I have carefully examined the dissertation of Mgr. Filip Dvořák. The thesis makes several smaller technical contributions, as well as a larger engineering contribution. The smaller technical contributions include:

1. In Section 1.5, the thesis describes a new technique for automatically reformulating domains described using a propositional representation into a variable/value representation. The experiments conducted in this section indicate that the resulting domain models perform significantly better than those generated by previous techniques on current state of the art planning systems. What is most surprising about this technique is that the computational overhead appears to be quite acceptable for a technique that is applied on an individual problem basis (rather than once for the entire domain). What is also surprising about this technique is that it is sometimes able to improve the encoding of domains already expressed in a variable/value representation.

2. In Section 2.4, the thesis shows experiments comparing two algorithms for incremental update of Simple Temporal Networks (STNs). The algorithms themselves, Incremental Full Path Consistency (IFPC) and Incremental Bellman-Ford Propagation (IBFP), are both known. However, to my knowledge there has not been a comparison of the performance of these two algorithms on a set of problems characteristic of the STNs generated by planning systems. This is an important comparison, and clearly shows the advantages of IBFP on the kinds of sparse networks often generated by planning systems.

3. In Section 5.1.1, the thesis shows experiments demonstrating how the lifted planning representation can scale much better for domains with a large number of objects. Current high performance planning systems use a
grounded state-space representation. While this has enabled the development of very effective search heuristics, this approach becomes impractical for large domains, such as those often found in real-world planning problems. The experiments in this section clearly illustrate this tradeoff.

The larger contribution of the thesis is the engineering development of the FAPE planning, scheduling, and acting system, now being used and extended at LAAS. FAPE is the first planning system that supports the majority of features in the ANML planning language (developed at NASA in 2008). Unlike the PDDL language used in current planning competitions, ANML is a much richer language that allows concise representation of temporal activities and relationships, numeric resources, and task decompositions (HTNs). As a result, it is a significant engineering task to build such a planner, since it involves the integration of classical planning techniques with techniques for handling temporal constraints, techniques for resource reasoning, and techniques for task decomposition. Despite early interest in the ANML language, it has taken 6 years for someone to develop such a planner, which is perhaps some indication of the amount of effort and integration involved.

I would be remiss if I did not also comment on what I regard as a few of the weaknesses in the dissertation:

1. Reformulation: the reformulation technique described in Section 1.5 was developed and demonstrated for only classical (non-temporal) planning domains. It is not immediately clear how the \( h^2 \) computation would be done for temporal planning, and therefore whether this technique extends effectively to temporal planning. As a result, the connection between this work, and the rest of the thesis is not as strong as it could be.

2. Events: In Section 4.1.7 the thesis introduces a top level action, Seed, and an action DeusExMachina. In ANML, one can specify

\[
\text{[all] contains \{task1, task2 \ldots\}}
\]

as a goal to force actions or HTN tasks into the plan, so the motivation for introducing Seed is not clear.

In ANML, one can also express top level statements like

\[
\text{[0,7) daylight := false;}
\]
\[
\text{[7,20) daylight := true;}
\]
\[
\text{[20] daylight := false;}
\]

that capture facts that become true at various times as a result of exogenous events. As a result, the motivation for DeusExMachina is not at all clear. It’s true that ANML does not yet have a general capability for describing...
exogenous events. However, it would seem much more natural and general to do this by introducing a general event construction similar to an action, and then specifying times at which specific events occur, e.g:

```
[7, 9] contains MeteorImpact(Smallville);

event MeteorImpact (location l) {
    duration := 2;
    [all] {life(l) :- false;}
    crater(l) :- true;
    dustcloud(l) :- true ;
}
```

3. Plan repair: Efficiency is often not the only consideration in plan repair – in many cases an agent may have made commitments in the original plan that need to be respected in replanning. For example, if the original plan is to deliver a sample canister to another robot at a particular time, breaking that commitment involves additional communication and cost. See Cushing & Kambhampati, ICAPS-05 for a more general theory of plan repair.

4. Evaluation of FAPE: since there are no other planners capable of handling the full range of ANML features, direct comparison of FAPE with other ANML planners is not possible. Section 5 does contain a number of more targeted experiments and evaluations, some more convincing than others. However, it would be possible to take temporal-numeric domains from past planning competitions, scale them up, and show how FAPE performs on those domains in comparison to existing metric temporal planners. You could then show the advantages of the metric and temporal capabilities of FAPE as the number of time constraints increases, and as the complexity of the resource reasoning increased.

5. English: I am generally sympathetic to the difficulties of writing in another language. However, there are a very large number of grammatical errors in the thesis – I estimate over 1000. I am sending a marked up copy of the dissertation. A bit more attention to this is in order.

Despite these shortcomings, overall I believe that the thesis 1) represents significant original technical work appropriate for a PhD dissertation, and 2) demonstrates the author’s ability to independently conduct creative and worthwhile scientific research.

Here are some possible technical questions that I might ask if present at the defense:

1. Reformulation – Is it possible to extend the reformulation technique described in Section 1.5 to temporal planning, and if so, how?
2. Resource types – In ANML, we deliberately avoided introducing resource types such as consumable, producable, and reusable. Whether or not a resource falls into any particular category is dependent on the effects of the actions, and on which actions are actually needed in the solution of any particular problem. Information about how a resource is used for a particular problem can be automatically derived from the action models in the domain, and further refined by simple reachability and relevance analysis for a given problem. What advantage are you claiming for the introduction of these additional constructs into the language.

3. Lifting – You chose to use a lifted representation in the design of FAPE. However, as we know, it’s much easier to develop strong heuristic guidance for a grounded representation. Is it possible to partially ground a domain – that is, ground those types having only a few members, while leaving those types with many members lifted. Could this result in more effective heuristic guidance?

4. STNs – In an addendum to their AAAI-93 paper, Peot & Smith describe the DMIN strategy, which delays resolving threats (like DUNF) but keeps a “witness” solution to ensure that the threats can actually be resolved. This idea can be generalized: given a general set of temporal constraints, we can solve the scheduling problem to get an STN. That solution serves as a “witness” that the constraints have a solution. When new temporal constraints are added, we first need to check to see if the existing witness can be extended to incorporate the new constraints. If so, no additional work is necessary. If not, the augmented set of temporal constraints must be solved again to get a new witness. If it cannot be solved, backtracking is required. Please compare and contrast this possibility with your approach where copies of the STN are kept for purposes of backtracking.

If you have further questions, or if I can be of any further assistance in your evaluation, please do not hesitate to contact me.

Sincerely,

David E. Smith

http://ti.arc.nasa.gov/people/de2smith/