Flexecution as a Paradigm for Replanning, Part 1

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This is the first of two essays about planning and execution with ill-defined and conflicting goals. The concept of flexecution—flexible execution—goes beyond simply adapting a plan as needed in order to reach our goals.

Rather, flexecution entails changing the goals themselves based on discoveries made during execution. In pursuing ill-defined goals, we must expect to revise and even replace the goals we initially stated during the planning phase.

One of my objectives in writing these essays is to describe the importance of goal discovery to planners and project managers who might not appreciate the difficulties posed by ill-defined goals. A second objective is to offer suggestions to computer scientists who design mixed-initiative systems about how to better support planning and execution with ill-defined goals.

We’ll begin with the notion of planning to set the stage for comparing planning using clear goals versus planning and execution using emergent goals.

Planning

Plans are prescriptions or roadmaps for procedures that can be followed to reach some goal, with perhaps some modification based on monitoring outcomes. Planning is generally considered the process of choosing and organizing courses of action on the basis of assumptions about what will happen in the future.\(^1\) Plans describe contingencies and interdependencies such as actions that must occur first as a precondition for later actions.

The more clear and detailed your goals, the easier it is to construct a plan, prepare a timeline, and gauge progress. Clear goals can be sufficiently specified to enable planners to identify tasks that, if followed, will reach the intended goal. A plan specifies a set of actions with which you intend to transform a current situation into a goal state. This type of planning is essentially problem solving—finding a way to take some actions that will result in the transformation, as represented in figure 1a.

Planning-as-problem-solving generally relies on a set of well-understood representations and mechanisms, such as planning graphs, task networks, search in a state space, chaining, type hierarchies, and constraints on variables.\(^2\)\(^-\)\(^4\)

These mechanisms and approaches seem to run into difficulty when faced with the intractability of large, messy, real-world problems. For such planning problems, the state spaces aren’t completely predefined, and planning requires human decision making based on knowledge and sensitivity to context.\(^5\)\(^-\)\(^7\)

The field of intelligent planning systems has reached into new areas in recent decades, such as distributed planning and continuous planning\(^8\) and mixed-initiative planning or “planning assistants.”\(^9\) My proposal is consistent with these developments, especially the notion of planning as a dialogue among human and machine agents.\(^10\)

Ill-defined goals and wicked problems

The challenge of ill-defined goals arises when many or most of the goals’ features can’t be specified in advance, as illustrated in figure 1b. Herbert Simon and other researchers have written about the differences between well-structured and ill-structured problems.\(^11\) Here, I focus on the clarity of goals, which is just one dimension of the problem structure.

We can represent well-defined goals using problem spaces\(^11\)\(^-\)\(^12\) and solve them by engaging in a systematic problem-solving process. (We use such mechanisms as hierarchical networks, constraint satisfaction, and analysis of state changes in a problem space.) Although a goal can
seem ill defined for a novice but well defined for someone who is proficient and appreciates what must be achieved;\textsuperscript{11} the criterion for a well-defined goal is generally that experienced judges agree on what counts as the goal’s accomplishment. For a well-defined goal such as solving an arithmetic problem, people who are competent in the domain will generally agree about the answer. But experienced judges usually don’t agree about what constitutes a good answer to satisfy an ill-defined goal. Commonly cited examples of ill-defined goals include writing a good essay and creating a good product design. Even if we provide clear criteria for scoring an essay, different instructors might disagree about the relative merits of various samples. A more recent example is the goal of creating democracy in Iraq.

To describe the challenges that ill-defined goals pose to social planning, Horst Rittel and Melvin Webber introduced the concept of wicked problems,\textsuperscript{13,14} which are ill-defined goals marked by incomplete, changing, and sometimes contradictory goal features. Attempts to solve wicked problems often lead to a new and deeper understanding of the problem rather than to a solution.

How can we plan when we’re faced with ill-defined, shifting goals? AI efforts at intelligent planning have taken planning as the primary function when the more frequent case is replanning. Abundant evidence for this appears as frequently cited quotations, such as “The best laid plans often go awry” and “No plan survives first contact with the enemy.”

A functionalist view: Plans as a resource for replanning

Planners can accomplish many things when they’re given clear goals. Their job becomes more difficult when they have to work with ill-defined goals. They must make the ill-defined goals more specific, changing the goals that they started with and modifying the plan. However, this is a weak form of replanning. In many cases, no amount of prior deliberation will yield the clear goals needed to make systematic plans. The goals emerge in the process of execution, through learning. People don’t just refine their goals while they’re executing their plans. By putting a plan into effect, people can make observations, see problems they hadn’t anticipated, diagnose the reasons for those problems, and learn more about their needs. By studying ways to make things happen, people discover interdependencies, relationships, and bottlenecks. Of all the real functions of planning, this one might be the most important: Plans are a vehicle for learning.

The planning and execution-tracking techniques and procedures that have been developed for well-defined goals\textsuperscript{1} might not apply for ill-defined and emergent goals. Worse, they might interfere with the activities in which people and teams engage when they’re actually planning and replanning. If we adopt the plan-then-execute model in designing software tools, we then have to add on some modification mechanisms, ultimately creating tools that impose on human activity a planning description that assumes well-defined search spaces and goals.

The human-centered approach begins instead with empirical studies of real-world planning activities, and it develops from there. Replanning for emergent goals is by far the predominant activity, especially in complex sociotechnical contexts.\textsuperscript{15} Furthermore, planning is not a one-off activity but a process in which resources are managed and priorities are adjusted:

The research strategy in cognitive science has been to represent … goals or plans then stipulate the procedures by which those constructs are realized as action. … The specification of procedures for action, in turn, has presupposed enumeration of the conditions under which a given action is appropriate. … In contrast to this view … [is] an alternative drawn from recent developments in the social sciences. … For situated action, the vagueness of plans is not a fault but is ideally suited to the fact that the detail of intent and action must be contingent on the circumstantial and interactional particulars of actual situations. … The foundation of actions is not plans, but local interactions. … The function of abstract representations is not to serve as specifica-

Planning, as we ordinarily conceive it, is really a supporting function for replanning. From the functionalist viewpoint, replanning doesn’t piggyback on planning, nor is it merely the creation of better plans from simple plans or some other form of iterative repair. Rather, planning is the prolegomenon to replanning. This is a different view compared to any approach that takes planning as the primary process and piggybacks onto it some mechanisms to support plan modification.

Recently in AI, there’s been some interest in rethinking the nature of a goal as defined in the traditional planning literature. Michael Cox and Chen Zhang proposed regarding goals as mutable (as they appear to be in actual human problem solving): “Planning is a context-dependent task of discovering, managing, and refining what one actually wants.”\textsuperscript{16} Moreover, they treated planning as “moving goals through a hyperspace in order to reach equilibrium between available resources and the constraints of a dynamic environment.” In the goal-manipulation approach, adequacy or optimality is based on achieving equilibrium of constraints or predefined dimensions. I propose to take these ideas a step further—to regard goal manipulation as more than resource allocation and optimization and to embrace planning situations in which goals can be emergent and even in conflict.

The actual function of plans isn’t to serve as roadmaps for solving problems. Rather, plans enable us to:

• muster resources;
• begin coordination processes and sometimes reduce coordination costs (because, at least at the outset, all the team members know what they have to do and how their actions might affect others);
• assign responsibility and accountability;
• track progress and, more important, generate expectations and know when to be surprised;
• identify and manage risks;
• support (even define) improvisation; and
• most important, shape how people think about the problem the plan is addressing.

As a consequence of these combined func-
tions of plans, plans are essentially resources for learning and replanning.

Coping with ill-defined and emergent goals

Ill-defined goals are expressed in general, abstract terms that don’t fit into operational definitions or objective measures and that hinge on human judgment and evaluation. This entails one sense of emergence—to clarify and revise. This occurs when we find ourselves pursuing goals that we don’t fully understand and therefore can’t clearly state at the outset. We must refine goal statements when we don’t understand their properties or implications at the outset, when we have to wrestle with conflicting goals, or when we aren’t sure which goal will be appropriate in a yet-to-occur situation. The parallel of this in the literature on wicked problems is the argument that an attempt to solve wicked problems often leads to a new and deeper understanding of the problem.

Military commanders often get directed to perform missions that are ill defined in this sense. In Operation Iraqi Freedom, US General Tommy Franks was given the mission to free Iraq. What did this mean? Did he succeed when his campaign defeated the conventional Iraqi forces? Did the plan succeed when Saddam Hussein was captured and his sons killed? Did the plan succeed when the Iraqis held their first free election two years later? At the time of this writing, maintaining civil order in Iraq is still an elusive goal. What does it mean to “free Iraq”?

A stronger sense of emergence occurs when we must discover and even replace goals while trying to achieve them, as figure 1b shows. Goals can be dynamic and can change completely as a function of changing circumstances. Goals can conflict with other goals in ways we can’t anticipate or resolve in advance. Goals can carry implications we can’t perceive or anticipate until events transpire.

Here’s a case in point. Following the Sumatra earthquake and tsunami on 26 December 2004, the Singapore Armed Forces ordered one of its ships to Indonesia to provide humanitarian assistance and disaster relief, advance diplomacy, and increase the Singapore government’s credibility. All of these are ill-defined goals. I had the opportunity to interview the ship captain. He’d been a military attaché in Jakarta so he had networks to draw on, but he was bracing himself for the unpleasant task of removing dead bodies, preparing mass graves, providing food and medical aid, and clearing debris. He wanted to avoid handling dead bodies because of the psychological stress on his crew and because of the risk of violating religious and cultural requirements.

Fortunately, upon arrival in Indonesia he found that enough resources were present to care for the corpses but that the country had a critical need to open up lines of access so that supplies could be brought in from the sea and air. This was a mission that his crew could perform—building helicopter landing pads, helping to coordinate needs and supplies, and providing an information interface between Indonesia and the rest of the world. It also satisfied the general guidance his superiors in Singapore had given him. Even though the guidance was vague and ill defined, the captain succeeded by discovering a way to satisfy a refined restatement of the initial goals as the mission unfolded.

Corporate executives encounter emergent goals when they try to define new products, prepare incentive plans, or change their company’s direction. Henry Mintzberg has shown how planning on the basis of ill-defined goals can result in strategic business failures. Attempts to define goals in advance are usually unsuccessful because conditions change, sometimes suddenly. Also, corporate goals set the stage for unanticipated goal conflicts because there are compromises among different constituencies that continue to lobby for their own interests even after a program gets under way.

Physicians sometimes wrestle with conflicting goals such as reducing a patient’s suffering versus promoting long-term health. Even firefighters must handle emergent goals in the sense of managing goal conflicts but also revising goals depending on the progress they make. Even firefighters must handle emergent goals in the sense of managing goal conflicts but also revising goals depending on the degree of progress they make. Firefighters facing a conflagration must use their experience to decide whether to call in a second and third alarm or just let the building burn down and prevent the fire from spreading. It depends on the likelihood of success, the risk to neighboring buildings, the nature of the fire, and the value of the building itself. There aren’t singular, simple, right answers.

Here’s a case study of a failure to take emergent, ill-defined goals into account. Software developers have to cope with emergent goals when they make planning decisions such as what features to include in the next system’s release. To help with this challenge of “creeping requirements,” Pär Carlshamre built a planning aid that balanced the costs of the new features with their value to the client. But the simple trade-offs that he built into his planning aid didn’t work—software developers rejected the system. They weren’t just trading off costs and benefits. Most top-priority requirements depended on lower-priority features. For instance, a given software requirement might depend on an employee who was going on maternity leave, so the feature had to be delayed until the following version. Carlshamre tried to take interdependencies into account, but his system was still too simplistic. The concept of “value to the client” combined

- strategic business value for the customer,
- long- and short-term value for a range of consumers with differing importance in different markets,
- compliance with laws and regulations,
- compatibility with new computing platforms, and
- internal cost savings.

In estimating the resource demands for a new feature, the developers considered factors such as individual employees’ workload and vacation schedules and their company’s recruitment plans.

Carlshamre’s system required users to assign values to the proposed requirements, values that were essentially arbitrary and unconvincing. The criteria couldn’t be defined in advance because many essential parameters are never quantified. The developers were always discovering properties as they planned—some criteria were only realized after solutions were presented.
And as they worked, the developers were continually gaining new insights about interdependencies. Carlshamre concluded that this simple trade-off—calculating a feature’s value against the resource required to field it—was actually the type of “wicked” problem described by Rittel and Webber: there’s no optimal solution (only ones that are better or worse) and no stopping rule. Planning ceases when the group runs out of time, money, or patience.

Coping with goal conflicts

Even when we’re given a well-defined goal, we aren’t home free. The reason is that we rarely if ever have to achieve only a single goal. We usually work with a set of goals, as well as general values that serve as goals. And any time we have more than one goal, we have the potential for goal conflict.

Consider two simple rules of engagement for a young police officer:

- Don’t fire at anyone unless that person first threatens you.
- Don’t inflict casualties on civilians.

Both of these are moderately clear. But what happens if an adversary takes a civilian hostage and opens fire? Is firing back permissible? Now the problem has gotten more difficult. The rules of engagement that seemed so clear are no longer straightforward. The concept of commander’s intent used by military planners is similarly an oversimplification.

Consider an exercise in which a manager is heading out to a meeting with a customer who hadn’t been paying his bills. The manager’s supervisor advised him to be firm and resolve the matter quickly. Neither directive by itself creates confusion, but together they result in ambiguity. What should the manager do if the customer offers partial payment immediately, or full payment in two years? The trade-offs between the goals is what creates confusion. Trade-off confusion unravels neat goal hierarchies. In learning about emergent goals, we must also learn how to trade off various levels of achievement for sets of goals.

Solving wicked problems

Ill-defined goals are clarified as the actions taken to achieve them fall short. People discover and define goals during the attempt to reach them. The nature of such problem solving is to simultaneously pursue the goal and define it. The frustrations and failures help us identify the real goals. The redefinition lets us formulate a better approach. Problem solvers often understand a goal just as they’re reaching it. As Carlshamre stated, “To define the problem is the same as defining the solution.” The most important clarification comes when we discover a better way to think about the goal and reframe the way we make sense of our efforts. We learn a great deal by experiencing failures and diagnosing what went wrong.

For example, one software developer decided to focus on decreasing users’ syntax errors. While trying to achieve this goal, the developer realized that many of the errors occurred because the system didn’t provide useful syntax. So, the goal for the next release shifted to creating a usable syntactical structure.

Our language distinguishes between planning and execution, but this distinction fails us during complex operations. Emergent goals don’t fit into a distinction between planning (formulating the actions) and execution (carrying out the plan). It’s tempting to say that we should just talk about replanning and drop the distinction between planning and execution, but people can do a lot of planning without ever executing the plans. Planning by itself usually won’t transform ill-defined goals into clear ones. Goal clarification emerges during execution. Certainly planning up front is useful because it lets us begin to learn about the situation. But once execution begins, we need to use what we are learning to replan.

Certainly planning up front is useful because it lets us begin to learn about the situation. But once execution begins, we need to use what we are learning to replan.

Flexecution captures this broader concept. During flexecution, we’re simultaneously trying to achieve goals and to discover, clarify, and define them. The process of flexecution is at the heart of being adaptable and resilient. The reason for introducing this new term here is to break the mindset of locking on to achieve a given goal without trying to learn more about the situation and diagnose reasons for difficulty in case the goal must be modified or replaced.

In the next issue, I’ll describe flexecution in some detail and suggest strategies for supporting it.

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