Métis meets Empirical Modelling: from ancient wisdom to emerging technology

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Abstract: The Métis project brings together a global virtual team for the collective creation of an advocacy advertainment film for the 2008 Beijing Olympics. This team includes computer and human scientists, artists, NGO officers, students, global Olympics volunteers and industrial partners from Europe, Africa, China and North America. The ambitious scope of Métis demands a technology for cooperation that can address the intercultural mediation of creative and innovative processes and that is highly adaptive to unstable contexts and unpredictable situations. As is suggested by its motto: *'Shooting the film while building the camera'*, Métis envisages the development of such a technology and infrastructure for cooperation as part of the concurrent responsibility of the global virtual team. This paper reviews the progress of the Métis project to date, with specific reference to the broad challenges being faced in deploying current technologies for computer-supported collaborative working and learning (CSCW/CSCL). These challenges, which stem from the diversity of the cultures, contexts and processes for creation, communication and production represented in Métis, relate yet more broadly and generally to topical issues concerning eAdoption worldwide. The paper discusses the prospects for addressing these issues with reference to the future emerging technology of Empirical Modelling.

Keywords: Digital divide, NGOs, Innovation, CSCW, CSCL, Interface Design, Virtual environments, Empirical Modelling (EM), Humanities computing, Cooperative creativity, Developing countries, Capacity Building, Cultural Context, Media content, Olympics.

1. Introduction

The Métis project [45] is a wide-ranging exploratory process that aspires to escape the usual logistics of participating laboratories. Empirical Modelling (EM) is an exploratory project [42] directed at developing an alternative view of computing that is likewise wide-ranging. This paper outlines how broader views of technology and creativity with cultural roots in ancient Greece and China that are topical for Métis can be supported by EM principles and tools. This potentially has wide implications for cross-cultural projects that involve computer-supported cooperation across the digital divide.

2. The context for the Métis project

The orientation of the Métis project is profoundly influenced by ethical concerns. A key objective for Métis is the promotion of the broader vision for the Olympics that is embraced by the Humanistic Olympic Study Center [43]. The vehicle for this promotion is an advocacy movie in the form of *advertainment*: a blend of advertising, artistry and

entertainment. Such a movie will advocate a conception of the Olympics where benevolent motivations for global good conjoin with passion for sports, arts and dedication to one's country – an antidote to the merry commercial and professional process to which the Olympic dream is in danger of being reduced.

Addressing the ethical agenda of Métis has far-reaching implications. Setting up the Métis project involves bridging gaps between the perspectives of science, art, commerce and technology. Its Olympic vision embraces global culture, peace and respect for the environment, but must also emphasise the importance of protecting the rich diversity amongst individuals, communities and ecologies. These vital messages are well perceived in the world: they constitute a powerful reserve of hope and humanistic expression which could be skilfully mediated by new information technologies. But our technologies cannot be based solely on the dominant culture and ideologies of the Western world.

The elaboration of the concept behind Métis can be seen as drawing on the two cultures that come together explicitly in the Beijing Olympics: the Chinese and the Greek. The importance of these cultural contributions is that they give insight into respects in which our accepted understanding of key concepts – such as *creativity* and *technology* – has become limited, perhaps in somewhat the same way that the modern conception of the Olympics has diverged from that of the ancient Greeks. These limitations motivate the practical approach adopted in the project, to be described in section 3.

The name Métis itself derives from the Greek word for 'wisdom'. In their analysis of the concept, as it relates to ancient Greek culture, Détienne and Vernant [16] observe that: *There is no doubt that mêtis is a type of intelligence and of thought, a way of knowing; it implies a complex but very coherent body of mental attitudes and intellectual behaviour which combine flair, wisdom, forethought, subtlety of mind, deception, resourcefulness, vigilance, opportunism, various skills, and experience acquired over the years. It is applied to situations which are transient, shifting, disconcerting and ambiguous, situations which do not lend themselves to precise measurement, exact calculation or rigorous logic.* Détienne and Vernant contrast this broad concept with the Modern Greek scholars' image of Greek thought – an image "in which mêtis is conspicuous by its absence". This contrast underlies the crucial difference between the path of the ancient Greek Technite and that of a typical contemporary engineer – the modern technician who has been disconnected from a cosmogonist view of the world because of their extreme specialization.

In the Métis project, the authentic concept of mêtis guides the development of a technology for cooperation and shapes its associated interactive environments. Of equal importance is the conception of the cooperative activity itself, and the nature of its products. The notions of 'creativity' and 'innovation' have particular relevance (see [21]), both because of the artistic aspect of advertiament and because of the need to accommodate a wide variety of cultural perceptions of these terms.

According to Lubart [28]: Creativity is the capacity to create something which is both new (original, unexpected) and adapted (useful, adapted to constraints). This pragmatic North American definition may be contrasted with the European conception of "being creative", which is understood metaphorically as referring to the willingness to express oneself freely without any practical aim in mind, almost detached from reality [19]. In so far as these two definitions can be construed as referring to a common activity, there are complex socio-political reasons why what is a scientific concept in USA was until recently still a metaphor in Europe. As Joas [19] has observed, such common construal is possible provided that the phenomena that are implicitly invoked in 'being creative' can be the target of a real experience.

As described in more detail in [21], the work of the sinologist-philosopher François Jullien [20] is helpful in looking at Western innovation and creativity from a Chinese point of view. Debray [15] and Latour [25] further stimulate the orientation towards China.

Where the Western traditions of thought attach great importance to originality and the contribution of self, Tao recognises only the harmony of individuals on the path originating in the consciousness of belonging to nature. This constitutes the fundamental recognition of correlativity: continuity and connexion between every single thing. In such a context, innovation is conceived differently – as making the relationships between things more readily experienceable by presenting them in such a way that they are more easily accommodated in the mind of the viewer. In contrast, the Western conception of innovation involves performance that purports to create novelty, and – by implication – promotes a vision of self and present reality that violates the Tao idea of *all reality as infinite* [20].

The above account of the context for the Métis project has been amplified in several previous publications [22, 38]. It highlights commonplace pitfalls in cross-cultural projects involving information technology. In relation to the Beijing Olympics, to follow the established practice in promoting the Olympics could be viewed as imposing alien cultural values where both the vision for the Olympics and the perception of innovation and creativity are concerned. At the same time, developing an alternative practice that does fuller justice to a broader Olympic vision is challenging on account of the very practices and technologies that have been developed to sustain Western cultural traditions. This has been the motivation for integrating 'building the camera' with 'shooting the film'.

3. Objectives and orientation of the Métis project

The framework for the Métis project encompasses three principal goals:

- **capacity building**: recruiting an intercultural global virtual team of volunteers composed of researchers in computer science, human sciences, movie professionals, artists, industrialists and students inclined towards interdisciplinary research.

- **film-making**: carrying out an advertisement cinematographic project within the framework of Beijing Humanistic Olympic Games 2008.

- **computer-supported cooperative working**: developing – through an ongoing iterative process of conception and test – a platform for the cooperative creation, follow up and mediation of the Métis project's artistic, scientific, technological and commercial components.

To date, the Métis project has explored several complementary aspects of its broad agenda, relating to issues such as Innovation Management [9], Ergonomy [31], Multimedia Document Management [9, 10], Education [24] and the technological needs of NGOs [23, 24]. This research has been aimed at clarifying how to organize such an innovative approach, both from the artistic, technological, educational, commercial and research point of view. Some comparative study of aspects of collective creativity in China and other cultures has also been carried out [38]. A pilot advertisement project is currently under way and results to be presented at the next International Olympic Forum in June will be available in preliminary form for IST-Africa 2006 in Pretoria.

The guiding principle behind the Métis project is that – in order for contemporary actors to exercise their artistic creativity and exploit radical technological innovation to the full – their interaction with each other should be mediated by an appropriate interface through which they are sensitized continuously to what makes the core of humanities: mêtis. This entails enhancing awareness beyond the scope so far envisaged in the CSCW literature – in ways that are not merely concerned with enriching the interaction between the members of the virtual team, but also with increasing each participant's reflective perception and self-awareness during the intercultural creative process. The intended effect

of this enhancement is twofold. Firstly, it broadens the focus of attention so as to take account of a larger and more comprehensive set of variables that are deemed to impact on the ongoing creative process. This is in keeping with Fischer's observation [17] that: "The power of the unaided individual mind is highly overrated. Much human creativity is *social*, arising from activities that take place in a social context in which interaction with other people and the artifacts that embody collective knowledge are essential contributors". Secondly, it augments the role of the computer so that, in addition to supporting the automation and repetition of routine tasks, it can help to address the uncertainty which is highly specific to innovation and creative processes.

In the Métis project to date, the key proposal for enhancing awareness is that of developing a *Trace Composer* to promote communication between the participants in cooperative activity. The function of this tool is to support information capture and integration in order to help the team members during the creative process. To this end, the Trace Composer will increase feedback that relates both to individual and collective activity. The monitoring of each virtual team member's activity is to be both voluntary and assisted (cf. [18]). Using the metaphor of the "mirror", the team member should be able to express – as far as possible – information both about their environment and their own cognitive, emotional, and conative state. This kind of information is also intended to improve awareness of meta-cognitions and hidden cognitive or emotional automatisms. The objective is to plunge the team member into a holistic view of their activity "in context", giving the kind of open systemic view that activity of an analytical nature rarely provides. In relation to teamwork, it enables each team member to have some idea of the state of mind and direction of thinking of other members. This can help to ensure that a new idea is not simply generated 'spontaneously' and trapped in a loop, but is instantly connected to the wider context of the team and broadly adapted to current constraints. It can also raise the profile of inappropriate hidden assumptions and automatic responses that can be constructively challenged. This potentially stimulates a re-generation of the creative process that leads to greater freedom of choice or flexibility, and a better understanding of the relationship between original ideas and valid constraints.

Where the implementation of the Trace Composer is concerned, two principal ideas have been under discussion. One relates to the need to provide feedback that is not mediated solely by document-based interaction. This motivates means to establish augmented consciousness through exploiting dynamic figures, pictograms, icons or images. The second relates to a potential role for Levy's Information Economy Meta-Language [26,40] in supporting the integration of the interdisciplinary information. The traces of the Trace Composer, multimedia in nature, might then comprise a set of linked units, each composed of an expression of subjective intention, a fixed or dynamic image, sounds, music, a meta-language referential from IEML, and an optional compendium of items (such as an object, drawing or storyboard) that increases the chance of conveying the meaning of "any complex personal experience".

The remaining sections of the paper will examine the prospects for addressing the Métis agenda using the principles of Empirical Modelling, whether as a complementary or as alternative technology.

4. Empirical modelling

Empirical Modelling (EM) is an approach to computer-based model-building that is based on three primary concepts: the *observable*, the *dependency* and the *agent* [42]. EM is seen in the first instance as a means of creating interactive artefacts and environments that serve a role in shaping the modeller's personal understanding of a situation or phenomenon. The core activity in EM is the construction of families of definitions ("definitive scripts") that resemble the abstract network of definitions that relate the cells of a spreadsheet. Each

definition attaches a formula to a variable. This formula may specify the current value of the variable explicitly, as in a conventional programming assignment, or give a recipe for computing a value from that of other variables. The effect of redefining a variable (cf. redefining a cell in a spreadsheet) is then to 'instantaneously' update the values of all variables whose values are directly or indirectly defined with reference to it. Within current EM tools, the variables in definitive scripts are drawn from standard 'definitive notations', each designed to represent observables of a different nature. Variables may represent geometric entities in a line drawing, components of a screen layout, or tables and views in a relational database, for example.

The modeller's interaction with a definitive script is the archetype for all interpretative processes that are associated with EM. Each variable corresponds to some entity external to the computer model that is an observable, in the sense that it has a distinguishable identity and a current value or status: the shadow of an object, the age of a person or the openability of a door. Each definition corresponds to an association between one change to the value of an observable and that of another that has – or can be deemed to have – the qualities of a mechanical linkage. Relationships between observables of this nature are pervasive in experience, and are called dependencies. Simple examples include the relationship between the position of a light source, an object and its shadow; the relationship between current year, date of birth and age; the relationship between whether a door is locked and whether it can be opened. In modifying a script, the modeller will add or remove variable definitions, or redefine an existing variable by substituting a new formula for it. Such an action on the part of the modeller corresponds to exercising some form of agency that is in general to be interpreted with reference to the external situation. For instance (referring to the examples given above), the modeller relocates the light source, updates the current year, or redefines the door that is now jammed as unopenable irrespective of whether it is unlocked.

EM puts modelling-with-definitive-scripts to a most general purpose: that of mediating understanding of *any* situation from the perspective of *any* agent. In this context, the term 'agent' is used to refer to anything that might be responsible for changing the current values of observables in a situation, whether this is a person, a device (such as a door spring) or a natural agency (such as gravity or the wind). The primitive interaction of modeller with script is in itself only sufficient in situations where relationships between observables and changes to their values can be studied in the absence of other agents, as in controlled experimental situations. Nonetheless, the same principle that is used to predict the shadow cast by a ray of light falling on a needle in the optical laboratory still applies to modelling the shadow of a sailing ship's mast in the light of a moon. To make the generalisation, it is 'only' necessary to model the ways in which the orientation of the ship and the locations of clouds, sails and sailors interact with the underlying dependency between illumination and shadow.

5. The railway EM artefact as an illustrative example

A full elaboration of EM principles and tools is beyond the scope of this paper (see [42]). A simple illustration, drawn from previous work specifically directed at using EM in CSCW, will be used to outline how EM might be applied to the practical Métis agenda.

Figure 1 is a screenshot from an EM artefact (a variant of `railwayYung1995` in the EM archive [41]) that was originally developed for tutorial purposes in connection with various aspects of railway modelling. Three different modelling perspectives are integrated within the model. A simple model railway layout, together with a control interface such as a model railway operator might use, features on the left of the figure. The depiction of the actual trains controlled from this interface is inconsistent with the model railway interpretation; it reflects instead the perspective of an observer in an actual electronic signal box, where the track segments that are currently occupied by trains are highlighted. On the right-hand side

of the figure, animated stick figures depict the participants in a train arrival and departure protocol, showing the interaction between the actions of stationmaster, the guard and the passengers. Note that the toy railway and the protocol animation were first developed independently – the schedule for visiting stations that features in the animation (train 1 travels from station A10 to B5 to A5 cyclically) was instantiated by identifying these stations with particular track pieces.
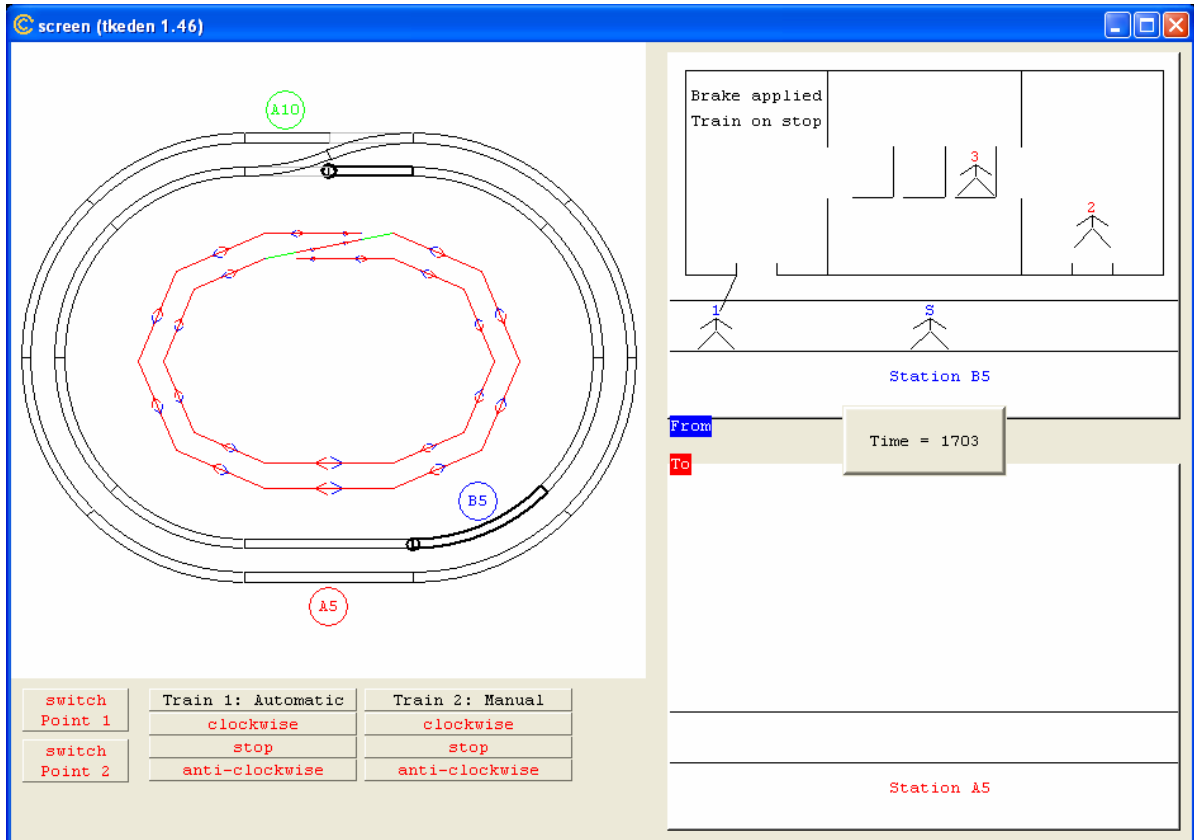

Figure 1: Screenshot of an EM railway model

The current state of the hybrid model shown in Figure 1 is determined by an extensive definitive script, comprising several hundred observables. Examples of observables include the location of the track pieces, the direction to which the track points are currently switched, the positions of trains 1 and 2, the positions of the buttons in the screen interface, the locations of the stations A5, A10 and B5, the status of the doors on train 1, locations and destinations of passengers, the abstract point currently reached in the protocol of interaction between the stationmaster and the guard. Dependency also features in many aspects of the model: the perceived location of a passenger on the train is determined by the location of the train; the stations and the heads of the passengers are colour-coded to indicate their intended destinations; the status of the lines depicting the orientation of the points on the display is determined by the setting of the points; the status of the railway operation depends on whether trains have crashed into each other or into the track points.

All manner of agency, both explicit and latent, is represented in the `railwayYung1995` model. As explained above, the role of the model-builder is perhaps most appropriately conceived as integrating that of several designers acting in different roles. The redefinitions that are accessible via the interface at the bottom left determine agency in the traditional computer user mode, and approximate that of a model railway operator. A more realistic representation of this role would allow the operator to "pick up" a train and replace it elsewhere on or off the track: definitions to accomplish this directly can be entered into the

model through the input window of the interpreter. The roles of agents that are internal to the animation (the trains, passengers and railway staff) are also mediated by definition, but in these cases redefinition is automated so that the movement of trains and the actors within the model can be simulated *as if* it were being carried out manually but without requiring any interaction on the part of the modeller. For this purpose, the actions of passengers and railway staff, though faithful to their intentions and protocols, are scheduled with an appropriate degree of randomness in respect of specific time of acting. In contrast, trains move from one track segment to the next in accordance with the abstract connectivity pattern specified by the combinatorial diagram displayed within the track layout on the left of Figure 1, in a fashion that is strictly clocked.

The `railwayYung1995` model illustrates in microcosm the potential for cross-cultural modelling of interactions between CSCW participants. Variants of the interpreter deployed in Figure 1 allow the roles of different agents to be distributed. This could be exploited to allow the roles of passengers and railway staff to be played by human agents, for instance, or to enable the various strands of modelling activity in the hybrid model to be separated and developed independently subject to looser constraints on collaboration.

6. Empirical Modelling and the Métis concept

Previous research on EM has examined the scope for deploying EM principles and tools in concurrent design from a technical perspective (for details, see [3,4,5]). Subsequent development has focused on developing a better conceptual foundation for EM principles, with particular reference to the role that EM plays in integrating the roles of human and automated agency [2]. This section identifies key respects in which the orientation of EM resonates with the concept of Métis, as introduced in section 2. The following section then briefly discusses how EM relates to the practical goals of Métis, as outlined in section 3.

The first obstacle to a clear understanding of EM is semantic in nature. Reflecting on the significance of an EM model leads to the conclusion that it is inappropriate to regard the meaning of such a model as being specified by a set of functional behaviours – as is the meaning of a computer program. By way of illustration, the EM railway model depicted in Figure 1 is to be identified with the definitive script that specifies its *current* state, as captured in the figure and by the values of all the values and formula attached to the observables *as of that moment*. It may be tempting to infer that this script can be read as a set of propositions, but this mode of interpretation is fundamentally unconvincing. For instance, perhaps train 1 is now at B5, but this is no guarantee that it will be always at B5. The train may move, or be picked up and replaced elsewhere on the track, or be redefined so as to become a ghost train such that other trains can pass through it without crashing. By citing each of these scenarios, all that is meant is that the 'very same script' could, by dint of minor redefinition of observables such as could be performed by agents in different roles, be transformed into a new state that it would be unreasonable to deem to be 'a new model'. Uncomfortable as this semantic notion may seem at first sight, it is the only viewpoint that can accommodate the ill-defined concept of 'meaning in the making' and 'meaning in the process of being negotiated' that has to account for how the railway model evolved to its current state, and how it even now remains so obscure in relation to possible interpretations. It is impossible to say decisively whether B5 is a track piece in a toy railway layout, or a track segment in an improbably contrived actual railway. Either interpretation can be made more or less plausible according to what future trajectory of agent actions is played out whether manually or automatically.

The nub of the semantic difficulty in this context is a philosophical problem. By directing future sequences of redefinitions in the script of Figure 1; by removing or introducing additional observables, dependency and agency; by exercising discretionary privileges to suspend any automatic activity; by invoking whatever imaginative

interpretations the current state of the model can legitimately bear; the modeller can make of the railway model not merely a model of a toy railway, actual railway, or train arrival and departure protocol, but a model of whatever takes their fancy. For the legitimacy of the modelling exercise, all that is required is that the continuity and connexion between the experience of the EM railway model as a railway and the experience of the 'self-same' model as something else altogether should be recognisable – to the modeller at any rate. And though it is natural to challenge the subjective nature of this characterisation, it is difficult to imagine any other evidence for its authenticity apart from the ability of the modeller to trace and retrace the path of interaction and interpretation followed in transforming the model from one place to another, and to account for this in a coherent and consistent manner. In this process of EM, the connection with creative activity in the Tao sense to which section 2 alludes is immediately apparent.

The openness of the modeller's interaction and interpretation of an EM model is not only significant in relation to the attribution and evolution of meaning. It is the basis on which an EM model can serve as a practical *construal* (cf. [42, 8]), embodying the patterns of observables, dependencies and agencies that the modeller believes to be valid in the situation to which it refers. In so far as an EM model is a good construal, it will prove effective in accounting for all manner of patterns of interaction encountered in a situation, even though these may not have been explicit in the initial conception. By way of illustration, it would be a relatively modest task for the modeller to introduce suitable definitions into the railway model *on-the-fly* to reflect the possibility that whilst train 1 was in motion from station A10 to station B5 it became necessary (as a result of some emergency) to stop the train for passengers to disembark instead at B1. The destination of a passenger could also as of that moment – as if in response to a general announcement – be redefined to that station location known to be nearest to the passenger's home, so that conceivably a passenger originally intending to travel to B5 would instead travel on to A5. This hints at the sense in which EM accommodates that broader notion of intelligence and thought that can be applied to "transient, shifting, disconcerting and ambiguous situations [that] do not lend themselves to precise measurement, exact calculation or rigorous logic" [16].

7. Empirical Modelling and the practical Métis agenda

The prescription for supporting cooperative creation proposed in Métis is problematic in several respects. If the Trace Composer is to serve its purpose, it has not only to register the actions of the participants but to interpret these in ways that convey intelligible information about the status of the cooperative design activity and the mood and intention of the designers. It is entirely reasonable to suppose that forms of communication other than explicit messages and the exchange of documents are required in mediating between participants. Supplying an appropriate semantic framework for making sense of these ingredients of "augmented consciousness" is quite another matter. A major issue is that it is exceptionally hard to sustain a sense of common environment and presence in cooperative creation at nodes distributed across an international network. Communication through icons and artefacts may work effectively and design actions may be readily interpretable when participants share a common location and culture, but cannot deliver the same results when each participant is in a different context. The standard recourse in seeking to address such problems of inter-agent communication in the modern computing culture has been to develop symbolic languages with richer more expressive semantics, as Métis does in invoking IEML in this context.

This section briefly reviews the prospects for applying EM principles and tools to the three principal goals of Métis set out in section 3. Invoking an EM approach entails new thinking about how best to support cooperative creation and innovation within Métis. This

stems from a conviction that, in giving a satisfactory account of a distributed cooperative working environment, an alternative semantic framework is needed to address the primitive apprehensions of state and sense-making activities that must precede the sophisticated interpretation of procedural actions and symbolic expressions.

Cooperative creation: Previous EM research strongly suggests that modelling with construals has highly significant advantages over any variety of computer programming where activities that involve an intimate integration of manual and automated activity are concerned. Whereas the interpretative framework that surrounds a conventional program is fixed on conception, the whole purpose of the construal is to reflect relationships that are fluid and negotiable. In contrast to programming, where there is a sharp distinction between development and use, it is a matter of interpretation whether a redefinition is associated with 'shooting the film' or 'building the camera' (cf. [2,29]). Research on themes relating to concurrent engineering [3,4,5], decision-support [6], educational technology [7,8], humanities computing [29] and on an underlying philosophical framework for EM [2] all points to the conclusion that modelling with construals supplies an essential bridge between pre-articulate human experience and interaction based on language. In particular, in a environment for cooperation, direct interaction with another's construals (cf. [12]) is a form of pre-linguistic communication that arguably has a fundamental role to play in boot-strapping the more radical high-level forms of linguistic interaction envisaged in the Métis project.

Capacity building: Though there has been limited external adoption of EM principles, and practical experience of EM has been largely confined to university project work over a fifteen year period, there is a considerable body of informal evidence to indicate that EM can help in addressing technical issues, topical for Métis, that have proved problematic in relation to existing technologies. A pervasive problem – that of adapting software to different platforms [35] – was resolved in the specific context of cross-platform broadcasting by work at the BBC R&D laboratories in which dependency-based models of content featured prominently [39]. The readiness with which extant models built by one modeller have been revisited and extended by another – sometimes in a casual off-the-cuff manner, illustrates the potential for models of cooperative development that are better suited to Métis's vision for a global virtual team, where only a modest investment can be expected from each individual. The aspiration in EM, partially realised in existing practice, is to avoid the deep technical commitment that is needed in order to create, comprehend and revise programs. Instead, in the spirit of constructionism (cf. [8]), EM seeks to integrate the role of the modeller and that of the non-computer-specialist whose primary interest and expertise lies in the subject domain. Finally, the vigorous accumulation of models, refinement of tools and enhancement of skills that has been manifest in EM project work, despite the modest resources that have been available to support this activity (cf. [42]), suggests as yet unrealised potential for capacity building that is based on informal cross-cultural interaction. This is consistent with the affinity between EM and spreadsheet development rather than conventional programming. For instance, Nardi [30] has made the case for spreadsheet software as well-suited to integration of specialist and non-specialist activities, whilst Baker and Sugden [1] compile strong evidence for its versatility in mediating between teachers and learners.

Film-making: There are two primary aspects to EM – its use of dependency, and its emphasis on the experiential significance of computer-based artefacts. Spreadsheets are a precedent for the use of dependency, but a precedent for interest in the experiential aspects of dependency-based models can be traced to the pioneering research of the Wyvill brothers

on computer graphics (see e.g. [36,37]). This research, though not formulated in terms of definitive scripts, establishes the principle of developing code to maintain relationships between geometric entities and re-using this in the design of applications. As described and illustrated by Chmilar, Wyvill and Herr [14], this principle can be applied to making computer animations. Related research that demonstrates non-trivial applications of dependency in creating images and animations includes the collaborative geometric modelling using HyperFun [32] described in [12] and Carter's use of dependency in developing compact representations of computer game assets [11]. At present, such techniques are not closely related to practice in film-making, but will become more relevant as digital photography matures. In the longer term, this may be expected to lead to some convergence between the development of software and that of films, whereby the kind of modelling activity that precedes the specification of software to perform a specific function is invoked in creating the resources from which film to realise a specific narrative is devised. In this context, EM artefacts such as the railway model sketched in section 5 may serve as a source of diverse experimental simulations that can be adapted and embellished as appropriate to generate appropriate scenarios for use in films. From a technical point of view, such developments would be associated with the development of new definitive notations (cf. section 4) such as might be used to describe digital images, for instance.

8. Conclusion

EM supports the broader conception of creativity identified by Métis as crucial to deeper cross-cultural East-West cooperation. By focusing on modelling with construals, there are excellent prospects for developing continuously evolving CSCW environments that allow modes of communication based on exchanging and manipulating construals. In due course, such environments can be expected to provide a foundation for visionary frameworks for communication such as have been envisaged by Levy, which aspire to forms of language and notions of creativity embracing global traditions, African, East and West. It remains to discuss the practical prospects for bringing EM principles to bear on Métis.

Both the Métis and the EM projects have attracted an international interest from would-be research collaborators that is disproportionate to their funding. In conclusion, a roadmap for the application of EM to the Métis agenda will be briefly mapped out and its broader potential industrial relevance and significance indicated. In the process, two aspects of the influence and potential impact of EM will be illustrated: EM as a way to give a good account of emerging technology and practice, and EM as a foundation to guide radically new developments in technology and practice.

The initial focus for cooperation between Métis and EM has been on establishing a communication platform for collaborative learning. For this purpose, some use has been made of a Cyber Schooling framework [13] for online conference sessions at which EM principles have been introduced to artists and scholars working in France. From this experience, it is evident that, whilst the qualities of EM models are potentially attractive to artists and designers, more effort needs to be invested in making EM tools and models accessible to the non-specialist. It is also apparent that there will be immediate practical benefits in developing a variant of the Cyber Schooling environment which is more closely integrated with the principles of EM. With this goal in mind, current research is being directed at embedding tools that have been developed for distributed EM into the Cyber Schooling environment. This will establish a framework within which online resources for teaching EM (such as can be found on the EM website [41]) can be more effectively exploited by external researchers and practitioners.

A strong motivation for promoting EM is that EM models are very lightweight compared with traditional software. The standard interpreter for EM is only a few

megabytes in size for instance, and – even allowing for the high level of replication of similar definitions that is frequently involved – the state of a typical model is represented in no more than a few hundred definitions. A feature of EM models is that they are relatively easy to combine and tailor to suit particular needs, and so lend themselves to integration and customisation without the prior need to negotiate upon standards. Indeed, as is illustrated by the lack of conceptual integrity in the railway model in section 5, the negotiation of meaning that integration entails is precisely the kind of activity to which EM is best suited.

From an industrial perspective, it is highly significant that the adoption of EM principles cannot be easily reconciled with conventional software development practice. For instance, in the highly successful application of EM principles to cross-platform broadcasting by Cartwright et al at the BBC R&D Laboratories [39], it was quite inappropriate to make use of the pre-existing approaches to tackling this problem based on using teams of highly-skilled programmers to develop tools and techniques for direct translation between the different standard broadcasting formats. Instead, it proved much more effective to formulate the content to be broadcast on each platform in the form of a definitive script that could be automatically derived from a generic script, thereby bypassing the need to translate between the conventional representational paradigms. This exemplifies a significant obstacle to the wider adoption of EM thinking – that it demands such a significant shift in perspective that orthodox thinking about software development is no longer directly relevant.

Equally significant in this connection is the fact that – despite the low profile of dependency in formal and methodological approaches to software development – commercial practice already points to a significant and developing role for dependency as a fundamental simplifying and enabling concept. It is conspicuous in highly successful products such as MatLab [44] or Sibelius [46], for instance, and is implicitly invoked in research on topics such as visualisation for archaeology [33] and in mixed-paradigm programming [34]. What is more problematic is the conceptual incoherence that results from trying to absorb the notion of dependency into orthodox thinking about computation, software development and computer science. As a corollary to this, the understandable reluctance to retreat from views of software development in which traditional formal computational semantic models are inappropriately privileged leads only to further confusion, and inhibits more radical innovation.

In assessing the timescale for major progress on the Métis-meets-EM agenda, it is difficult to predict whether and – if so – when attitudes to computing in scientific and engineering circles will undergo the prerequisite change. The difference in orientation between EM and classical computer science thinking recalls the difference in thinking and philosophical orientation between the cultures of the East and West. For instance, EM works within a framework in which 'what an action in the world entails' cannot be absolutely prescribed, but is forever open to investigation and new interpretation (cf. the Taoist notion of reality-as-infinite); in contrast, classical computer science acknowledges no alternative means of representing action other than to ascribe a meaning to it with reference to specific goals and a closed context of reference. Potentially, EM principles can be viewed as giving authority to an alternative view of computing, but training receptive developers demands a form of education counter to traditional thinking in computer science. The technical innovation is well within reach – indeed there are already many commercial products and platforms that demonstrate high capability where dependency management is concerned – but there is a major philosophical problem to address in encouraging designers to think primarily in terms of states, environments and interactive relationships rather than processes, procedures and systems. More generally, as Lévy-

Leblond observes [27], researchers in science and technology are reluctant to reveal the often erratic and exploratory nature of their methods.

For EM to become established and flourish in practice there is a need to enable comprehensive representation of state by scripts of definitions. For this purpose, much more investment in developing definitive notations is required. Meeting the demands of cooperative model-building will involve creating industrial-strength platforms for the communication and management of scripts of definitions. Further research is required to build bridges between model-building activities and the traditional goal-oriented activities associated with creating programs, identifying processes and constructing narratives. The EM tools that have so far been developed are sufficient for proof-of-concept, incorporating management of dependency and agency that reflects the depth of thinking behind EM and is conceptually very sophisticated – but much greater investment is needed to bring it to maturity. Wider dissemination is vital in this connection – an objective that is possibly well-served by re-implementation in Java. Whilst it is most unlikely that all these ambitious goals can be realised within the short timeframe of the Métis Humanistic Olympics project, it is possible that Métis-meets-EM can help to promote the broader awareness that is essential to their ultimate attainment. In any event, it is to be expected that Métis-meets-EM can make a practical contribution to the Métis agenda for the Beijing 2008 Olympics.

Acknowledgments

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