Designing Human-Centric Applications: Transdisciplinary Connections with Examples

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***Abstract*—This paper discusses a number of solutions considered as human-centric applications with a particular attention to their typical transdisciplinary connections. In order to illustrate the cases when an algorithm, a model or a method originally introduced in a specific area of knowledge is applied to and significantly affects the design of an application from the different human-centric subject domains. To serve as examples, a number of our recent projects are selected including a travel-centric application, an educational tool, an IT-addiction self-control system, and an approach to testing software applications with a nonstandard graphical user interface. With respect to human-centric design process, we examine the importance of human-centric application assessment with some interdisciplinary insights into software readability which, in turn, is an obvious attribute of software quality, regardless its area of application.**

I. Introduction

Human-centric computing (which is also often referred as human-centered computing, HCC) as a field has flourished and transformed rapidly from an emerging area mostly limited to human-computer interaction issues to a wide domain with its own distinctive research agenda. Human-centric applications respond to the demands and opportunities brought about by the present-day technology dependent society. Many researchers have produced insights into the current perspective of human-technology interaction which is, in great measure, about designing solutions addressing human and societal problems and expectations which are not just for or within a certain technology or context [1].

A large variety of HCC applications affect society as a whole and particular individuals, and bridge the gaps between different disciplines with respect to design and implementation of computer systems supporting various human activities [2]. Thus, the interdisciplinary nature of human-centric computing is obvious: as it is clearly described in [3], HCC relates to and spans many disciplines including computer science, cognitive science, economics, and social sciences. As far back as 2006, Rogers formulated a human centric ubiquitous computing paradigm which includes making use of human creativity and resourcefulness in exploiting human environments and extending human capabilities [4]. Since that time the research agenda for HCC has been enlarged significantly.

One specific present-day trend is to develop personalized and adjustable interfaces for better and easier access to various information services. Surprisingly, we might face problems quite unexpectedly: convenient tools and interfaces (designed in order to be used as effort- and time-saving artifacts) may sometimes lead paradoxically to the deterioration of human abilities and may hide the benefits of less flexible tools that might seem inconvenient or outdated [5]. So, better personalization and usability does not automatically lead to improving users' creative abilities, extending user productivity, nor increase usability for people with a wide range of capabilities (which are major objectives of human centered design (HCD) according to the ISO 9241-210 standard [6] "Human-centred design for interactive systems").

We know numerous HCD application areas including health informatics [7], learning and educational systems [8], software engineering [9], [10], Internet-of-Things [11], geovisualizaton [12], multimedia networking [13] and many others. Regardless of the "final" application domain, based on the understanding that the successful solutions can only be achieved by combining multidisciplinary skills and perspectives, many researchers approach further insights by going into human-centric computing *trans*disciplinarity.

As defined in [14], *transdisciplinary research* is, on one hand, a kind of interdisciplinary research involving scientific and non-scientific sources or practices, while, on the other hand, it is a form of collaborative and cooperative learning and problem solving. In the following examples we make an effort to demonstrate that transdisciplinary research does not simply assume either the integrated use of tools, techniques and methods referring to various disciplines nor the interconnection among academic disciplines (as it is mentioned, for example, in [15]), but rather an application of solutions achieved in one area of knowledge to a different human-centric domain. An important aspect of this is pointed out in [16], where the author argued that *automation* is an integral part of transdisciplinary knowledge generation and dissemination methods assuring evolution "from being aware to being knowledgeable" [17].

II. Case Study

In this study we use a number of our ongoing projects as examples to be analyzed from the perspective of the transdisciplinary character of human-centric application development.

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A. Travel Guide Assistant

It is human to discover outward things, and traveling is one of remarkable ways to do so. Information management solutions for travellers are automatically multidisciplinary. However, in this essay we do not unduly emphasize the intrinsic multidisciplinarity of travel related services, but analyze how models originally introduced within other areas of knowledge might be applied to a problem in automated interactive itinerary construction, and how requirement specification might be refined as a result of system assessment.

Despite the emergence of e-books and web service-based solutions, travellers still use traditional paperback editions of numerous travel guides containing plenty of maps and city plan fragments. The reason for this is that travellers are often not totally satisfied with the quality and integrity assured by electronic solutions. However, books are hardly able to present changing events or to introduce different views of particular tourist attractions, compared to digital services that provide multimedia features, electronic maps, GPS-navigation and tracking, and so on.

Instead of taking predefined packages, many people like to prepare their own itineraries with the help of information available on web sites for travellers. While planning a trip to some area for a certain period of time, tourists are unlikely to be able to visit each attraction. In effect, they solve a kind of fuzzy optimization problem in order to select something that would be specifically interesting to them. Tourists select points of interest (POIs) depending on their significance from a certain perspective or point of view.

With the current high level of travel industry digitalization, the focus of emerging solutions is on creating a technology which would not only support a kind of time-budget optimization problem, but would allow travellers to develop their own memorable experience [18], [19].

In our earlier works (see [20], [21]), we described an approach to designing an application for constructing an interesting travel itinerary (i.e. a kind of digital guide). We attempted to address the needs of professional experts and amateur guides who are able to prepare their tours both in automatic and manual modes. Figure 1 provides a sketch illustrating that our research was generally organized according to the human-centric design process. Each large iteration contains the following stages (which, in reality, might be overlapping):

- Domain context analysis (with careful examination of existing resources and solutions);
- Analysis of existing prototypes developed in the adjacent application areas;
- Requirement elicitation with involvement of potential stakeholders and interested users;
- Developing knowledge models including design of domain-specific ontologies;
- Implementing early designs; and
- Assessment of the developed implementations in order to discover finer requirements and to expound the application context better.

In sum, currently our early design supports the following features:

- Ability to create the route itself and to add the annotations containing text information, images, audio, links to web sites, etc.;
- Ability to modify the created tourist route;
- Ability to search POI-related information on the web; and
- Automated tourist route construction by using a number of attractiveness evaluation algorithms dealing with the set of predefined POIs and working under time/distance constraints.

Let us be reminded that the ISO standard 9241-210 [6] "Human-centred design for interactive systems" defines the following HCD key activities:

- Understand and specify the context of use,
- Specify the user requirements,
- Produce design solutions to meet these requirements, and
- Evaluate the designs against requirements.

Importance of early designs is nicely analyzed in [22]: "The HCI literature rarely talks about working systems as a sketch, and instead elevates them to a low / medium / high fidelity prototyping status, which people perceive as increasingly suggestive of the finished product". The suggestive (in contrast to "describing"), explorative (in contrast to "refining"), and provocative (in contrast to "resolving") nature of the early designs (despite having many drawbacks and much incompleteness) [23] provides a good foundation for HCC-application assessment and further requirement adjustments. Interesting insights into the iterative nature of HCD with respect to possible alternative entry points and process trajectories can be found in [12].

As an example of an automatic route generation algorithm we can cite an adoption of the ant colony optimization (ACO) general algorithm to a case of travel itinerary automation that we described in [21]. However, after implementing the component supporting automatic route generation and arranging a series of experiments both with our application and with a number of multimedia guides for mobile devices, we came to an interesting conclusion. We realized that in addition to the formal automated solutions, one can use GPS-tracking applications (similar to [24]) together with an interface, which would support adding multimedia annotations by an expert simply walking in the area. So, a route might be automatically constructed "in the background" using positional information achieved in the process of tracking, while the excursion contents might be delivered by an expert (e.g., using the smart device's interfaces) [25]. We also noticed that such a transformation of an application architecture can also be useful for resolving a problem of automatic computation of a tourist attraction visibility area, where automatic solutions are not trivial (especially if we consider a three dimensional landscape model where an object of interest can be overlapped by other objects). The problem of a field of vision geometrical definition can be partially resolved by using the above mentioned procedure of creating an itinerary attached to a tracking

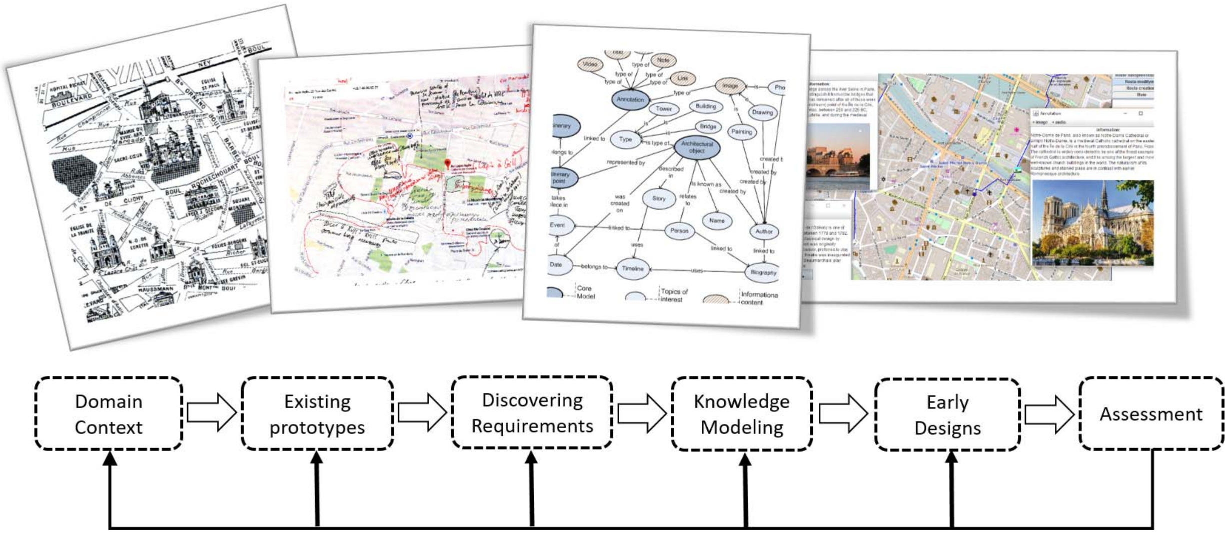

Fig. 1. HCC process

application (where not only distance, but also other constraints like walk duration, day or night time, season, etc. can be taken into account).

Thus, we come to the further requirements refinement as a significant result of the application assessment, which, in turn, is an important part of the HCD process. This refinement leads to elicitation of a transdisciplinary connection: GPS tracking is used for a quite different purpose, which is to provide a canvas for scenery for an interactive travel guide to be constructed in cooperation with an expert.

B. Math Equation Similarity

In [26] we studied math equation structural similarity patterns and approaches for math equation similarity evaluation. Apart from analysis of mathematical equations themselves (which, with a large variety of semantically equivalent constructions, provide a non-trivial case for information retrieval [27]) we made a stress on mathematical equations syntactical similarity by using structural and subexpression based similarity patterns.

Figure 2 provides a hint how the user interface of our prototype is organized. Let us note that the algorithms used in equation searching and in the analysis of math texts serve well the area of math learning, specifically for automated selection of suitable exercises aiming at advancing student skills achieved during classroom work or at preparing tests corresponding to the studied topics.

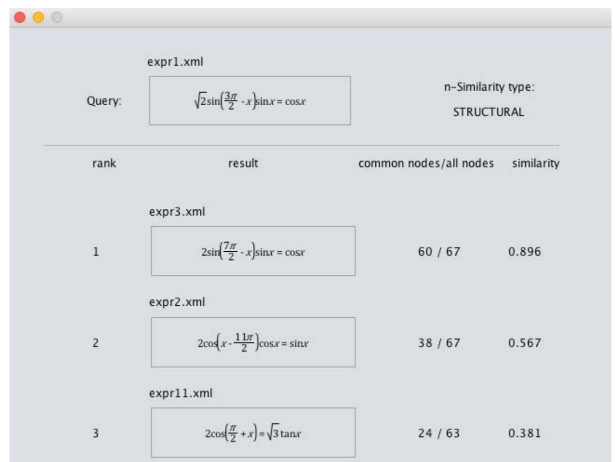

Fig. 2. Equation structural similarity evaluator: application interface

C. IT-Addictiveness and Gamification

In [28] we investigated a problem of IT addiction with the example of watching TV series delivered by online video streaming services. We paid attention to a problem of the interfaces, which are dynamically adjustable to user behavior (for better and easier access to information services). However, sometimes such an adjustment might provoke a type of addictive behavior. We examined a number of self-control and self-assessment tools aimed at striving with such addictive behavior without completely blocking access to a potentially addictive service.

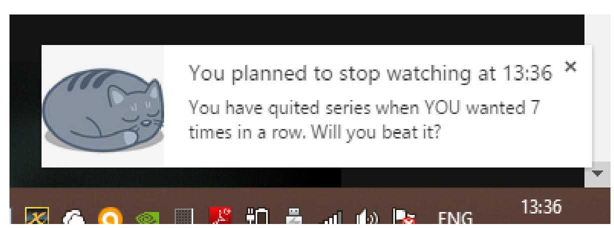

Fig. 3. A browser extension for streaming video watching self-control

In the prototypes we implemented for Google Chrome, we made an effort to implement two self-control scenarios. In the

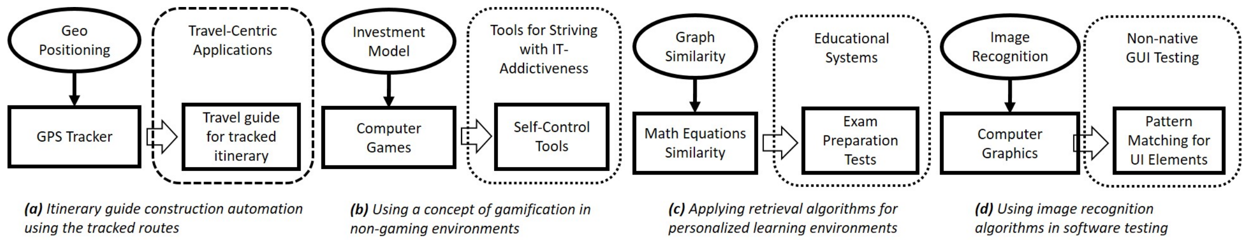

Fig. 4. Transdisciplinary connections: examples of HCC-applications

first one, access to a streaming service is automatically stopped or suspended as soon as the viewing time (previously set by the user) is over. In the second scenario (which interests us most in this research, see Figure 3), the users decide what to do by themselves after the system reminds them that the viewing time is over. In the latter case, the system appeals to the previous user achievements (i.e. to the number of times that the user won against his or her own addiction), so there is a variety of options for subsequent gamification of the self-control process. A concept of gamification (which can be defined as using game-like activities and mechanisms in non-gaming contexts aimed at increasing user involvement and motivation [29]) is presently one of the highly researched topics, which have a strong transdisciplinary nature. In Gartner's IT Hype Cycle 2012, gamification was mentioned as among a number of the top inflated expectations-technologies taking 5 to 10 years for market adoption [30], [31]. "Gamification has been utilized across various fields of research and domains, aiming for enhancement of conventional techniques" [10] including such different areas as software development and engineering (particularly in a case of software testing [32], [33]), e-learning [34], [35], and social adaptation [28].

D. Image Recognition in Software Testing

Let us mention one more illustrative example of ongoing work on testing *Unity* applications [36] focusing a problem of testing software applications with a non-standard (e.g. hand-drawn) graphical user interface (GUI), where a traditional approach for GUI unit testing automation does not work. In order to simulate application usage scenarios, the only option is to identify GUI elements using image recognition algorithms. Thus, pattern recognition methods (which originally had no direct connection to software testing) are used for the purpose of testing nonstandard GUI applications in combination with a number of other technologies including traditional automated unit tests and functional testing frameworks.

E. Summary

Figure 4 provides a summary of the above discourse in visual form. In each project, we can find an algorithm or approach originally designed for or aimed at resolving problems in an area which was not directly connected to the discussed applications. Thus, geo-positioning algorithms used in mobile trackers were utilized for refining requirements for the travel annotated itinerary construction automation (Figure 4(a)); the investment/reward model which is a basis for many computer (and non-computer) games was applied to the domain of IT-addictiveness self-control tools (Figure 4(b)); tree similarity algorithms (actively used in numerous information retrieval models, and math equations serve as examples) are applicable to improving e-learning systems, for example, by implementing algorithms for automated selection of mathematical equations for exam preparation exercises (Figure 4(c)); image recognition algorithms help with testing non-native and hand-drawn GUI in software applications (Figure 4(d)).

Let us also note that many commonalities can be found in modern convergent digital industry that pertains to shifting its focus from individual products to cross-industry experiences [37].

III. Discussion: Van Eyck's Case

Since this article refers to a number of aspects related to developing different kinds of human-centric software applications, let us suggest one more cross-disciplinary insight into software readability which is one of the obvious factors contributing to software quality. As an essential software property, program readability is connected to software analysis from the prospectives of both an engineering product and an object of art. This dualism is very close to the understanding of the balance between artifact-centric and human-centric approaches in software engineering [9]. Software readability as one of the achievements of a software engineer who, in a sense, *programs* not only a computational process, but also a process in which a beholder reproduces a developer's ideas.

Indeed, in art works the ways a *"reader"* learns the author's intentions are not occasional. Of course, they are not totally fixed within a painting, a novel, or a music composition, but in many cases there are hints and implicit traces drawn by an author. We *follow the traces existing inside the work*, as it was nicely described by a Swiss-German artist Paul Klee (quoted in George Perec's *La Vie, mode d'emploi* [38]).

Jan van Eyck's *The Annunciation* (circa 1434–1436, National Gallery of Art, Washington, D.C.) is an exceptional example of rich symbolism of Renaissance iconography. This masterpiece is particularly interesting for us because it shows the directions to read the painting "inserted" inside the work extraordinarily clearly. A possible rendition is demonstrated in Figure 5.

Our attention is immediately attracted by the disproportionate (to the surrounding environment) figures of the archangel

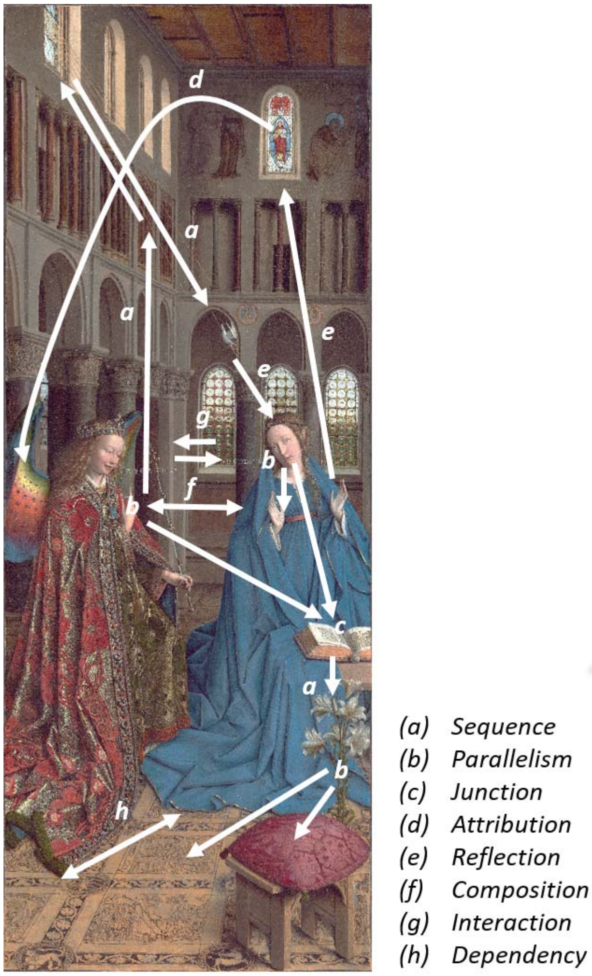

Fig. 5. Van Eyck's *The Annunciation*: Following the traces inside the work

Gabriel and the Virgin "connected" by two messages: *"Ave gratia plena"* [1] in the direction from Gabriel to Mary, and *"Ecce ancilla domina"* [2] backwards. Then, depending on our selection, we can start, for example, from noticing the archangel's finger pointing in the upper direction to seven rays of light coming from the left-side window. By following these rays, the eye makes a stop on the longest one, because of the white dove symbolizing the Holy Spirit descending to Mary. We abandon here the in-depth analysis of other emblematic elements in favour of paying attention to the other directions and structural elements of this painting.

From the Mary's figure the eye might go up to the stained-glass window (where the Lord is standing atop the Globe) implemented with using the same color tonality as the archangel's wings: so, technically, the connection between two elements of the composition are achieved by using color attributes. The second option is to descend to a book (apparently, the New Testament) which provides an implicit connection between two main figures, and further to the floor of the church displaying many symbolic images. One particularly interesting thing is a strong dependency between the figures of Gabriel and Mary, and between the places where they stand. Mary stands over the Virgo Zodiac sign (corresponding to September), while the angel stands over Aries (corresponding to March, and particularly to the date of the Annunciation which is March, 25) [39]. Of course, from the viewpoint of Christian iconography and art criticism, our superficial analysis does not discover many important aspects, connections and allusions (some of them may be found, for example, in the above cited article of J.O. Hand [39]).

If we return to software programming, is is known that software readability is often attributed to having sufficient comments in the source code. However, in some interesting research presented in [40], after a series of experiments arranged by involving professional developers as code annotators, the authors came to a quasi-paradoxical conclusion, which is in contrast to the common educational practice in programming teaching. Despite the belief that comments form a very direct way of communicating intent (so one might expect that their presence increases readability dramatically), in fact, they are surprisingly only moderately well correlated with the notion of code readability. Thus, better code readability can only be achieved through well-considered code structure and good models, and not thanks to many detailed (external) comments. Reading directions are mostly inside the work – and as we have suggested, this notion is applicable both to engineering and art works.

[1] *Latin*: Hail, full of grace *(Luke 1:28)*.

[2] *Latin*: Behold the handmaiden of the Lord *(Luke 1:38)*.

IV. Conclusion

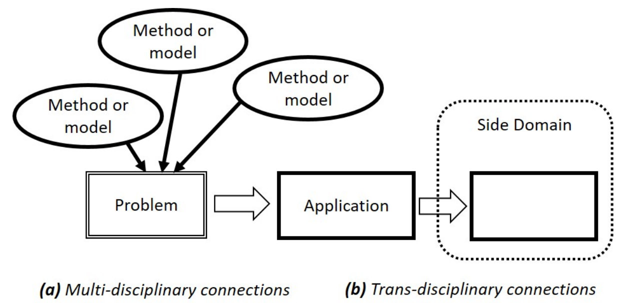

Fig. 6. Convergence of inter- and transdisciplinary models

In this study, reviewing a number of projects from a variety of subject domains, we can acknowledge both the inter- and transdisciplinary nature of present-day human-centric applications. Figure 6 draws a simplified model which serves to illustrate two important aspects. First, it is a *cooperation* of a variety of algorithms and approaches from different knowledge areas struggling with a certain societal problem or applied to a certain technology. Second, it is a *transition* of the successful solutions or applications to a distinct application domain. We believe that such a conjunction of cooperative and transitive relationships forms a convergent environment of present day human-centric engineering.

Afterword

In 1902, in response to *printing quality problems* caused by excessive humidity in the Sackett-Wilhelms Lithographing & Publishing Company of Brooklyn, Willis Carter, an American engineer, proposed a scheme that became recognized as the world's first modern *air conditioning* system [41]. Why might this not be an excellent example of a transdisciplinary human-centric application?

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