CONTENT 2021

The Thirteenth International Conference on Creative Content Technologies

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CONTENT 2021 Editors

Hans-Werner Sehring, Tallence AG, Hamburg, Germany

CONTENT 2021

Forward

The Thirteenth International Conference on Creative Content Technologies (CONTENT 2021), held on April 18 - 22, 2021, continued a series of events targeting advanced concepts, solutions and applications in producing, transmitting and managing various forms of content and their combination. Multi-cast and uni-cast content distribution, content localization, on-demand or following customer profiles are common challenges for content producers and distributors. Special processing challenges occur when dealing with social, graphic content, animation, speech, voice, image, audio, data, or image contents. Advanced producing and managing mechanisms and methodologies are now embedded in current and soon-to-be solutions.

The conference had the following tracks:

- Data Transmission and Management
- Web content
- Domains and approaches

Similar to the previous edition, this event attracted excellent contributions and active participation from all over the world. We were very pleased to receive top quality contributions.

We take here the opportunity to warmly thank all the members of the CONTENT 2021 technical program committee, as well as the numerous reviewers. The creation of a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and effort to contribute to CONTENT 2021. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations and sponsors. We also gratefully thank the members of the CONTENT 2021 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope CONTENT 2021 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of creative content technologies

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Human to Artificial (H2A): from Duets with Robot to a New Model of Relationship

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Abstract— **The current technological revolution is significantly transforming different sectors and areas, creating new cross-cutting and disruptive opportunities. Aware that the pervasiveness of certain technologies -in particular, those falling under definition 4.0- will be increasingly horizontal, it is necessary to try to hypothesize, at this time, new forms of interaction and relationships. It could serve as pillars for a change and development that defines technology as a means for innovation and not as the end of it. This research was born from the meeting between a design research group and an innovative Italian singer-songwriter, who study and experiment, each with their own skills, new possible kinds of relationship stimulated by the digital transformation that is investing our society: the research therefore aims to highlight the opportunities that may arise from the intersection between the creative and design worlds and the technologies of robotics and Artificial Intelligence used in music. Starting from the last artistic project of one of the authors, which fits perfectly in the highlighted area of interest, a second goal is to try to hypothesize a new paradigm of relationships between human beings and the aforementioned technologies, defined Human To Artificial (H2A), which can be a starting point to understand and further develop new approaches to technologies that will be increasingly present in everyday life, starting from creative stimuli.**

Keywords-Design of the new relations; robot; artificial intelligence; artistic process; music piece

I. INTRODUCTION

The continuous and recent innovations in information technology have led to the fourth industrial revolution and introduced the concept of Industry 4.0: this term refers to a group of technological advances that implement the degree of digitization of a sector [1]. Four key components (Cyber-Physical Systems, Internet of Things, Internet of Services and smart factory) and six disruptive technologies (Industrial Internet of Things, digital production, Big Data, Artificial Intelligence, collaborative robots and Virtual Reality) are normally identified as pillars of the Industry 4.0 concept [2]. Until now, the attention to these technologies has been focused almost exclusively on the technical improvements that their implementation can guarantee. In fact the term Industry 4.0 connote this technological set from a productive point of view, not considering the potential and the opportunities that could arise if they are able to intersect with less technical fields, such as critical-design thinking and creative thinking. Some authors [3] already refer to the concept of Industry 5.0, in which the different 4.0 technologies collaborate and interact in a more humanized way. They hope and hypothesize a further evolution of this concept, defining a new model of society 5.0 [4], where the cooperation and the relationship between men and technologies such as Artificial Intelligence and robots, are realized in order to seek the well-being of people and not only for the sake of technology itself [5].

Two concepts prove to be fundamental to hypothesize and describe new possible forms of interaction between human beings and 4.0 technologies, which can direct innovation towards this goal: design and creativity. In design and in the design process, it is recognized the ability to rationalize inputs from many different areas and to abstract the horizontal peculiarities, in order to conceive and conceptualize new approaches, ways of use and relationship with technologies. Creativity and the creative process are instead a stimulus for the construction of disruptive interconnections between human capabilities and artificial faculties, which can be a source to develop these relationships. The construction process and objectives of this paper are based on what has been stated so far: musical creativity meets innovation, generating an experience that, interpreted and analysed through design, allows to outline the distinctive features of a new approach between people and technology.

In Section 2, a brief description of the EDME Interdepartmental Laboratory of Politecnico di Milano will

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be provided in order to better grasp the background of the actors and researchers involved in the project; in Section 3, the main questions and the core of the research will be highlighted, and the case study, which will be further analysed in Section 4, will be introduced. Section 5 will be dedicated to the introduction and the description of the suggested new model of relationship between human and digital technologies. Finally, in Section 6 a resume and the conclusions of the paper will be presented.

II. EDME LABORATORY

The Environmental Design Multisensory Experience Laboratory (EDME), established within Politecnico di Milano, is the first result of a multidisciplinary integration path that synthesizes, in a systemic optics, the multiscale relationships that contribute to delineate the complex identity of instruments of investigation, interpretation and representation of experiential scenarios. The EDME Laboratory has been organized and managed to focus on multisensory interactive experiences, and combines, in a physical space, innovative Information and Communication Technology, sensors and latest generation materials. Research and experimentation activities are based on a system able to simulate complex actions and interactions, and to generate useful data. Further research activities of the Laboratory will concern the implementation of theoretical and applicative models with the aim of investigating and creating new relationships between physical and digital dimension. Marco Di Noia's experience and knowledge, described in details in the following paragraphs, are helping to lay the foundations for the development of further research patterns able to investigate the relationship between sound and music and the digital domain.

III. THE ARTISTIC PROJECT MEETS INDUSTRY 4.0

In 2016, the Sony Computer Science Research Laboratory (CSL) released “Daddy’s Car”, a song created in the style of The Beatles, composed by an Artificial Intelligence called Flow Machines. The new hit was created with a software, which used a database of 13,000 existing songs. The catchy track, that could be easily found on the web, was later arranged and produced by Benoît Carré. This song is both a great example of interaction between man and Industry 4.0 technologies -in this case, an Artificial Intelligence- and the source for different questions: are they a tool to help artists or an artificial alternative to them? Or neither of them?

Creativity and creative process, guided by a design mindset, could solve these questions, leading to new ways of perceiving some technologies, neither tools nor a replacements, but participants themselves in the process. So, how can these technologies contribute in the artistic process, acting as cooperative actors for its development?

In the following paragraphs, the featuring experience with two real robots -iCub and TeoTronico- within two recorded songs will be described. These experiences may be the first evidence of new possible models of interactions between human beings and robots or Artificial Intelligence.

IV. CASE STUDY: THE EP “LA SOVRANITÀ DEI ROBOT”

“La Sovranità dei Robot” (The Sovereignty of Robots), released on the 22nd of October, is a music EP whose lyrics are dedicated to some of the most popular robots, replicants, androids and cyborgs of the fiction. The EP is enriched with some pioneering elements and audio experiences: in this case, the recording of TeoTronico, conceived by the Italian Matteo Suzzi, which plays the piano in one of the tracks; and the recording of iCub, one of the world most evolved, relevant and popular platform to support research in embodied artificial intelligence, created by the Istituto Italiano di Tecnologia, that reads a poem as the last track of the EP.

A. TeoTronico

TeoTronico, shown in figure 1, is a pianist robot, conceived and designed by Matteo Suzzi at TeoTronica company, an Italian Start-Up based in Imola. Version 1.0, with 29 fingers, was completed in 2007. Starting from version 3.0 (2012), it was implemented with 53 fingers dynamically driven by electromagnets, able to control the gradations of any acoustic piano. TeoTronico can read musical scores in digital format, playing them on the piano in a literal way. Since 2017 it is also equipped with feet to control the sustain pedal of the piano. It can also play some “mirror-pianist” if connected to a digital piano played by a person. In the “mirror-pianist” mode, TeoTronico can also play as a solo pianist with orchestra, in chamber ensembles and accompanist with singers, even remotely, miles away. Teo can also talk and sing. It can reproduce written texts, grant or be dubbed in real time: in both modes, its lips movements are synchronized to the speech, in any language. Thus TeoTronico can interact with its interlocutors, even with its facial expressions: moves its head, mouth, eyes, eyelids and eyebrows. Equipped with proximity sensors, it can turn to the people who are approaching it. When dubbed in real time, it can answer questions from the audience. It can also perform with other musicians with an impressive versatility. Even if TeoTronico had never recorded any tracks before, it had a long international career on different stages.

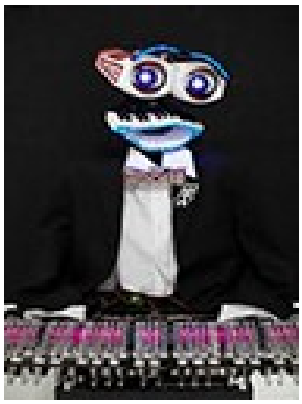

Figure 1. Photo of the robot TeoTronico (retrieved from http://www.teotronico.it/who/).

TeoTronico recorded a solo, on an acoustic piano, and some vocals on the 13th September 2020 for the track "La Sovranità dei Robot", a song inspired by Isaac Asimov's anthology "I, Robot". The musical instrument used by the robot was a Yamaha C3 Coda, recorded with a usual microphone set for acoustic piano. A couple of episodes are remarkable about this session: as TeoTronico recorded the solo three times, the team expected to listen to three identical performances. On the other hand, the three recordings were slightly different each other. So, the sound engineer had to pick the best part of each recording, and he made a composite, as it happens with human pianists. This charming evidence could have happened because the springs below the piano keys do not always react in the same way, even if they are pushed with the same force; or because TeoTronico's plastic fingers got loose more and more during the playing. Or, maybe, because of some kind of noise in the circuits. This episode could be intended as a clue for the embryo of a new model that will be further presented in the next paragraphs: exposed to the same task and activity, robots could act in slightly different ways, because of variations in sets and environments, or because minor instabilities within their system. Furthermore, before the recording started, TeoTronico "warmed up" on the piano, playing the file of "Bohemian Rhapsody" by Queen. The singer was near the robot and kept singing the song along with him, and the result was a jam session warmly appreciated by the people standing in the room, probably because of the funny facial expressions of the robot, which was playing and singing together with the artist, moving its head, mouth, eyes and eyebrows during the performance.

As anticipated, TeoTronico could sing and speak as a simple speaker, with an already recorded audio file playing from a computer, or a microphone connected to it for a live interaction. The movement of its mouth and face could be programmed with a MIDI file, or go random. By the way, the team decided to record TeoTronico in a vocal booth. Its voice had been recorded seven times (verses and refrains), with a different vocoder associated for each recording. Finally, in the control room the one which sounded better in the mix was picked. After the performance, TeoTronico had been interviewed: using its second vocal interaction mode, the one connected to a human (Andrea Messieri) speaking into a microphone, it was possible for the robot to answer the questions.

B. iCub

The robot iCub, shown in figure 2, is a humanoid robot developed by the researchers of the Istituto Italiano di Tecnologia and adopted by more than 40 research laboratories in Europe, USA and Japan. The robot iCub of the IIT laboratories in Genova is the version 1.4, with the following skills: it recognizes and uses objects, it learns to act and interact with people and the environment, he has got the senses of sight, hearing and touch – represented by an artificial skin which covers its body. The iCub has been specifically designed to support research in embodied Artificial Intelligence. At 104 cm tall, the iCub has the size of a five-year-old child. It can crawl on all fours, walk and sit

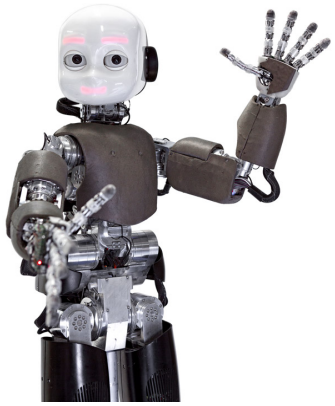

Figure 2. Photo of the robot iCub (retrieved from https://robots.ieee.org/robots/icub/)

up to manipulate objects. Its hands have been designed to support sophisticate manipulation skills. The iCub is distributed as Open Source following the General Public License/Lesser General Public License, and can now count on a worldwide community of enthusiastic developers. The iCub has 53 degrees of freedom with the majority in the upper body and 9 in each hand. The iCub sensors include cameras, microphones, force/torque sensors, a full body skin, gyros and accelerometers and encoders in every joint. The iCub controllers have been designed to be programmable and its software system as a state-of-the-art middleware called YARP.

The recording of iCub's voice took place at the IIT Center for Human Technologies of Genova, on the 5th October 2020. The sound environment around the IIT symbol's voice has been designed using synths and space sounds publicly released by NASA on its own website (Kepler Star, First Likely Marsquake Heard, Jupiter Sounds, Cassini Saturn Radio Emissions etc.). Moreover, the audio track finally published has been mixed binaural (so called "3D audio"). As it had been done with TeoTronico, the desire was to record iCub's voice with microphones, and getting the video of the experiment, instead of having its voice sent by email as a simple file to insert in the mix; although this last process would have been surely faster and easier. iCub has a vocal system different from TeoTronico: the IIT robot speaks with a speech synthesis system. The vocal timber of iCub and its pitch was chosen by the IIT researchers, but it was decided to record also the noise made by the machines used provide energy to it, that, in a sense, represents part of its true sound emission. Anyway, if TeoTronico is a robot made just for entertainment, iCub is a humanoid platform used mainly for research purposes in scientific environments. So, the IIT staff set up iCub standing still on a trailer, with the movements of its mouth, legs and arms, disabled. Even though, factually, only its voice was needed, the experience resulted a little bit cold. So, the researchers in the room were asked to activate iCub's mouth, arms and hands, through strings of programming language, which made easy to ask it to say particular words in real time, making the experience richer and warmer. This episode is also interesting to get

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partial answers to the overarching questions posed throughout the paper: is it possible to hypothesize a new model of relationship with this technology? Which should be its characteristics and shapes? When the robot started to act like a human, it became easier to be involved with it and to collaborate towards the mutual goal.

C. *Other experiment: sound morphing*

The EP "La Sovranità dei Robot" includes a third experiment, which doesn't feature real robots, but it is inspired by fictional robots: in this case, replicants. The hosting song is titled "Westworld", whose lyrics are a reference to the homonymous modern TV series based on Michael Crichton's movie. In quite the same way, the song is enriched with the digital replicas of two human musicians, a woman and a man, playing two acoustic musical instruments. To achieve the expected results, the sound engineers tried to recreate the sound and the touch produced by the musicians. In practice, the musicians were asked to write and record their parts with their instruments and send the scores to the team, to generate Musical Instrument Digital Interface (MIDI) files. Thus, the engineers recreated the two musicians' sound, using virtual instruments and audio editing software, and their "touch", working on dynamics. Finally, they made a morphing of the real registrations and the virtual ones to have "sound replicants" for confusing the listeners' perception.

V. Towards a New Model of Relationship: Human to Artificial

When robots are not considered just instruments to improve the artistic activities, like any other editing software or MIDI execution devices, but they are involved as co-performers or co-artists, they can succeed in creating a relationship with humans that can move beyond the master-slave paradigm: through the explanation of the case studies, we wanted to show that it is already possible to interact in a less detached way with robots and Artificial Intelligence. Collaborating to achieve an objective needs all the actors involved to communicate and to coordinate in the right way, to trust each other, and to act with a mutual approach towards the goals [6]. This, as stated before, can be applied to the reference scenario, especially because in this case the artist and the robot were expected to join forces in order to achieve a shared goal [7]: the creation of a track. So, as these relationships will for sure continue to grow and to be improved exponentially, the interactions between human and robots will have to change: today, the perception of their roles is moving fastly to higher expectations [8].

Despite the always growing numbers of interactions between us and computers and machines, we need to feel and perceive that these interactions are taking place with another individual. This phenomenon is known as social presence [9], and it can be used to introduce the concept of believability [10] as one of the most relevant in this kind of relationships: how much an individual can forget that a robot is artificial and not in possession of typically human abilities. Other authors [11] affirm that to make socially acceptable robots they should have a high level of reliability, simplicity of use, and a human friendly design. So, for sure, if we analyze the relationship in the direction that moves from artificial to human is easy to define its foundations through the merge of the previous characteristics: it can be sum up in the concept of human friendship, conceived as the grade of reliability and believability a robot should have. Higher the grade, deeper the level of the involvement they will achieve, and major the suspension of belief regarding their artificiality will be, while relating with them.

As stated in the introduction, these technologies are going to be even more innovated and implemented, and so their presence and influence in our lives will grow dramatically. What we want to try to highlight with this contribution is the necessity to design a bidirectional relationship with the aforementioned technologies, in order to let everyone be prepared for the upcoming changes that will not only invest the technological fields, but also different areas of human activities. We can adapt to technology and we have done it several times before. Let us think about the evolution of User Interface (UI): we were not used to the gestures (scrolling, swiping, pinching) when they were once introduced in smartphone interfaces, but we have learnt how to use them without even thinking. When the disruptive power of a technology can deeply modify the way we conceive our existences, its development must be also guided by seeking innovative approaches, modalities of use, opportunities for well-being, and not only by the search for progress itself. The period we are experiencing right now is showing us how much we are not aware of their potentialities and of the possibilities they can open up to conceive different aspects of our daily life. So, by taking into account the other direction of the relationship, from human to artificial, and, thus, addressing what we need to do in order to facilitate this new relation, some concepts become fundamental. At first, we must acknowledge the importance of constant updates within the domains regarding technologies, their potential impacts on our life, and the languages they use to communicate. We must not fear them, but always try to convert into opportunities what we first saw as a threat. This should be the approach that guide us in this relationship, because it implies the need for continuative learning and updating regarding technologies. Thus, learning is what become essential and, in first place, comprehending not only what concerns our interactions with technologies, but especially the logic behind them, their history and their influence on culture and other factors that not only interest their technical side [12]. We need to spread model of distributed knowledge in order to accelerate this process. Therefore, creating a rich, diffuse and distributed body of knowledge in regards of robotics and Artificial Intelligence would enable an increasing number of people to interact more smoothly and naturally with these technologies. This would create a mature environment for the implementation of certain innovations, lowering the possibilities for misuse or unjustified fears.

We must understand that we are not dealing just with instruments, but with beings increasingly looking and acting like companions. In a metaphorical perspective, we have to let our counterpart build trust in us. How should we do it? By

implementing and not replacing them, as we do with our household appliances. Again, as stated before, distributed knowledge and Open Source models must be spread in order to let more individuals get to understand how to act with these technologies, repair, update and get used to them.

VI. CONCLUSION

First of all, with this paper and by showing the experiences presented as case study and applied research, we want to stress the importance of creative mindsets and approaches, which can be found in music and song production and composing, towards technology and its possible uses: it is already a powerful and helpful tool for musicians and music producers, but it can become a real companion, someone that should be able to participate in the process of creation, by means of something more than mere instrumental functions. Furthermore, and in the regard of the aforementioned questions, we want to try to understand which elements and features of robots are contributing in the shift regarding their conception from tools to co-actors of creative processes. This passage helped us in defying the initial and possible characteristics of a new model of relationship between human and artificial, which highlights the importance of a biunivocal direction, while keeping in mind the next technology developments and their consequences.

We recognize in design one of the discipline able to further deepen this area of research for its attitude to see technological innovation as a catalyst for other forms of innovation: compared to engineering and hard sciences, design surely lacks the capabilities and the know-how needed to fully grasp every aspects, features and characteristics of technology. Nevertheless, design analyses and uses it guided by needs and aims which differs from the improvement and the innovation of technology itself: directed by this different point of view, it could bring to disruptive and innovative applications, uses, and modalities which, therefore, could shape new relations, mediated by and together with the reference innovations. In this way, an already thriving and established connection between engineering and design disciplines could become one of the most suitable methodology to address the deep changes at various levels, caused by technological innovations.

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On Integrated Models for Coherent Content Management and Document Dissemination

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***Abstract*—Content plays a central role in many information systems and commerce applications. Throughout such systems, content is dealt with in various places: storage, editing and management, quality assurance, transmission, relationship with various data, etc. Typically, software provides according functionalities in a generic way for all content applications, but they each heavily rely on a content model and need to be mapped to content individually. An alternative approach is to instead define all content utilizations in conjunction with the content model so that they are coherent throughout the whole system by design. In this paper, we study such coherent models by considering request-based document transmission that underlies, e.g., the World Wide Web. For these cases, we demonstrate that such a model-based approach is feasible, and that a configuration of generic functionality can be derived from the integrated models.**

***Keywords*—content management; content publishing; content distribution; web publishing; communication protocol.**

I. Introduction

Websites and mobile apps are an important user interface to information sources, and they constitute a means for companies to get in touch with their customers. These applications are based on content that is presented to users in a suitable form.

Contemporary implementations of *Content Management Systems* (*CMSs*), online shops, campaign management solutions, and other content-based systems deal with content in various places: databases, application code, user interfaces, remote calls, URL formatting, HTTP request handling with content lookup and caching, tracking, targeting, campaign management, and many more. Figure 1 gives a rough overview.

Each of the indicated functionalities is related to the underlying content model, and all share a common notion of both this model and all content constellations. Or, viewed the other way round, a content model defines multiple interfaces that are consumed by different audiences, for example in a CMS:

- editors that are guided by the editing tool when entering content into forms, and that are supported during quality assurance of webpages,
- application programmers that customize the CMS (services, editor, search engine),
- application programmers that develop client-side apps (JavaScript apps, mobile apps), and
- template programmers that implement the rendering of content into documents.

In fact, each of the roles uses more than one interface, and all need to agree on the conceptual content model in order to use and serve the interfaces correctly. In particular, content needs to be encoded as data, and data need to be interpreted as content.

Therefore, for coherence in content-based applications, there is a need for central models that are consistently implemented, or schemas and code for such systems are generated from such models.

In this paper, we study the process behind content distribution, typically consisting of requests for documents, the generation of the requested documents from content, and their transmission. To this end, we start in Section II by introducing our basic notions of content, documents, and document delivery. We use the *Minimalistic Meta Modeling Language* (*M³L*) to discuss the integration of transmission protocols into content models. As a foundation, Section III briefly introduces the concepts of the M³L and its application for content management tasks. As part of our experiments, Sections IV and V present models for multilingual websites and for website campaigns, respectively. The paper closes in Section VI with a conclusion and an outlook on future work.

II. Content Management and Delivery

Before discussing content presentation and shipping, we introduce basic content management terms.

A. Content

Content, in the digital domain, means the content of digital publications: (meaningful) texts, images, videos, etc. Typically, the overall set of content is composed of single *content items* that may be structured in themselves. Often, the term *asset* is used for content that cannot be divided further: a smallest text fragment, an image, and similar.

Content management strives to store content in a neutral form that allows a versatile use: in a reusable way, so that content can be combined in more than one way; media-agnostic, so that it can be used for publications on different channels; internationalized, so that it can be applied in multi-language environments; etc.

Typically, other data and information is managed on top of content, e.g., for a website:

- description data and metadata used to manage content
- navigation structures by which content is organized
- redirect rules to direct web accesses in certain cases
- header information of webpages to direct search engines, external caching layers, and other external systems

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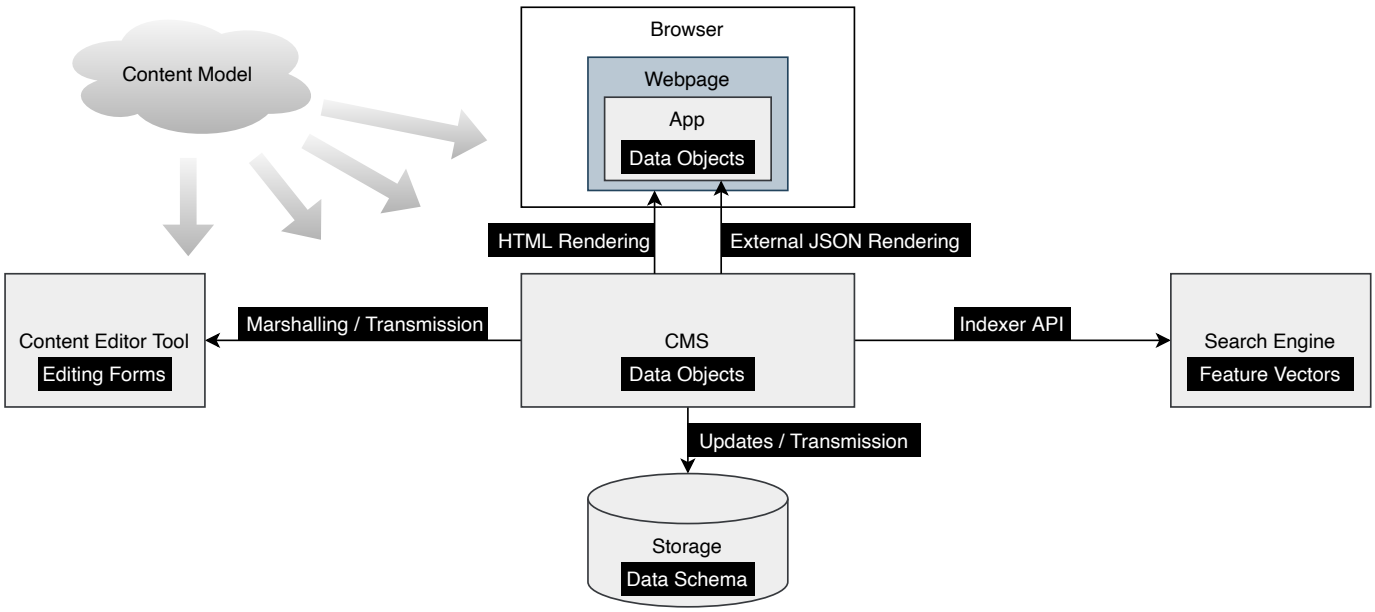

Figure 1. Content model references in a typical content management system.

B. Documents

Documents are presentations of content used for publication. They are created by applying a layout. The process of document creation is called *rendering*. In many cases, it is based on *templates* that implement the layout and declare at which positions in a layout content is filled in.

Documents may be rendered in a uniform way, or they are tailored to the needs of individual users or user groups. The individual preparation of documents is called *personalization* or *targeting*. It is based on content items that are related to certain topics and rules for the selection of items for a document. These are evaluated for a classification of users called user segments [1].

C. Document Transmission

Dependent of the communication channel used, the documents are shipped to users. In the case of the *World Wide Web* (*WWW*), HTTP(S) requests are received, and documents in the form of an HTML resource are sent in response. With so-called headless CMSs becoming popular, content may also be transmitted in the form of a data file, e.g., in JSON format, and be interpreted on client-side.

For personalization, requests need to provide some context information on the user and the environment. This information is used in the rendering process. Examples are:

- language / country / locale for multilingual content
- device or network information for adaptive rendering
- users' interests, active campaigns, or similar for targeting

D. Document Requests and Their Relation to Content

In order to identify a document and to provide context, requests for documents consist of content in themselves. For example, a URL contains a path, query attributes, header attributes, and a request body. Plus, the request's content has a close relationship to the actual content that is queried, very much as in information retrieval [2], or like a correspondence in schema mapping [3]. Typical examples are:

- IDs of content (items)
- content structure paths or navigation contexts of content
- (context) parameters to content (variants)

Because of these associations, there is a close connection to the content model. Consequently, requests and response formats have to be defined in accordance to a content model for coherence. Content-based software has to be developed with respect to the content model in all respects, including document distribution.

Software components can, to a large degree, be generated from such a content model. Typically, functionality is fixed in many components, and code only varies in the way that input and output is mapped to content. This mapping is based on the content model. Previous work proved the feasibility of a generative approach for large-scale applications [4].

III. Content Management by the Example of the Minimalistic Meta Modeling Language (M^3L)

For the discussion in this paper, we use the M³L since it proved to be a suitable language for the modeling of various aspects of content management. To this end, we briefly introduce the M³L, and we present some exemplary base models for content management and for publication on the WWW. These base models will be used for the case studies of multilingual content and of campaigns.

There are many more applications for multi-everything content management: multi-site (different domains operated by a central CMS), multi-brand (different presentations of shared content), personalization [1], and others.

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```
01 Person { Name is a String }
02 PersonMary is a Person {
03  Mary is the Name }
04 PersonPeter is a Person {
05  Peter is the Name
06  42 is the Age }
```

Figure 2. M3L statements.

A. A Short Introduction into the M³L

In this section, we briefly introduce the M³L by highlighting those features that are central to the underlying experiments.

The basic M³L statements are:

- **A**: the declaration of or reference to a *concept* named *A*
- **A** is a **B**: refinement of a concept *B* to a concept *A*; *A* is a *specialization* of *B*, *B* is a *generalization* of *A*
- **A** is a **B** { **C** }: containment of concepts; *C* belongs to the *content* of *A*, *A* is the *context* of *C*
- **A** |= **D**: the *semantic rule* of a concept; whenever *A* is referenced, actually *D* is bound; if *D* does no exist, it is created in the same context as *A*
- **A** |- **E F G.**: the *syntactic rule* of a concept that defines how a string is produced from a concept, resp. how a concept is recognized from a string; when the representation of *A* is requested, it is produced by a concatenation of the strings produced out of *E*, *F*, and *G*; when no syntactic rule is defined, a concept is represented by its name; vice versa, an input that constitutes the name of a concept without a syntactic rule leads to that concept being recognized

If a concept that is referenced by one of the statements exists or if an equivalent concepts exists, then this one is bound. Otherwise, the concept is created as defined by the statement.

Existing concepts can be redefined. For example, with the definitions above, a statement

```
A is an H { C is the I }
```

redefines *A* to have another generalization *H* and *C* (in the context of *A*) to have *I* as its only generalization.

Every context constitutes a *scope*. A redefinition of a concept in a context is only applied in that context. When a redefinition of a concept takes place in another context as the original definition, we call that redefinition a *derivation*.

The concepts that are defined by such statements are *evaluated* when used. Evaluation means looking up or creating concepts and applying semantic rules.

Before a concept is referenced and before a statement is evaluated, all concepts are *narrowed down*. The narrowing of a concept is computed as follows:

1) The effective definition of a concept in some context is the set of all definitions in that context and all of its base contexts (transitive).
2) If a concept *A* has a subconcept *B*, and if all concepts defined in the context of *B* are equally defined in the context of *A*, then each occurrence of *A* is narrowed down to *B*.

Figure 2 shows some examples of M³L statements. Given those sample definitions, the result of an additional statement **Person** { **Peter** is the **Name 42** is the **Age**} is narrowed down to *PersonPeter* since *PersonPeter* is specialization of *Person* and its whole content matches. The statement **Person** { **Mary** is the **Name 42** is the **Age** } is not narrowed down further. It does not match *PersonPeter* since *Name* has a different specialization, and it does not match *PersonMary* since it has no matching content concept called *Age* or *42*.

B. Basic Content Management

The M³L is universal and has many applications. Amongst other modeling tasks, it has proven useful to describe content as characterized in section II-A. This applies both to content models as well as content items since the M³L does not distinguish model layers such as type and instance.

For example, with a content model like:

```
Article is a Content {
 Title is a String
 Text is a FormattedString
 Image is an OpaqueContent }
```

according content can be created:

```
NewsArticle123 is an Article {
 "Breaking News" is the Title
 "This is a report about ..." is the Text
 Asset456 is an Image
 Asset789 is an Image }
```

C. Basic Document Rendering

For textual formats, like for example HTML, documents can be rendered from content through syntactic rules of content as declared in the previous subsection. On the level of the content model, syntactic rules describe document templates, on the content item level they render single document instances.

A sample template for *Article* from the previous subsection is:

```
Article |- <div class=\"article\">
    <div class=\"title\"> Title </div>
     <div class=\"text\"> Text </div>
     <div class=\"image\">
     URL from ImageResource {
      Image is the Content } </div>
    </div> .
```

The syntactic rule defines an HTML structure into which the concepts from the content are integrated. These may themselves evaluate to content strings of embedded HTML structures.

Please note that, e.g., * * is a valid concept name, as is *class=\"article\">*. Since new concepts are declared the first time they are referenced, and because they syntactically evaluate to their name by default, they can be used like string literals. The concept name **\"** is an escape sequence for the quote character (not a quote sign for identifiers).

In this example, *ImageResource* may be a concept of an image resource that has a *URL*.

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```
01 URL { Protocol Host Port Path }
02 |- Protocol :// Host : Port Path .
03 WebPage { Title Content URL }
04 |- <html>
05    <head> <title> Title </title> </head>
06    <body> Content </body> </html> .
07 Cookie {
08  Name is a String
09  Value is a String }
10 |- Cookie: Name = Value
11 Request {
12  URL ProtocolVersion Method
13  Parameters HeaderAttributes
14  Cookies is a Cookie Body }
15 |- Method " " Path from URL " "
16    Protocol from URL / ProtocolVersion
17    \n HeaderAttributes \n Cookies \n \n
18    Body .
19 ResourceResponse is a Response {
20  Protocol ProtocolVersion Cookies
21  Content }
22 |- Protocol / ProtocolVersion " " 200
23    " " OK \n Cookies \n \n Content \n .
24 WebHandle {
25  2 is the ProtocolVersion
26  Request {
27   ...
28  } |= Response {
29   WebPage {
30    URL from Request is the URL
31   } is the Content
32   Cookies from Request is the Cookies }
33 }
```

Figure 3. Basis HTTP concepts in M3L.

D. Basic Document Delivery

To study the interplay of content and document transmission protocols, we also sketch possible models for the latter. In particular, we use a simple subset of HTTP because it is the protocol of the WWW, and it is a text-based protocol with a simple grammar and, therefore, easy to model with the M³L.

Figure 3 shows a set of concepts representing HTTP.

Documents become (web) resources by making them available under a URL. A concept *URL* is modeled in a simplified form after RFC 1738 in lines 1–2. Further concepts may be introduced to configure a *URL*, e.g., **HTTP** is a **Protocol**.

With URLs, webpages may in a very simple form be modeled by the concept *WebPage*. In this example, they just have a page title, the content displayed on a page, and the URL under which to reach the page. In real-world applications, the URL is generated from, e.g., the website's navigation structure instead of being maintained explicitly. This simple form is sufficient for the discussion of this paper, though.

```
01 MultiLingualWebsite is a Website {
02  Language { Code }
03  URL { Code } |- Protocol :// Host :
04                  Port / Code Path .
05  WebHandle {
06   Request |= Response {
07    WebPage {
08     URL from Request is the URL }
09    from Language {
10     Code from URL from Request
11      is the Code }
12    is the Content } }
13 }
```

Figure 4. Basic M³L concepts for multilingual websites.

Requests to a URL are answered by a web server with a response that contains the addressed resource. Such a web server can in essence be modeled by the concept *WebHandle*. It is a base concept to derive web servers from.

For the construct to work, we assume a M³L runtime that accepts input coming from network connections and recognizes it in the context of the *WebHandle* at hand. When the input is recognized as an HTTP request, then a *Request* concept will be constructed from it. Once the *Request* was created, its semantic rule will fire, thus finding or creating a *Response*. In case a web page has been found, this will be a *ResourceResponse*. (We omit all error handling and error responses.)

The response is created with that webpage as content that has the requested URL assigned. This is achieved by the matching in lines 29–31 of Figure 3. Cookies are echoed from the request, so that they are sent back to clients (line 32).

Of course, HTTP contains many more elements. Here we just picked those ones that we need in the course of this paper.

The syntactic rule of *Request* is used to recognize requests, that one of *ResourceResponse* to create the response output. Let the concept $\backslash n$ be defined to syntactically produce a line break in this example.

IV. Multilingual Websites

As the first case for the study of the integration of a content model and a request protocol, we consider a multilingual website. For the purpose of this paper, we only consider localized content; a very basic form of localization [5]. Other kinds of multisite platforms like websites in different countries, for different brands, etc. may be modeled in a similar fashion.

Assume a website with multilingual content and webpages that are requested by URLs that have a language code as their first path segment. This is a typical example of content and access protocol being related: the first path segment of a URL uses a language code that is also used to select a content variant, and the remaining path of a URL identifies the content.

Figure 4 shows base definitions for such kinds of websites. For each multilingual site, a language context is defined based on *Language* in line 2. The language context is identified by a

```
01 ACME.com-Site is a MultiLingualWebsite {
02  WebPage4711 is a WebPage {
03   URL4711 is the URL {
04    ... /bignews is the Path ... }
05   MainArticle is an Article,
06                  the Content {
07    Image789 is the Image }
08  }
09  English is a Language {
10   en is the Code
11   WebPage4711 {
12    "Big News" is the Title
13    MainArticle { "..." is the Text } }
14  }
15  French is a Language {
16   fr is the Code
17   WebPage4711 {
18    "..." is the Title
19    MainArticle { "..." is the Text } }
20  }
21 }
```

Figure 5. A sample multilingual website.

language code, and translated webpages will be defined within a language context.

URLs are redefined for multilingual websites so that they include the language code.

The *WebHandle* is changed for multilingual websites so that it evaluates the language setting in the URL path. It establishes the relation between URLs and content. Requests use the redefined *URL*s that recognize the language code. The *Content* of a *Response* is assigned a webpage that is retrieved from the corresponding language context: the *Content* is assigned the webpage with the matching *URL* (line 8 in Figure 4) resolved relative to the *Language* context with the given *Code* (lines 9-11). The *URL* is matched without considering the *Code* when it is not contained in the *URL*s assigned to webpages.

An example of an application of this base model for multilingual websites is shown in Figure 5. It shows a basic sketch of a website that is available in two languages. One page, *WebPage4711* is defined with its *URL* and an *Article* as its *Content* that contains one (language-independent) image.

In the two language contexts, translated derivations of the webpage are defined. These have translated titles and article texts.

Since the whole website is derived from *MultiLingualWebsite*, URLs with paths */en/bignews* and */fr/bignews* will be recognized and resolved to the two translated webpages.

V. Campaign Management

As part of modern digital marketing, campaigns are used to attract users and to direct their attention to certain parts of the offering. Campaigns originate in many places, also outside a website or even any digital channel. One of their goals may be directing customers to the website, though. In that case, a

```
01 WebsiteWithCampaigns {
02  LandingPage is a WebPage
03  Campaign {
04   Key
05   LandingPage }
06  WebHandle {
07   CampaignRequest is a Request {
08    CampaignKey
09     is the Value from Cookies {
10      campaign is the Name }
11   } |= CampaignResponse {
12         WebPage {
13          URL from Request is the URL }
14         from Campaign {
15          CampaignKey is the Key }
16         is the Content
17         Cookies from CampaignRequest
18          is the Cookies }
19   LandingPageResponse
20    is a CampaignResponse {
21    WebPage is a LandingPage
22    CampaignCookie is a Cookie {
23     campaign is the Name
24     Key from Campaign {
25      WebPage is the LandingPage }
26     is the Value }
27    is a Cookies }
28  }
29 }
```

Figure 6. Basic M³L concepts for website campaigns.

website typically offers touchpoints for campaigns in the form of *landing pages*. Such pages welcome the user to continue the *customer journey* one the website.

When a user enters a website through the landing page of a campaign, then the customer journey continues in the context of that campaign. Assigning the user to a campaign can possibly be used to track the further journey accordingly, to present special offers as part of the campaign, etc.

Tracking campaigns can be based on a key, similar to site languages that have a code in the example in the previous section. In a sample implementation considered in this section, a visit to a landing page leads to a *cookie* with the campaign key being set.

A base model for a site with this behavior is shown in Figure 6. For such a site, campaigns are contexts derived from *Campaign* that have a unique *Key*. In this context, campaign-specific webpages may be defined.

The page variants in the context of the campaign may, e.g., define the page with different content that relates to the campaign. If no derived page is defined in the context of the campaign, the original page from the outer context of the website will be used.

On top of that, each campaign defines a webpage as a *LandingPage*. When a user visits such a landing page, a cookie

```
ACME.com-Site is a WebsiteWithCampaigns{
 Product2Page is a WebPage {
  Product2 is the Title
  Product2Description is a Content }
 BuyAProduct1Campaign is a Campaign {
  BuyAProduct1Campaign is the Key
  BuyAProduct1Page is the LandingPage {
   "Buy More Product1" is the Title }
  Product2Page {
   Product1Teaser is an Article {
    "Buy a Product1" is the Title
    "Go to Product1 page" is the Text
    Product1PreviewImage is the Image }
   is a Content }
 }
}
```

Figure 7. A campaign website example.

with the corresponding campaign key is added to the request. This is performed by a specific web handler.

The web handler for campaign tracking has to deal with two cases:

1) When the user accesses a *LandingPage*, then a cookie that identifies the campaign is set.
2) When a user accesses any other page, then existing campaign cookies are maintained.

This behavior is achieved by narrowing the response that the web handler generates.

For campaigns, we add a derived kind of request that extracts a campaign key (if one exists) from a cookie with the name "campaign". The webpage delivered in the response *CampaignResponse* is the webpage with the requested URL. The lookup of webpages originates in the context of the campaign, though, in order to allow campaign-specific webpages. Cookies, in this case, are just echoed from the request.

Additionally, there is a specialized response for the case that the resulting webpage is a landing page. Through the narrowing of concepts, this derived response is used for landing pages. Other than the *CampaignResponse*, the *LandingPageResponse* sets the cookie *CampaignCookie* for the campaign to which the landing page belongs. This is done by looking up the campaigns that name the webpage as their *LandingPage*. The cookie's name is "campaign", the one which *CampaignRequest*s look for.

Figure 7 shows an example of a campaign tracking website based on *WebsiteWithCampaigns* from Figure 6.

An access to the landing page *BuyAProduct1Page* will lead to the campaign cookie being set. When a user accesses the page *Product2Page* with that cookie being set, then this page will be presented with an additional *Product1Teaser*.

VI. Summary and Outlook

The paper concludes with a summary and an outlook on future work.

A. Summary and Conclusion

Content models, like most data schemas and information models, are of central importance for a software system since many components of the overall system relate to them. In particular, the delivery of content in an interactive, request-based manner relates to to content in various ways through requests, request handling, and the resulting responses.

Using the examples of multilingual and campaign-specific content, we demonstrate that the details of interactions during content transmission can basically be included in content models. In the examples given, this would be the utilization of the users' language preferences and the consideration of customer journeys that relate to a campaign.

We furthermore deduce from the studies presented in this paper, that a content modeling language that has a notion of context eases the implementation of systems from content models since it allows expressing details on content variants and their relationships.

B. Outlook

The examples in this paper have been checked by the M³L environment that evaluates all statements given. For real-world applications, it will most probably be necessary to generate dedicated software components from the content model. This has been studied before for database applications [6] and for *Concept-Oriented Content Management* (*COCoMa*) systems [7]. Future work will investigate how such a software generation approach can be transferred to M³L statements.

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