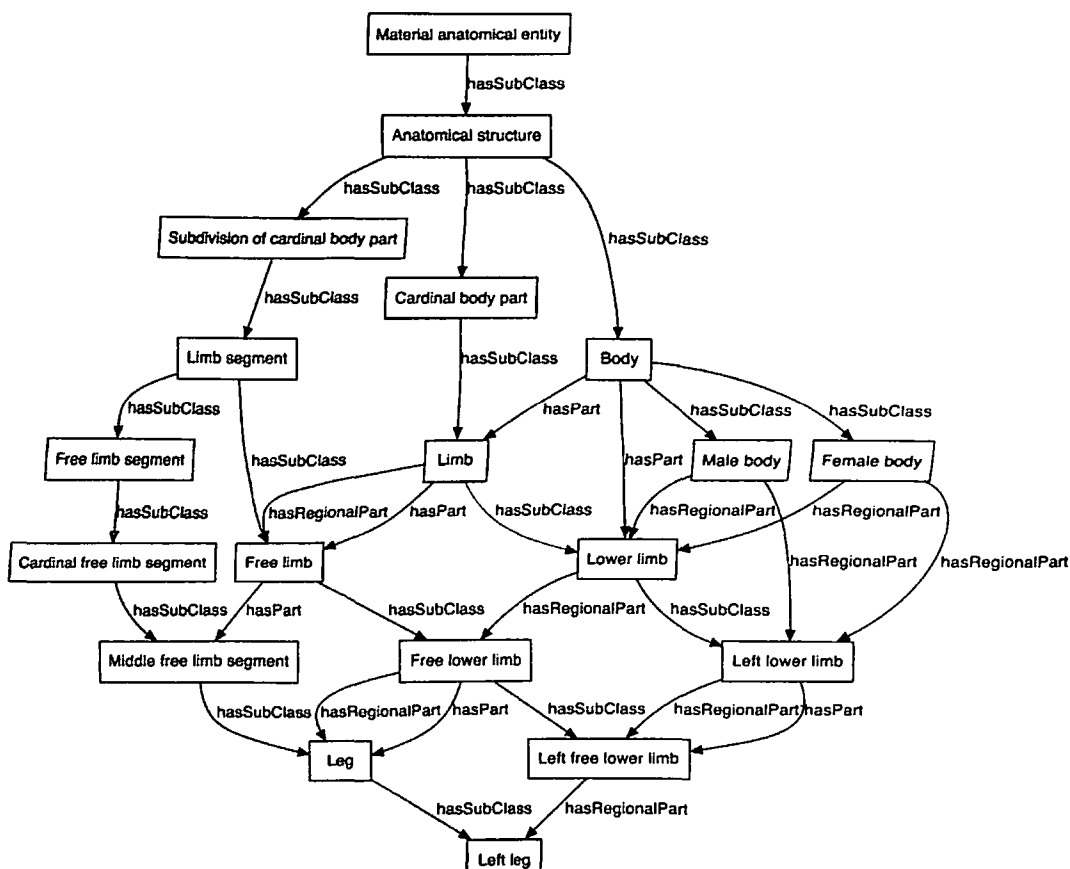


FIGURE 7. Classification of the entity "Left leg" in the Foundational Model of Anatomy.

proteins and by medical scientists to classify diseases, drugs, therapies, and body parts. An example of the latter is the Foundational Model of Anatomy (FMA), which is an ontology of normal adult human and mammalian anatomy. Figure 7 shows the classification of "Left leg" in the FMA, in which it is categorized, among other things, as being a body part that is part of the left lower limb of either a male or female body.

Ontologies are making inroads also in the wider culture. There is an explosion of so-called folksonomies used to tag images on the web. The CIDOC ontology is being used by museum authorities to classify cultural artifacts (Doerr 2003). Ontologies have also been developed to assist lawyers in resolving disputes over the nature of patent and copyright and in determining how different versions of musical or literary works are to be treated for purposes of intellectual property protection (Ceusters and Smith 2007).

Ontologies of the kind just sketched are primarily used directly by humans to perform some classification task, as, for example, to provide appropriate general descriptors for organizing scientific papers in a library collec-

tion. Users of the library, on the other hand, can use this same ontology to find papers on topics they are interested in. An example of this sort of ontology, for web pages rather than scientific papers, is the DMOZ ontology from the Open Directory Project (2007). However, ontologies are increasingly being designed to support computer-based services directly—that is, without human intervention. Among the earliest such applications were ontologies applied to text-mining tasks such as indexing, topic extraction, and summarization of information presented in textual format. Here we will focus on another illustration of the way in which ontologies are being used to help unlock the secrets of human culture, an illustration drawn from the domain of human bodily movements.

The Ontology of Motion

Our movements are being captured on video, and considerable resources are being invested in the development of techniques to extract information about them from the digital outputs of video surveillance cameras. Human movements can be classified, in the first place, from a purely kinematic point of view. But what are kinematically the same movements may still need to be classified in entirely different ways because they occur in different contexts. Consider a short movement of one lower leg crossing the other leg with the foot pointing outward. Such a movement can be part of a mannequin's step on the catwalk, an epileptic jerk, the kicking of a ball by a soccer player, a signal (“Get



out!”) issued in heated conversation, or a “half cut” in Irish *Sean-nós* dancing (fig. 8). When we focus on dance movements, image classification is made all the more difficult by the fact that, while the kinematic phenomena which with we are dealing are constrained, in complex ways, by systems of rules, these rules are themselves artifacts of culture that are marked by complex spatial and temporal variations. Like the cultural

FIGURE 8. Irish *Sean-nós* dancer (right) doing a “half cut” with the right leg.

artifacts they govern, they are subject to a continuous process of evolution. A host of additional problems are created for software agents designed to “understand” what is displayed in video images, by the need to translate information about the changes in the pixel configurations that constitute such images into information about movements carried out by the corresponding entities in reality. Can ontological engineering help us to understand what dancing is all about? As a first step toward answering this question we shall explore some of the problems faced when we seek to create software to help the machine recognize what dance is being performed in a particular video.

Pushing the Boundaries of Information Retrieval

Dance has served throughout history as an important force for social cohesion, and public interest in social dancing is once again booming. Western Europe, in particular, is witnessing a huge revival of interest in folk dancing, meaning dance of a sort that is rooted in the culture of some population but has undergone certain characteristic families of changes in the course of time. These dances include especially those that in countries such as France, Belgium, Germany, and the Netherlands are called *bal folk dances*, in reference to the events at which they are performed. They comprise dances such as the polka, mazurka, Scottish, *an dro*, *hanter dro*, *bourrée*, *branle*, (old-time) waltz, *chapellose* (Aleman’s *marsj*), and *cercle circassien* and are becoming increasingly popular among dancers of all age groups, complementing a no less intensively burgeoning interest in modern “ballroom dancing”—the waltz, foxtrot, American tango, and so forth. Social dancing events such as *Le Grand Bal de l’Europe* in France, *Andanças* in Portugal, *Gran Bal Trad* in Italy, and Dance Flurry in Saratoga Springs, New York, to mention just the most important ones, each attract several thousand dancers every year.¹

There is clearly a need, supported by a broad and still growing community, to gain a better insight into this complex of dance cultures and associated traditions and also to make sure that it is preserved in its full richness for the future. Growing in tandem with this need is an enormous demand for more and better information about such dances, not only from individual dancers, dance organizations, and dance historians, but also from cultural agencies, libraries, tourist organizations, and dance teachers. Questions relate to the origins of these dances, to the rules governing their performance, to their variations across space and time, and thus also to the question of when a given dance can properly be referred to as “the same” as a dance popular some centuries earlier.

In answering such questions, traditional dance resources and archives fall short—and this is so even where the relevant information is made available online. If one is not an expert in dance history or choreography, which most social dancers are not, then it is nearly impossible to formulate a search question in such a way that the answers retrieved are relevant and useful to the individual dancer. Search engines that include video resources in their search space may, for example, perform well when it comes to retrieving videos in which a specific dance such as a Viennese waltz is displayed—but only if the user includes the exact term “Viennese waltz” in his query. This, however, supposes that the user already has command of the terminology relevant to the dance he is interested in and in the relevant language, something that is not always the case.

Search Scenarios

Google can readily provide images in response to search inputs such as “Werner Ceusters” or “Barry Smith.” A much harder, and more interesting, challenge would be for a search engine to identify a user-submitted image as an image of Werner Ceusters or of Barry Smith. Can we, in similar vein, envisage a search engine able to analyze fragments of video, extracting information that would allow it to tell the user what the video depicts? Here are a few scenarios: A tourist bringing home video fragments of people dancing in a *fest-noz* in Brittany might like to know the name of the particular dance depicted so that he can pursue questions concerning its region of origin or choreography. Or a researcher studying the evolution of specific dances over time might wish to retrieve videos of dances with similar choreographies. More ambitiously, a historian might wish to assemble an entire evolutionary history of dances of a given type, with genealogical trees indicating influences. Or an American country dance choreographer might want to ensure that a commissioned creation is sufficiently different from what already exists in the genre in question; she would find it most helpful to be able to submit a video of her creation to an intelligent library that could match fragments of her choreography against other dances. Here again we address a characteristically ontological question: when do given dance fragments manifest the *same* choreography?

To exhibit useful sorts of behavior in response to such challenges the system would need to bridge the semantic gap between the information that the computer can extract from given multimedia material and the interpretation

that would be useful to a human user in a given situation (Smeulders et al. 2000; Roach et al. 2002). This gap is very large. Imagine a video fragment that shows a person walking in the direction of the camera. Not only does the analysis software need to identify the moving group of pixels as a person, it must also avoid misinterpreting its enlargement as the person moves toward the camera as the result of the person's growing larger. Bridging this gap seems to be achievable, but thus far only in certain very specific application domains, as for example a system that allows users to search for similar fragments in videos of soccer and tennis games (Izquierdo et al. 2004). The similarity of the fragments is computed automatically on the basis of visual features such as color and texture (Xu et al. 2004), a technique also used in the system described by Christmas et al. (2001), which also incorporated search facilities based on auditory clues. (When a goal is scored in a soccer game, at least part of the audience responds by shouting and applauding.) Similar achievements have been reported in relation to tennis videos (Dahyot et al. 2003) and news broadcasts (de Jong, Ordelman, and Huijbregts 2006). But however impressive these results may seem, the problems to be solved before applying the techniques to the domain of dancing remain enormous.

Setting the Research Agenda

These problems fall into at least two categories: one involves representing the domain of dancing in a way that can be understood by software agents; the second involves applying such representations to the semantic analysis of the sort of content provided by video images. The latter entails primarily engineering issues; the former, however, requires the ontological engineer to crack a hard historicosociocultural nut: in order to “represent” dancing in the computer, we must first have a good insight into what dancing is. Before addressing this question, we consider, first, the narrower, engineering-related problems involved in the software analysis of video content.

Challenges in Automatic Video Understanding

Automatic video understanding is a relatively new field for which the research agenda has been set only fairly recently. Cetin (2005) identified two “grand challenges” for video analysis: to develop applications that allow a natural, high-level interaction with multimedia databases, and to find adequate algorithms for detecting and interpreting humans and human behavior in vid-

eos that also contain audio and text information. A number of additional, intermediate-scale challenges relevant to successful human-behavior analysis have also been identified. Some of these, such as problems inherent to face detection, might at first seem irrelevant in the context of dancing. They turn out, however, to be of crucial importance, at least for dances of certain sorts. Facial expressions are in some cultures an intrinsic part of a dance; Argentine tango dancers, for example, tend to look rather serious on the dance floor, while ballroom champions invariably smile, though often in a way that is somewhat strained. Facial expressions might thus provide clues as to the sort of dance on display.

Automatic recognition of the type of dance displayed in a video requires facilities for detecting human bodies, their poses and postures, and their activities, and this in spite of manifold variations in background (including, for example, indoor and outdoor settings). It requires robust techniques to discriminate and track body parts (arms and legs) and to distinguish those belonging to one body from those belonging to another, despite the fact that members of a dancing couple or group often wear similar costumes. In fact, recognizing objects in still images and video remains an unresolved open problem in general and one of the main topics of research in content-based image retrieval (CBIR).

With respect to storage and retrieval, multimedia databases with semi-automatic or automatic natural interaction features do not exist. The ACM Multimedia Special Interest Group (SIG), created over ten years ago, recently identified two further grand challenges that are relevant to the analysis of dancing videos (Rowe and Jain 2005). The first is to make the authoring of complex multimedia publications as easy as using a word processor or drawing program; while high-quality software packages for a number of specific subtasks now exist, there is a conspicuous lack of seamless integration. The second is to make capturing, storing, finding, and using digital media everyday occurrences in our computing environment. The example provided, “*show me the shot in which Jay ordered Lexi to get the ball,*” is of the same nature as the kind of services that would be needed with respect to dance. This request requires techniques that push paradigms such as motion-based classification and segmentation much further than those currently realized (IEEE Computer Society 2005). Because digital representations of bodily movement are nothing more than groups of pixels appearing and disappearing in sequence, recognizing such movements in isolation, or recognizing movement-sound complexes such as *tap, stomp, clap, scuff*, requires insight into how such phenom-

ena are captured in digital representations such as videos. Further aspects relevant for video analysis involve the ability to apprehend, classify, and track backgrounds, costumes, multiple couples, camera positions, and so forth. Feature extraction algorithms are as yet insufficiently mature to capture subtle differences between a “ground cut” and a “half cut” in Irish *Sean-nós* dancing, or a *polska* and a *hambo* turn in Swedish traditional dances. This is not only a matter of pixel granularity, which may be insufficient to capture the necessary detail (such as the foot movements of a particular couple dancing in a crowd), but also a problem of knowing what is there to be captured.

A system with the capacity just sketched should, ultimately, be able to recognize not only what dance is being performed but also whether the dancers depicted are experts or beginners. It should be able to identify the various phases of a dance (say, specific figures in a Scottish *ceilidh* or successive moves in a contra dance, or even short meaningful fragments such as a *pas de bourrée* in ballet). It should also be able to detect differences in style, distinguishing, for instance, between the old and the modern Sevillana dancing styles (both still danced socially today), between older *bourrées* (dating back some hundred years and now seen only in dance performances) and their modern counterparts, and between *bourrées* as they are danced in different parts of Europe. Clearly, such differences have to be clarified before video analysis becomes possible at this level at all—which brings us to the second, more properly ontological, challenge to be addressed, namely, what is dance, and how can dances be classified?

Challenges in Understanding Dancing

Dancing has been a subject of research for thousands of years and from a variety of different perspectives. The questions that interest us here concern (1) What is dancing and how can it be distinguished from other complex forms of human behavior (or combined therewith, as in the martial art *capoeira*)? and (2) How have specific dance types evolved culturally over time?

UNESCO classifies dance as belonging to the what it calls “intangible heritage,” a term that, with the adoption of the Convention for the Safeguarding of the Intangible Cultural Heritage in 2003, superseded the older term “folklore” (UNESCO 2007).² The earlier, folklore model supported scholars and institutions in documenting and preserving a record of disappearing traditions. The intangible heritage model, by contrast, aims to sustain a living tradition by supporting the conditions necessary for cultural reproduction. This means ac-

ording value to the “carriers” and “transmitters” of traditions, as well as to their habitus and habitat.

A further dimension that enters here is that of socioeconomic factors. In the cultural experience of Europe, for example, as contrasted with the North American case, cultural forms were usually generated by and aimed at cultural elites, being transmitted to larger swaths of the population only gradually and after some elapse of time. This pattern constitutes the backbone of the European cultural tradition in domains as various as religion, music, eating habits, dress, manners, and daily life in general (Liehm 2002). And it holds too for dancing, which, although initially a focus of display within elite society, rapidly came to be appreciated across all levels of the social hierarchy. As we can learn from the history of social life and culture in Glasgow, for example, Scottish country dancing began as an elite activity whose refinements were overseen by various dance academies; the latter were, however, unable to keep pace with the “penny reel” gatherings that became increasingly popular at fair time. By the 1830s local householders were cashing in on the crowds attending Glasgow Fair by making their homes available for dances at a penny a time. Dancing was on its way to becoming a marketable commodity with mass appeal (King 1987). But as dances moved further from their cultural roots, there were inevitable clashes between traditionalists and innovators. As Trenner (1998) puts it, “Old-timers are motivated by their loyalty to the history of, the techniques of, and subtle sophistication of their forms. Newcomers are propelled by their enthusiasm, and will provide structure even when they have little information to guide them.”

Dance, like culture in general, is always changing, and has to change in order to remain meaningful from one generation to the next. As current historiography teaches us, our past and our heritage are not things preserved for all eternity but processes that must constantly revalidate themselves. The successful, living aspects of culture produce new experiences for its users. Change in the way dances are performed is a matter not just of the passing of time but also of progressive delocalization—they are both a part of the identity of a region and incrementally evolving ingredients in a universal artistic language. They contribute, on the one hand, to the blossoming of cultural diversity and the enrichment of specific cultural identities, while on the other hand, their plasticity renders them capable of nourishing the dialogue between and intermingling of disparate cultures (Rouger and Dutertre 1996). Social dancing therefore forms one of the cultural areas that is best adapted to achieving the cultural objectives set out in the Treaty on European Union,

which include “contribut[ing] to the flowering of the cultures of the Member States, while respecting their national and regional diversity and at the same time bringing the common cultural heritage to the fore,” and “encouraging cooperation between Member States and, if necessary, supporting and supplementing their action in the following areas: improvement of the knowledge and dissemination of the culture and history of the European peoples; conservation and safeguarding of cultural heritage of European significance; non-commercial cultural exchanges; artistic and literary creation, including in the audiovisual sector” (Article 151 [ex 128]).

“Ontologies” and “Ontology”

Earlier we presented a view of ontologies as representational artifacts that, when designed in appropriate ways, can help humans and software agents in performing classification tasks. The question here is whether they can also be used in the context of analyzing the content of dancing videos by bridging the semantic gap between pixel sequences and classificatory content. We will now present some reasons to believe that they can. Hakeem and Shah (2004) showed that for the analysis of videos of corporate board and project meetings, the most promising way to bridge the semantic gap is by using an ontology. To support analysis of video content in the domain of dance, we shall need to create two ontologies, the first describing real-world phenomena relevant for the domain of dancing itself, the second covering how these phenomena are exhibited in videos through image and sound. The former would require generic segments covering relevant aspects of human motion, more specific parts focused on the broad domain of dance motions, and still more detailed components relating to the sorts of dances contained in the collection from which information is to be retrieved, including temporal indexing to enable capture of historical aspects of the dances’ evolution over time. Building ontologies of this level of complexity poses a challenge in its own right, as witnessed by numerous past mistakes (Ceusters and Smith 2003; Ceusters, Smith, and Goldberg 2005; Ceusters et al. 2004a, 2004b). It is here that “ontology” as a scientific discipline, rather than a computational artifact, comes into its own.

“Ontology” is of course a term having its roots in philosophy, where it means, roughly, the science of being. For a long time ontologists working on information systems ignored the fruits of ontological research in philosophy, and thus they often recommitted errors of a characteristically philosophical sort, above all by confusing the classification of entities in reality with the

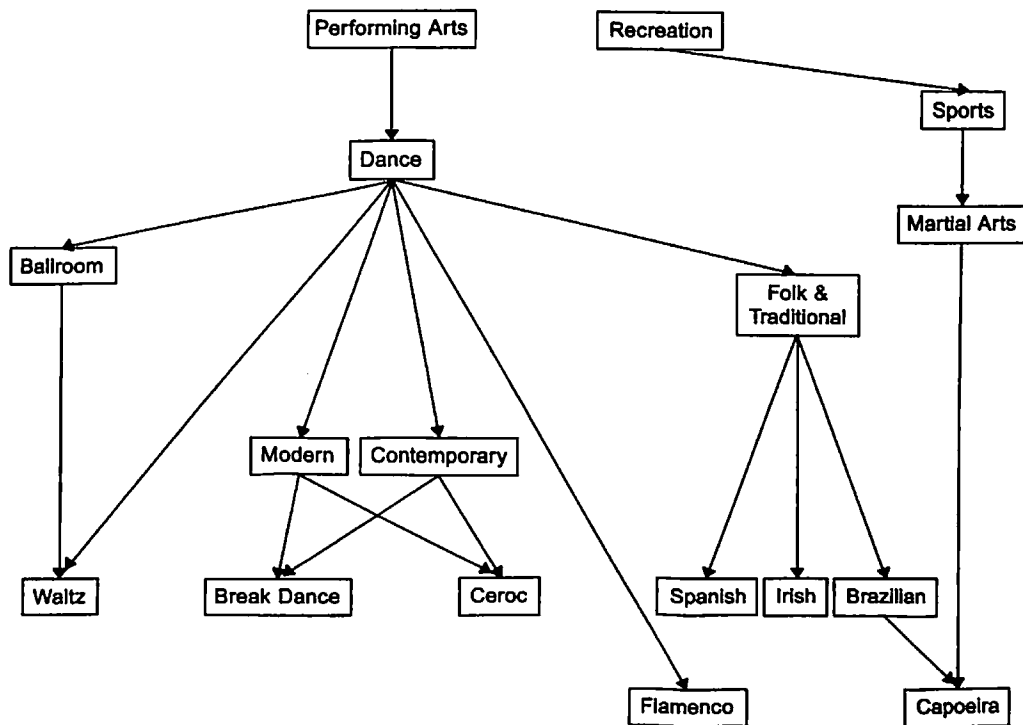


FIGURE 9. Part of the classification of “dance” in the Open Directory Project.

classification of words or data describing such entities. Increasingly, however, it is being recognized in at least certain circles of ontological engineering that data integration of a useful sort cannot be achieved merely by classifying the words or concepts that different groups of experts associate with different types of data. The problems created by the differences in word usage among such groups are indeed precisely what need to be solved with the aid of ontologies.

In addition, ontology builders often fail to take into account the fine details that are needed in order to make their representations conform to what is the case in reality, or they resort to representational languages or systems that are insufficiently expressive to capture such details. An example is the classification of “dance” in the Open Directory Project mentioned above, a small portion of which is shown in figure 9. There are several questions that might be raised here:

- Is a waltz just a ballroom dance? (Apparently not, as it is found in many of what ODP calls “folk and traditional dances” too.)
- Can all dancing activities be considered to be performances, let alone works of (performing) art?

- Why distinguish between *modern* and *contemporary* dance if the subtypes of the former are all and only subtypes of the latter?
- Why are “waltz” and “flamenco” classified twice—once directly and once indirectly, under “dance”?
- Can only *capoeira* be danced for recreational purposes ?
- How can a particular event be at the same time an instance of a dance and of a martial art?

Other, more fundamental questions, not clearly addressed in the ODP documentation: What precisely is being classified here? Actual instances of dancing (datable performances) or general types? As danced within a single culture or community, or across all of human culture? In a single era or throughout human history? To avoid building ontologies that lead to questions of this sort, a mechanism for making clear what the terms in the ontology are actually about—that is, what they represent on the side of reality—is imperative, as also is a clear account of the relation between the ontology and what it describes.

Ontology and Dance

With respect to dance ontology, relevant work has been done by philosophers such as Roman Ingarden, whose *Ontology of the Work of Art* (1989) treats in succession the ontology of musical works, pictorial images, architecture, and film on the basis of a general ontological theory of the structure of the work of art that distinguishes strictly between the work itself as a complex stratified object that is neither physical nor mental, and its various realizations in readings, performances, or physical artifacts. For present purposes it is Ingarden's treatment of the work of music that is of most direct relevance. Here we can distinguish between the work itself, the score, the various performances, and the concretizations of the work in the experiences of listeners. For Ingarden it is important that the work itself, even though it is a bearer of identity from one realization to the next (and a benchmark for the faithfulness or adequacy of such realizations), nonetheless has a history (what Ingarden calls a “life”), encompassing changes, for example, in performance style, instrumentation technology, and interpretations.

Of more direct relevance is the work of movement theorists such as François Delsarte, Frederick Matthias Alexander, Émile Jaques Dalcroze and Rudolph von Laban, all of whom developed influential techniques for thinking about movement. Delsarte was interested in enhancing dance pose and

gesture through an understanding of the natural laws governing bodily movement. To that end, he carefully studied aspects of human gesture in everyday life and compiled records of thousands of gestures, each identified with specific descriptions of its time, motion, space and meaning (Shawn 1974). Alexander was an actor responsible for the educational process that is today called the Alexander Technique, a method of helping people learn to free up their habitual motor reactions through improvement of kinesthetic judgment (1989). Laban was an Austrian-born architect, philosopher, and choreographer who developed a sophisticated system of movement observation and description (Laban Movement Analysis, or LMA) that enables the observer to identify and articulate what parts of the body move, and when, where, and how they move. The body's relation to "space," "shape," and "effort" (or inner impulses) are some of its primary elements, but in contrast to other methods LMA places no emphasis on which movement quality or shape is desirable from aesthetic or other perspectives (Hutchinson 1991).

Such movement analysis and annotation methods can be used to write out dances, an activity that is called choreology, methodologies for which were developed not only by Laban but also by Feuillet, Stepanov (Nijinsky), and Benesh. As an example, Benesh developed a purely kinetic language that allows positions, steps, and other movements to be directly represented, including movements of multiple dancers involved in complex dance productions. Not only can the reader see the movements that are written in a score, the mode of recording is sufficiently realistic that they can also be felt motorically. The advantage of using a purely kinetic method for describing dance and movement is that it is the movement itself that is conveyed, rather than some analytical, functional, scientific, or poetic verbal description (Benesh and Benesh 1983).

From the scientific perspective, folk or social dancing has generally been considered to be an incidental part of musicology and thus has attracted little attention from scholars, who have seen it as lacking the prestige enjoyed by other aspects of musical life. Thus far, research in dance history has been primarily focused on dance culture during single epochs, for example, in relation to important political events such as the Congress of Vienna of 1815. This has made it very difficult to gain a clear understanding of the continuity or discontinuity in dance culture from one epoch or culture to another. It is indeed much easier to compile statistics about the numbers of dancers active at given times and in limited geographical areas than to gauge differences and similarities between, say, waltz choreography today and at different times in

the past. Even state-of-the-art research such as has been published by Monika Fink (1996), Richard Semmens (2004), or Jean-Michel Guilcher (2004) fall far short of conveying an adequate picture of how dance nomenclature and terminology have evolved and whether or not the changes have adequately reflected the simultaneous evolution of the dance types being studied. In addition, most projects have focused on individual dance practitioners. And because the results have been published mostly in the form of printed collections, such as Valerie Preston-Dunlop's *Dance Words* (1995), they cannot be searched efficiently, nor are they very useful for the analysis of dance practice, as they tend to be colored by historically and culturally specific theories of what dance should be, rather than what it actually is, or was at specific stages in the past.

There is clearly room here for a more objective analysis that can be tested against the real-world needs of large communities of interested persons and in a way that will not only contribute to the quality and quantity of information available online but also yield deeper scientific insights, for example, as concern global patterns in transmission of cultural phenotypes from one generation to the next.

Ontologies for Video Analysis, Indexing, and Retrieval

An important component of future tools for video image understanding will be the ability to make decisions based on a progressively closer approximation to a correct analysis of complex motions based on successively more refined hypotheses as to the activities involved. Recent work has investigated the application of hidden Markov models (HMMs) in a layered approach to the recognition of individual and group actions on the basis of multimodal recordings (McCowan et al. 2005). In this approach, a first layer integrates modalities and recognizes low-level elements such as motion patterns and tempo. A second layer takes likelihoods from the lower layer as input features, integrates them with features coming from audio analysis, and generates hypotheses as to the nature of the actions involved, for instance, the type of dance being performed by a group and the level of expertise of the dancers. Initially, simplifying assumptions are made, which then need to be relaxed in order to address the complexities of real situations. In particular, combinations of activities may change over time, sometimes gradually, sometimes abruptly. The system must recognize and adapt to these changes. Predictive platforms have to learn to respond to such changes efficiently. Also, prediction algorithms need to

be able to infer actions in the presence of multiple persons engaging in the multiple sorts of complex actions that are involved in any given instance of social dancing.

Achieving efficiencies of this sort will involve the use of algorithms that can evolve in light of lessons learned in successive applications. Examples of such approaches include applying high-level learning algorithms like neural networks (Gurney 2002), reinforcement learning (Mozer 2005), semisupervised learning of Bayesian network classifiers, and case-based reasoning in complex environmental settings (Cohen et al. 2004). Though each such approach can form the basis of the resolution of certain tasks that will be required in a powerful dance analysis system, none as yet achieves high-level recognition specifically targeting dancing events. Practical applications thus far are limited to areas such as video surveillance in railway stations (Cupillard et al. 2004), banks (Georis et al. 2004), or combat areas (Kalukin 2005), where the goal is to assess automatically coarse-grained phenomena such as crowding, blocking of entries, vandalism, and so forth. But these applications take advantage of the fact that video-surveillance cameras work with more or less fixed backgrounds and under conditions where it suffices to detect large-scale movements. The requirements for identifying what sorts of dances are being recorded on video are more demanding, though progress toward the necessary fine-grained analysis is being made. Kiranyaz et al. (2003), for example, describe a system that is capable of indexing domain-independent large image databases, and that allows retrieval via search and query techniques based on semantic and visual features. In the professional annotation module of the BUSMAN system, an advanced interface for automatic and manual image annotation has been developed, although the automatic annotation functionality is mainly based on low-level descriptors such as simple shapes, colors, and textures (Waddington 2004). MediaArchive, from Blue Order (2007), is a powerful industrial archiving system allowing storage and retrieval of any media files and is currently used by several major broadcasters across Europe to give users access to their collections. However, much research is still required, the coordination of which is being attempted in Europe by SCHEMA, the Network of Excellence in Content-Based Semantic Scene Analysis and Information Retrieval (Kompatsiaris 2004).

Specifically ontological contributions to video annotation include that of Nevatia, Hobbs, and Bolles (2004), which describes an event ontology framework, a formal representation language, and ontologies for the security and meeting domains. However, the representations of the domains selected are

highly simplified, and each of the developed ontologies contains not more than a dozen entities. Clearly, the framework needs to be refined in such a way as to be applicable to much more complex events, and the ontologies need to be expanded significantly. Also extremely small in design is the TRECVID 2005 “ontology,” which works with only ten entities (Over 2006). The same applies to the Large Scale Concept Ontology for Multimedia (LSCOM), a work in progress developed by IBM in concert with Carnegie Mellon University, Columbia University, and the University of California, Santa Barbara. LSCOM envisages an ontology of the order of some one thousand entities, given that this ontology is designed to be used for “understanding” the entirety of news broadcast content (J. Smith et al. 2005).

Moving in the direction of more structurally coherent ontologies, Bremond et al. (2004) developed a video event ontology consisting of representations of entities of two main types: physical objects in an observed scene and states and events occurring in the scene. The former are divided into *static objects* (a desk, a machine) and *mobile objects* detected by a vision routine (a person, a car); the latter, into (static) primitive and composite states and (dynamic) primitive and composite events. The authors use logical and spatial constraints to specify the physical objects involved in a scene and also temporal constraints, including Allen’s interval algebra operators, to describe relations, for example, of temporal order. The result serves as a framework for building two ontologies for visual monitoring of banks and metro stations using ORION’s Scenario Description Language.

A comprehensive review of existing content-based retrieval systems and video retrieval literature is provided by Izquierdo (2003), and several such systems are now available for use. For example, Query by Image Content (QBIC) (IBM Corporation 2007), an image-retrieval system developed by IBM, is currently in use at the Hermitage Museum for its online gallery (State Hermitage Museum 2003).

To make an endeavor of this magnitude succeed—that is, to make it possible to extract low-level (e.g., kinetic) features from videos in such a way that they can be combined into constructs of a higher order corresponding to bodily movements and gestures—requires that the varying existing multimedia standards be bridged by ontology standards. Several recommendations issued by the World Wide Web Consortium, above all the Resource Description Framework (RDF) and the Ontology Web Language (OWL), have a role to play from the ontological point of view in realizing this goal, but these languages are not yet sufficiently mature to be usable for the representation of complex

spatial-temporal detail of the sort entailed in the challenges at issue here. They are also not yet easily combinable with the multimedia standards developed by the International Standards Organisation (ISO) and the International Electrotechnical Commission (IEC), such as JPEG 2000, MPEG-4, MPEG-7, and MPEG-21, when dealing with issues such as storage, transmission, and editing of still and video images. Some of these standards are versatile enough to accommodate some of the multimedia access services described above, but much work still needs to be done. Currently, audiovisual content described with MPEG-7 elements (description schemes and descriptors) are expressed solely in the language known as XML Schema. The latter has been ideal for expressing the syntax, structural, cardinality, and data-typing constraints required by MPEG-7. It has also been used to build a preliminary dance ontology based on Labanotation (Hatol 2006). However, in order to make the descriptions accessible, reusable, and interoperable with other domains, the semantics of the MPEG-7 metadata terms need to be expressed in an ontology using a language like OWL. Therefore, new specific data types geared to multimedia content and media-specific data types have to be proposed. A first attempt to build a dance movement ontology called DVSM (Dance Video Semantics Model), is proposed by Ramadoss and Rajkumar (2007); the goal of the authors is to use this ontology in the context of video annotation, but it should be applicable also to some of the other scenarios described above.

Toward a Semantic Web-Based Infrastructure for Experience-Based Search and Retrieval for Multimedia Dance Resources

Delivery of and access to audiovisual content is a business that has accounted for a significant percentage of the world's gross domestic product in recent years and that continues to expand. Current stocks of audiovisual content are growing at an exponential rate, and multimedia services are becoming increasingly sophisticated and heterogeneous. On the consumer side, video on demand, copying, and redistribution, as well as retrieval and browsing through video portals such as those offered by Google, Yahoo, and YouTube, are becoming progressively more popular. Although this development brings increased revenue for the telecommunications and content-provider industry, it also brings a challenging task: to deliver customized functionalities for fast query, retrieval, and access.

Building a digital repository and related analysis, search, and retrieval tools for the domain of video representations of dance is indeed only a small

fragment of the totality of what is required to meet this global challenge. Tackling this narrow fragment will, however, involve addressing many of the same technical problems as need to be addressed on the broader front and will surely bring valuable lessons. It will also improve our knowledge of and access to an important aspect of our cultural heritage and lead to better research and education in this area. As an example: why are culturally educated people not at all shocked when, in the 1954 film version of *Brigadoon*, English contradance choreographies are used to represent and evoke a Scottish dance event, or when a mazurka and non-Regency quadrille are danced in the 1940 film *Pride and Prejudice*? The latter is no less an anachronism than Monet paintings or Rolex watches would be in a film about the life of Mozart. Nevertheless, the former pass unnoticed, while the latter would be considered an insult to our historical consciousness. Stimulating a systematic quest for data and analyses of collected data around dance culture will help to rectify this situation, with broader consequences for our level of sophistication about our own historical past.

The system would be a tremendous help for analyzing both the form (the danced steps) and the ways in which this form becomes meaningful to its users (the meanings found, for example, in ethnic and national dances). As such, it will further contribute to the critical reevaluation of dance, and through dance, of our wider cultural heritage. Dances can be illustrative of the cultural trajectories, influences, fashions, and traditions of an entire continent. Understanding and learning the dances of an alien culture can help us to understand this culture in new ways. A system with the capacities that we described will also foster the development of new traditions by bringing to our attention cultural influences that may be both temporally and spatially distant: looking at pictures of the waltz as danced in the nineteenth century can give us new ideas as to how to dance it today, how it is related to other dances, and so on.

Conclusion

Developments that would allow video search in areas such as dancing cross disciplinary boundaries, particularly those between the arts and humanities, on the one hand, and technology, on the other. Innovative ideas can only derive from a tight integration of professionals from different fields; appropriate state-of-the-art technology cannot simply be put to use by end users but must be designed with them and for them. As research and publication increasingly

move to the Internet, so research materials have to become more accessible via computerized interfaces, and research in the arts and humanities has to become more efficient. Software applications such as the ones envisaged here will enable speedier recovery of data and facilitate its analysis in ways that will assist both archiving of and research on dance. The ontologies that have to be produced as the basis for such software applications should be made openly accessible to researchers. Research questions raised in conjunction with such developments can be adapted to other fields, hopefully also with innovative results. Indeed, the vision algorithms and theories that have to be developed to make such searches possible can be reused for other scientific and practical purposes in all contexts where a video corpus has to be analyzed and queried.

Notes

1. For *Le Grand Bal de l'Europe*, see <http://gennetines.org>; for *Andanças*, <http://www.pedexumbo.com>; for *Gran Bal Trad*, <http://www.granbaltrad.it/en/indexen.html>; and for *Dance Flurry*, <http://www.danceflurry.org> (accessed October 30–November 1, 2007).

2. The convention, adopted by the thirty-second session of the UNESCO General Conference, defines intangible heritage as including creations originating in a given community and based on oral traditions, customs, languages, music, rituals, festivities, traditional medicine and pharmacopoeia, the culinary arts, and all kinds of special skills connected with material aspects of culture, such as those involving tools and habitat.

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