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Roots of SPAR—Shared Planning and Activity Representation

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Abstract

The Defense Advanced Research Projects Agency (DARPA) and US Air Force Research Laboratory Planning Initiative (ARPI) has initiated a project to draw on the range of previous work in planning and activity ontologies to create a practically useful Shared Planning and Activity Representation (SPAR) for use in technology and applications projects within their communities. This article describes the previous work which has been used to create the initial SPAR representation. Key examples of the work drawn upon are published in this issue. The paper provides a comprehensive bibliography and related world wide web resources for work in the area of plan, process and activity representation. SPAR is now being subjected to refinement during several review cycles by a number of expert and user panels.

1 Aims for SPAR

It is important that information about processes, plans and activities are sharable within and across organisations. Cooperation and coordination of the planning, monitoring and workflows of the organisations can be assisted by having a clear shared model of what comprises plans, processes and activities. The Shared Planning and Activity Representation (SPAR) is intended to contribute to a range of purposes including domain modelling, plan generation, plan analysis, plan case capture, plan communication, behaviour modelling, etc. By having a shared model of what constitutes a plan, process or activity, organisational knowledge can be harnessed and used effectively.

The design of SPAR provides structure where there is a consensus on the key entities and relationships amongst those creating and using planning and activity representations. It specifies the structure to a level of detail judged to relate to the needs of the majority of potential users of the representation. However, planning and activity representations are the subject of active research. Some of the current approaches are conceptually simpler or more uniform than SPAR is intended to be (e.g. using pure logic or all constraint (Joslin, 1996; Tate, 1996a) bases). Even where the structure of SPAR itself is not suitable as a basis for novel research or applications, the intention is that the *semantics* of the SPAR representation should be clearly defined such that it can be translated to alternative representations. This also provides the important capability that SPAR-represented information will be able to be communicated to future representational frameworks as and when those are adopted in a widespread way.

2 Scope

The principal scope of SPAR is to represent past, present and possible future activity and the command, planning and control processes that create and execute plans meant to guide or constrain future activity. It can be used descriptively for past and present activity and prescriptively for possible future activity.

Within the SPAR structure it is possible to specialise the representation through the provision of application, domain or technology specific extensions via Plug-in Ontologies or Grammars with their associated Lexicons of the terms used. This is the level at which current and novel representations of activity and the constraints on activity will be attached. The plug in ontologies or grammars may draw on standard representations being adopted in the AI planning research community such as PDDL (McDermott et al., 1997) or more constrained grammars may be specified for practical use in today's applications.

Where further shared structure can be agreed in future within a sufficiently broad community, it could be included in a future revision of SPAR. Where more limited communities representing vendors, specific sector users or research interest groups agree on a shared representation, it may be possible to create an extension used within that community using a mechanism such as the PIF Partially Shared Views (PSVs) (Lee & Malone, 1990).

Any practical use of a planning and activity representation naturally will relate to more detailed models of the objects involved or the organisational relationships between the people or agents included. It is not intended that SPAR itself prescribes structure for detailed object models or for detailed organisation or agent relationship models. SPAR can co-exist with one or more such models which can therefore be chosen to reflect standards established elsewhere. An example of a detailed object description standard is that established by International Standards Organisation's STEP (ISO, 1995) or EXPRESS (Express, 1995) for product interchange in manufacturing. Examples of organisational and agent relationships models can be found in the Enterprise Models (Fraser & Tate, 1995; Fox et al., 1993) and the ORDIT Organisational Model (Blyth et al., 1993).

SPAR may be expressed or represented in a wide variety of ways. It is intended that reference designs and implementations for a number of those which will be mostly commonly useful will be provided. KIF (Genesereth & Fikes, 1992), CommonKADS Conceptual Modelling Language (Schreiber et al., 1994), Conceptual Graphs (Sowa, 1984), LOOM (Brill, 1993), CDIF (Ernst, 1997) or other representations of SPAR are possible.

3 History

The AI planning community has used explicit domain description languages and plan definitions for more than 25 years (Tate et al., 1990; Allen et al., 1990). As long ago as the late 1960s, work on the STRIPS operator representation of actions (Fikes & Nilsson, 1971) was used to practical effect for planning and control of the SRI Shakey robot. This early application was based upon more theoretical roots in the QA3 theorem prover (Green, 1969) and situation calculus (McCarthy & Hayes, 1969). There is now a wealth of experience of defining plan representations from both theoretical studies and practical planning. In 1992, under the DARPA/Air Force Research Laboratory (Rome) Planning Initiative (ARPI) (Fowler et al., 1995), a number of participants created the KRSL plan language (Lehrer, 1993). Although this has been used for some transfers of information between planning components within the ARPI (in particular an Integrated Feasibility Demonstration called IFD-2 (Burstein et al., 1995)), it has not had the widespread impact desired. Its structure was too rigid and KRSL excluded much that was already being done within AI planning research. However, it did establish a range of entities which needed to be in a plan representation and was an influence on subsequent work.

In 1994, a group was formed to create an ontology for plans, using new insights gained over the last few years in the knowledge-sharing community in the US (Neches et al., 1991; Genesereth & Fikes, 1992; Gruber, 1993) and Europe (Uschold et al., 1998; Breuker & van de Velde, 1994). This led to an outline plan model called KRSL-Plans (Tate, 1996b). However, this work was not brought to a conclusion though it did feed into subsequent work.

Since 1995, there have been a number of initiatives to standardise terminology in the subject area of activities and plans. These include enterprise processes in PIF (the Process Interchange Format (Lee et al., 1996)); workflow (International Workflow Management Coalition (WfMC, 1994)); CASE systems data modelling exchange in CDIF (Ernst, 1997; Navarro, 1996); manufacturing

processes (NIST's Process Specification Language (Schlenoff et al., 1996)); and the Object Model Working Group's CPR (Core Plan Representation—(Pease & Carrico, 1997)). These initiatives have involved academic, government and industry participants.

In the US military planning research community and beyond, there has been work to use verb/noun phrase grammars to represent plan objectives and activities (Valente et al., 1996; Hess, 1996; Kingston et al., 1997; Drabble et al., 1997).

In August 1997, DARPA and the Air Force Research Laboratory (Rome) Programme Managers for ARPI proposed a renewed effort to tap into this accumulated expertise, and to create a shared plan representation suitable for practical use in ARPI and on applied research programmes in their communities. The representation is expected to be considerably more detailed than the more conceptual ontology efforts which have gone before it.

SPAR is drawing on this wide range of previous work (see Figure 1).

Plan ontologies and representations created by participants of ARPI-related projects include:

1. ARPI KRSL 2.0.2 (Lehrer, 1993), as noted above.
2. ARPI KRSL-Plans ontology (Tate, 1996b) as noted above.
3. SRI International ACT language from the Cypress project (Wilkins & Myers, 1995) and SIPE's domain description language (Wilkins, 1988).
4. Edinburgh O-Plan Task Formalism (Tate et al., 1994; Tate, 1995) and the related <I-N-OVA> constraint model of activity (Tate, 1994; Tate, 1996a).
5. CMU OZONE scheduling ontology (Smith & Becker, 1997).
6. CMU Prodigy (Carbonell et al., 1992) work on decisions made in planning.
7. ISTI IDEON Object-Oriented Enterprise Ontology (Madni & Mi, 1997).
8. The Planning Domain Definition Language (PDDL) (McDermott et al., 1997) created by a community of researchers wanting to exchange planning challenge problems. PDDL draws on work on expressive planner operator languages in ADL (Pednault, 1989) and hierarchical task network planning (Erol et al., 1994).
9. Process Interchange Format (PIF) standard being worked on by a number of projects interested in exchanging process information (Lee et al., 1996).
10. USC/ISI work on EXPECT regarding the representation of goals and tasks (Swartout and Gil, 1995), its recent application to structured representations of air campaign objectives (Valente et al., 1996) as well as USC/ISI work on the SENSUS ontology and lexicon (Knight & Luk, 1994).
11. Edinburgh and ISX Corporation work on process models and grammars for describing the actions and products flowing for US Air Campaign Planning (Kingston et al., 1997).

SPAR has drawn on the ontologies created on collaborative projects related to Enterprise Modelling and Integration including:

1. Enterprise Ontology (Edinburgh, Lloyds Register, Logica, IBM UK and Unilever) (Fraser & Tate, 1995; Uschold et al., 1998) and the report of the Enterprise Project workshop on "Content,

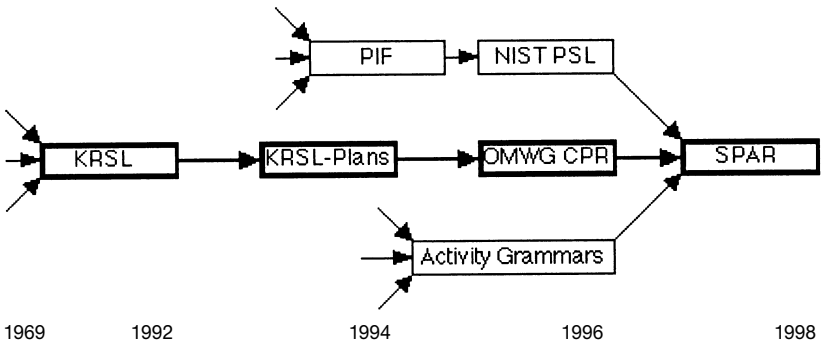

Figure 1 SPAR roots

Form and Methods for Ontologies" in May 1994 (Moralee, 1994). that were provided to the KRSL-Plans, PIF and other communities.
2. TOronto Virtual Enterprise (TOVE) ontology (Fox et al., 1993).

In addition, there is relevant work on Structured Analysis and Design Techniques (e.g. SADT (Marca & McGowan, 1988)), Issue-Based Design Methods (e.g. IBIS (Conklin & Burgess-Yakamovic, 1995)), Process Management Models and Methods (e.g. IDEF (NIST, 1993)), Entity-Relationship Modelling (Chen, 1976), Object-Role Modelling (e.g. Nijssen's Information Analysis Method (NIAM) (Nijssen, 1989)), Process Workflow Support, etc.

Since 1994, work within ARPI on plan representations has proceeded in parallel with pre-standards work on process interchange and representation. ARPI researchers have been involved in these activities, and others have supported the continuing ARPI work—including helping in the development and review of SPAR. The relevant standards activities that have been jointly pursued are:

1. Object Model Working Group (OMWG) Core Plan Representation (CPR) (Pease & Carrico, 1997).
2. National Institute of Standards and Technology (NIST) Process Specification Language (PSL) (Schlenoff et al., 1996).
3. Workflow Management Coalition work in standardising workflow systems and process terminology via their Glossary of Workflow terms (WfMC, 1994) and their interface 1 - the Workflow Process Definition Language (WPDL).
4. CASE Data Interchange Format (CDIF (Ernst, 1997)) group of the Electrical Industries Association who are standardising data model exchanges between CASE systems in a number of areas including the Project Management, Planning and Scheduling Subject Area (Navarro, 1996).

A common model of processes and activity has emerged from this work and has been used as the basis for the initial version of SPAR.

4 Development, refinement and review process

SPAR is being developed in the following way:

1. The SPAR Core Group has merged existing plan ontology work into a solid core representation as a starting point.
2. Via three panels, the Core Group is seeking input to the SPAR work, reviews of the representation proposed, and issues raised by it. The panels are:
   (i) User Requirements Panel.
   (ii) Specialism Experts Panel.
   (iii) Formalization Review Panel.
3. The Core Group will take the lessons learned in (2) to refine (1), and repeat the process.
4. The Core Group and others will communicate the work in progress and then promote the availability of the representation to the potential user, technical and standards communities.
5. The research community will collect experience in the use of SPAR and use lessons learned to refine the representation.
6. The research community will publish a report on the representation and experience gained.

5 SPAR model

A set of statements called the KRSL-Plans description (version dated 20-Sep-96) was used as a starting point for the SPAR model of planning and activity. These were created by the Plan Ontology Construction Group within ARPI. These statements were a refinement of an earlier

version dated 2-Feb-95 (published in Tate (1996b)). The later version of these statements was also used to provide ARPI participants input to the development of OMWG's Core Plan Representation (CPR). (square brackets are used to indicate phases or options that were not fully agreed). The top level statements are:

1. A PLAN is a SPECIFICATION of ACTIVITY to meet one or more OBJECTIVES.
2. A SPECIFICATION of ACTIVITY denotes or describes one or more ACTIVITIES.
3. An ACTIVITY may change the STATES-OF-AFFAIRS.
4. STATES-OF-AFFAIRS is something that can be evaluated as holding or not. [They can refer to an individual world state (such as NOW), or may refer to world histories, changes between world states, etc.]
5. An AGENT can perform ACTIVITIES and/or hold OBJECTIVES.
6. An OBJECTIVE may have one or more EVALUATION-CRITERIA.

Then at a second level of detail, the statements are:

7. An EVALUATION-CRITERIA is an ASPECT of [past, present or possible future] STATES-OF-AFFAIRS or an ASPECT of [one or more] PLANS.
8. An EVALUATION is a predicate (holds/does not hold) or a preference ranking on [one or more] EVALUATION-CRITERIA.
9. An ACTIVITY takes place over a TIME-INTERVAL identified by its two ends, the BEGIN-TIME-POINT and the END-TIME-POINT. The BEGIN-TIME-POINT is temporally before the END-TIME-POINT.
10. An ACTIVITY-SPECIFICATION may have CONSTRAINTS associated with it [and its TIME-INTERVAL].
11. An ACTIVITY-SPECIFICATION may be decomposed into one or more ACTIVITY-DECOMPOSITIONS.
12. ACTIVITY-DECOMPOSITION: The specification of how an ACTIVITY is decomposed into one or more SUB-ACTIVITIES; this may include the specification of constraints on and between the SUB-ACTIVITIES [and their TIME-INTERVALs].
13. SUB-ACTIVITY: Sub-activities are the constituent activities designated in any ACTIVITY-DECOMPOSITION.
14. PRIMITIVE-ACTIVITY is an ACTIVITY with no (further) ACTIVITY-DECOMPOSITION.
15. CONSTRAINTS can be stated with respect to none, one or more than one time point. They express things which are required to hold. They are evaluable with respect to a specific PLAN as holding or not holding. Such constraints may refer to world statements (conditions and effects), resource requirements and usage, authority requirements or provision, etc.

The model is expected to develop from this base.

6 Status

A project has been started within the ARPI community to develop a Shared Planning and Activity Representation (SPAR) for practical use in technology and applications projects within US government research and development communities and beyond.

An initial version of SPAR has been produced utilising the wide range of previous work on plan, process and activity ontologies and representations. This is being subjected to review and refinement through a number of Request For Comment documents involving technical specialists and application-oriented user panels. Following these reviews, the intention is to publish a first version in mid-1998 and then to collect experience in the application of the representation.

It is intended that a process for sharing experiences of using SPAR will be established and continuing design issues tracked. A collected volume of papers describing SPAR and relating experience in using, adapting or extending the representation is planned in the medium term.

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