European industry is strong in the development of complex systems in which innovation is realised primarily through software, such as high-end vehicles and robotics, but the interconnected nature of software-intensive systems is causing software to exponentially grow in complexity. In combination with increasing functional demands, this leads to development time and cost increases. Model-driven engineering aims to counter this with domain-specific abstractions and automation, while modelling tools focus on specific notations (such as text, diagrams, tables or forms) and engineers may have different notation preferences. This limits communication, particularly across disciplines.

BUMBLE has created a different manner of using models, enabling a mixed representation of a single system so that engineers can work in their preferred set-up. Changes made in text, for instance, are automatically reported graphically. This co-evolution of blended models allows for collaborative work on a system while avoiding inconsistencies in the overall model, which is expected to greatly boost the development of complex, multi-domain systems that feature heterogenous components and stakeholder roles. BUMBLE has achieved this via a consortium that involves end-user companies facing complex system design, tool providers that sell licenses for tools used by designers and consultancy companies that can open up new business models in coaching and support services.

**Technology applied**

At the core of its technological innovation, BUMBLE allows for the generation of blended modelling environments from DSML specifications and the generation of mechanisms for on-the-fly synchronisation of notations. The subsequent collaborative blended modelling based on customised multi-representation model versioning and co-evolution of blended models enable seamless, concurrent use of graphical and textual modelling. Another key development is BUMBLE Technology Bricks (BTBs), a toolset for providing continuity between requirements, design and implementation. Technical reporting and reviews are structured according to the BTBs, which cover areas like platform integration and blended model access; different combinations lead to different blended solutions for specific platforms and use-cases and can be used to refine a project’s scope and measure its success in a practical manner.

BUMBLE has also demonstrated these innovations in various domains, highlighting the diverse applicability of the technology. Canon, for instance, has applied BUMBLE’s results to allow engineers with different backgrounds (such as architectural developers with a high-level view and programmers using C code) to collaborate on printer technology development. In civil engineering, meanwhile, Pictor has used the project to add value to blended system modelling via 3D visualisation of DSML for large infrastructure (such as bridges), which experts in different domains can work on and then bring together. These industrial partners have been supported by universities, which pushed forward the research boundaries of the project, and end-user Unibap, which tested the tools in aerospace development. This has allowed BUMBLE to cover the entire range of fundamental to applied research.

**Boosting cross-discipline collaboration with blended modelling**

The ITEA project BUMBLE (Blended Modelling for Enhanced Software and Systems Engineering) has created a system and software development framework based on textual and graphical modelling notations/languages, providing automatic generation and management of fully-fledged blended modelling environments from arbitrary domain-specific modelling languages (DSMLs).
**Major project outcomes**

**Dissemination**
- A tutorial at the 20th International Conference on Software Architecture, 2023

**Exploitation (so far)**
- Technology-agnostic engine for providing a cross-platform and language-independent real-time collaborative capabilities for already existing language and modeling workbenches.
- HoTs for generation of synchronisation / migration transformations.
- DclareForMPS - improved Dclare with BUMBLE functionalities in terms of collaboration features and blending capabilities.

**Standardisation**
- github - open-source software: platform (MPS, Eclipse, EAST-ADL)

**Spin-off**
- Timing & Variability in EATOP EAST-ADL

ITEA is the Eureka R&D&I Cluster on software innovation, enabling a large international community of large industry, SMEs, start-ups, academia and customer organisations, to collaborate in funded projects that turn innovative ideas into new businesses, jobs, economic growth and benefits for society. ITEA is part of the Eureka Clusters Programme (ECP).

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