Actions and Movements

David Israel
Artificial Intelligence Center
SRI International

John Perry
Philosophy Department,
Stanford University

Syun Tutiya
Philosophy Department
Chiba University

Abstract

We present an account of action whose main features are that actions are content, properties that agents have in virtue of *(i)* the bodily movements they effect and *(ii)* the wider circumstances in which those movements are effected. 'The account includes definitions of one action being *a way oj* doing another, and of performing one action *by* performing another. Although this account is intended to form part of a theory of intelligent action, including the deliberate and intentional actions of human agents or of autonomous robots, in this paper we abstract from the information processing and cognitive factors involved in such actions.

1 Introduction

Action is the goal of planning, for planning is reasoning about what actions to perform, given certain circumstances, in order to achieve a goal. Most actions, perhaps all, involve movements of an agents body, or more generally of its movable parts. What is the relationship between actions and movements[7] Are actions movements that are caused in a special way, for example by way of certain aspects of the mental states of their agents— their beliefs, desires, and intentions? This seems wrong, for our notions of actions involve much more than mere bodily movements, however caused. Consider a simple example: moving a block from one location to another. First,, we must determine whether we are thinking of one nonrepeatable particular or of the repeatable kind of action: moving a block from one location to another. If the latter, if is clear that different kinds of bodily movement might be involved. Moving a block from one place to another may be a kind of action, but it is not one kind of movement. Moreover, whether we have in mind a single nonrepeatable event or a repeatable kind, it is

also clear that moving a block requires more than a bodily movement, however caused. It also requires a block, and (roughly) a path through which the block can be moved. The action of moving a block cannot be characterized solely in terms of the bodily movements of agents that perform the action; on the other hand, bodily movements can be characterized independently of the actions those movements are associated with when performed in given circumstances.

What is the relationship between actions and movements[7] On our theory, actions are not special kinds of movements, but *content properties oj agents* that agents have in virtue of performing those movements in certain circumstances. We proceed to explain this idea and to show how a theory based on it can be used to develop accounts of relationships between actions that are central to a theory of intelligent action

It will be useful to begin by examining a report of an action. In the course of this brief examination, we shall introduce much of our theoretical vocabulary, and some of our theory.

Consider:

(1) John turned on the light.

We take (1) to describe an *act* an unrepeatable event in the past. *Actions,* on the other hand, are temporal properties of individuals (agents), in the sense of being predicable of an individual at a time. Turning on a light, is an action, as is turning on some particular light 1. Various people at various times have had the property of turning on a light; the same is true or could be true for the property of turning on 1. The act described by (1) is a movement of John's that has the property of resulting in Is being turned on. Thus actions are not kinds of acts, but properties of individuals at times.

(1) does not mention movements, nor use the term "result". But there are movements and results involved in John's action, in his having the property of turning on the light then, and we think these movements and results are the keys to developing a theory of movements, actions and the relations among them. When John turned on the light a complex movement of his body occurred. His elbow straightened somewhat,; his upper arm rotated forward and upward at the shoulder. His right, index finger bent somewhat while the other fingers of his right hand were bent more into a fist (keeping them out of the

way), and his body remained stable and his feet station- ary. Given his position in front of the light switch, the movement, resulted in the switch being flipped to the *on* position, the appropriate circuit closing, and the light going on. John's turning on the light thus consisted in his *effecting* a movement which, given the circumstances of the movement, had certain results.

Actions are grounded in movements. Most of the things we do, we do by producing effects on the objects around us by moving our bodies.[1] We plan what, to do in accord with what we know about relations among ac- tions. Intentional action requires *executing* various types of movements, with knowledge of which effects they will have. Which effects are produced is not merely a mat- ter of which types of movements are executed, how- ever. They also depend on the circumstances in which the movement, occurs; not only the. immediate circum- stances, but ones that are quite remote. In the example above these would include, for example, the continued operation of the electrical generating plant that, supplied the lights with power. The type of movement John exe cuted will turn on a light in circumstances like the ones he was in—which light depending on which light is con- nected to the switch he is standing in front of; in other circumstances it might, result in someone being tweaked on the snout., or someone being insulted, or a circus dog being commanded to do a somersault.

Reasoning about action, either in planning/practical reasoning or in plan recognition, must ultimately be grounded in reasoning about movements. In designing robots able to act effectively in a wide variety of environ meuts, we must keep in mind that the tilings the robot can directly control are the movements of its own effec- tors; to know how to do things in any of a wide variety of circumstances is to know how to move one's body ap- propriately in those circumstances. For any intelligent agent, there will be a repertoire of types of movements that meet two conditions:

(A) The agent can produce movements of these types in a very barge range of circumstances.

(H) The agent knows what effects movements of these types will have in (at least, some of) the types of circumstances it, encounters.

That, is, an intelligent agent must, grasp at least part of the causal role of the movements it can produce in the environments in which it is likely to find itself. It must associate with the movement types a pattern or rela- tion between types of environments and the effects move- ments of that, type will have in these environments. We call these relationships the *meanings* of types of move- ments.

The term "meaning" suggests the perspective that un- derlies our approach. We regard movements as having propositional contents, and in this regard there is a struc- tural similarity to utterances. The propositional con-

tent of an utterance what, is expressed—depends on the type of sentence used and the context and wider circum- stances in which it occurs. The propositional content of a movement what it results in—depends on the type of movement and the context and wider circumstances in which it, occurs. The term "meaning" has been used for the relation between circumstances and propositional content associated with sentences. Here we extend it to types of movement and types of result.[2]

Our account is based on a good deal of oversimplifica- tion and streamlining, both with respect to agents and the language we use to describe thern, and our goals are strictly limited. We assume that the agents in question can be viewed as systems with a set of effectors related by an architecture; the types of movement, of the whole system are systematically determined by the types of movements available to the effectors and the architec- ture. These agents *effect* movements; movements are concrete, unrepeatable particulars that belong to vari- ous *types* Acts, then, are movements effected by agents. An agent who effects a movement of a given type is said to *execute* that type. Such *executions,* which play the role of basic actions in our theory, constitute our first category of actions.

When an agent effects a movement, of a given type in certain definite circumstances, that, movement will have various results, propositions made true by the effects of the movement. We say that the agent, *beings about* these results. This is our second category of actions, which we call *accomplishments.*[3] We consider only these two categories of actions in this paper and focus most of our attention on accomplishments.

Actions are mainly of interest t.o people insofar as they are done purposively, intentionally, vindictively, and the like. The part, of our theory that we present here does not touch any of these interesting features of action. The only reason it doesn't apply to a tree falling as well as to a man shooting is that the former is not an act: frees don't *effect* movements; they just. move. Nothing in our theory explains the difference between acts and other movements.

Before we can develop an account of the meanings of movements, we *need* to develop some ideas about move- ments themselves. We turn to this in the next section, and to the meanings of movements in §3. In §4, we introduce actions and focus especially on those actions (accomplishments) that can be characterized in terms of the result brought about We also define certain centred relations involving actions and movements. In §5, we briefly discuss related work and the last section contains some conclusions and a preview of further research.

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[1] We do not here address the issue of purely mental actions. In the interests of simplicity, we shall be dealing only with the kinematics of movenients, abstracting completely from considerations of masses and forces. Finally, we shall not consider actions of maintenance and/or prevention.

[2] We do not assume, however, that an act has a unique content. In [Israel and Perry, 1989, Israel and Perry, 199I], we develop a notion of content that allows an event (act, utterance, etc.) to have multiple contents.

[3] The result that is brought about need not be intended; we are using the term "accomplishment" in what might be called its wry sense, according to which one could focus on a quite unintended result, of someone's endeavors, and say, "That's quite an accomplishment".

2 Movements

We take movements to be concrete particulars. They belong to various types, and are effected by agents at particular times, in particular places, and in specific circumstances. The results of a movement depend on the type of movement- effected, the agent, time, place and circumstances. Our example focuses on a a certain coordinated movement of arm, hand and finger that, we call shall "flicking". As we have noted, the same type of movement can be used to do different things by different agents, in different circumstances, at different times. Thus it is natural to associate relations between circumstances and results with types of movements. We call these relations the *meanings* of the movement types.

The movement types with which we associate mean nigs involve the whole body and all its effectors. Con sider again John s flicking in the immediate neighborhood of the light, switch. When we said that that type of action in that, circumstance would have- as a result that the light gets turned on, we didift really just imagine John flicking. We imagined him Nicking while standing still. If he had moved his feet so as to take a full step backward, while his right, arm went forwards and upwards, he would not have turned the light on, but would merely have pawed the air ineffectually If he had moved his feet so as to take a full step forward, he would not have turned the light on, but merely have hanged his knuckle against the wall.

When a person flicks, his arm and hand move as a part of an ensemble of movements and non-movements of other bodily parts. The movements that we deal with m this essay are complex movements of the whole body People often think of partial movements (and movement types), and 'flicking' can be thought of as a label for such a partial type. In so thinking, they are focusing on a (perhaps) complex partial movement and ignoring the movements (or non-movements) of the rest of his body These latter form the *movement contest* for the salient partial movement. The flicking is salient because it constitutes the increment, *given* the movement context and the wider circumstances, necessary for turning on the light. In a more complete account, we would need to be able to keep track of these other movements; to have a theory of movements of persons and other systems, we need to relate it to a theory of the movements of their parts. For our purpose in this paper, however, a very simple conception will suffice.

3 Meanings

Let us suppose that, John executed the flicking movement and turned on the light, intentionally. We can imagine him realizing that he was standing right in front of and in easy arm's reach of a switch that he believed was connected in the appropriate way to the light. Why does he effect the movement that, he does'/

We might represent what John knows about movements that explains his doing what, he did, as a generalization about (i) movements of the body, (ii) complex types of movement (iii) circumstances in which those movements occur, and (iv) results.

(2) If J effect a movement of the flicking type, while otherwise standing still, in circumstances in which I am standing directly in front of and within easy arm's reach of a light switch of a certain kind that is in on the 0/7 position and which is correctly connected up to a functioning light, then a result of such a movement will he that the light so connected will get turned on. Moreover, if 1 simply stand still, then, in those very same circumstances, the light will not get, turned on.

The second sentence should not. be interpreted as saying that there is no other way, in those circumstances, for John to bring it about that, the light is turned on. It simply says that if John's total body movement is a sufficient condition, in the circumstances, of the light, being turned on, then his flicking movement, 111 particular, is a necessary part of that sufficient condition.

bet us now attempt to generalize and abstract, by way of the following generalization over movements (m) involving parameters for total movement types (M), circumstanees (C, plus auxiliary parameters for objects and relations involved in (7), and results (P, plus auxiliary parameters).

(*) Any movement *in* that is of type A/, that is effected in circumstances of type $C(x_1, \ldots, x_n, m)$, will have as a result that $P(x_i, \ldots, x_l)$ $(1 \leq i \leq l \leq n)$.

(oven (*), we can associate a relation between (types of) circumstance, and (types of) results with the movement type *M.* We call this its *meaning* and denote it, as $[\![M]\!]$. Thus we say

$$[\![M]\!](C, P) \text{ iff } (*).^4$$

4 Actions

We distinguish two categories of actions, *executions* and *accomplishments*.

4.1 Executions

Executions are actions defined simply by the types of movements executed. We use $\mathcal{E}M$ as short for "executes

$$\mathcal{E}M(a, t, m) \text{ iff}$$

1 a executes m at /

2. m is of type *M*

We assume that the results of a movement of type A/ occurring are identical with that of an agent, executing a. movement of type A/. Someone interested in the theory of dance, for example, might *he* interested primarily in executions; typically, however, both as agents and theorists, we are not primarily interested in executions, but in accomplishments.

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[4] Note that *C* is not quite a property or type of circumstance, and /' is not quite a proposition. They are what might he called parametric properties and propositions.

4.2 Accomplishments

Accomplishments are actions defined by results; they can be reported by way of a certain canonical form: α *brings it about that P.* We use *BP* as short for "brings it about that P".[5] Later, in §5.1, we shall introduce a formal language within which to model some of the logic of accomplishments; in this section, as in the previous sections, our treatment is informal.

$BP_{x_1,\ldots,x_i}(\alpha,t)$ iff
$\exists M, m,$ and C such that

1. $\mathcal{E}M(\alpha,t,m)$
2. $C(x_1,\ldots,x_n,m)$
3. $[\![M]\!](C(x_1,\ldots,x_n,m), P(x_1,\ldots,x_l))$.

4.3 The *way of* relation

Our account allows us to analyze various important relations between actions.

Consider the following piece of practical advice or expression of commonsense know-how:

(3) Flipping the light switch to the *on* position is a way of turning on the light (to which the switch is connected in the appropriate way).

What, do we mean when we say that, flipping the switch to the *on* position is *a way of* turning on the light[7] There is a relativity to circumstance that is suppressed. We really mean that flipping the switch to the *on* position is a way of turning on the light in certain circumstances *C* when the wiring is installed, the fuse is not blown, the power is on, etc. On the view sketched so far, any case (act,) in which an agent flips the switch will involve that agent's executing a movement type that, in the given circumstances, has as a result that the switch is flipped. The same is true for any case of an agent's turning on the light. When we say that accomplishing the first is a way of accomplishing the second, we are claiming that however, in those fixed circumstances, you bring about the first, you will have brought about the second.

It will help to introduce the concept of an execution being a *mode of* an accomplishment in a circumstance:

$$\mathbf{MO}(C,\mathcal{E}M,BP) \text{ iff } [\![M]\!](C,P).$$

Now let C be fixed as above. In C, bringing it, about that the switch is flipped to the *on* position is a way of bringing it about that the light is on iff any type of (total body) movement *M* which is a mode of bringing it about that the switch is flipped to the *on* position is a mode of bringing it about the light (to which the switch is connected) is turned on. More generally, we define a. family of two place way of (WO) relations between accomplishments parameterized by *C*:

$$\mathbf{WO}_C(BP,BQ) \text{ iff } \forall M \quad \mathbf{MO}(C,\mathcal{E}M,BP) \Rightarrow \mathbf{MO}(C,\mathcal{E}M,BQ).$$

We have in mind cases in which the relevant causal chain does not involve the beliefs, desires, and intentions of another agent. We do ultimately intend to accomodate cases, e.g., in which one person brings something about hy convincing another to perform do something, but the intuitions we rely on here pertain to the simpler cases.

These relations are pre-orders; they are reflexive and transitive. Reflexivify is a mildly and innocuously counterintuitive property: in C, bringing it about that the switch is Hipped is a way of bring it about that switch is flipped. Transitivity is central to means end reasoning. What of symmetry and antisymmetry? In the circumstances C, bringing it, about that, the light is turned on is not, a way of bringing it about the switch is flipped to the *on* position, but nothing in our account, rules out cases m winch, relative to some circumstance C", bringing it about that, the light is turned on is a way of bringing it about that switch is Hipped to the *on* position and vice-versa. Plausible examples of symmetry, though, are hard to come by. We preempt the search for such cases by declaring in advance our readiness to accept, the antisymmetry of the WO relations, and thus, our acceptance of the claim that, *given a jutd circumstance ('*, accomplishments form a partial order.

4.4 The *VO* and *PER* relations

In the foregoing, we defined two temporal properties of agents, (i) that of an agent executing a movement, of a type at a time, and (ii) that, of an agent bringing it about that *P* at, a time. We also introduced relations among action properties and circumstances: (i) the relation of a movement execution property being a mode of accomplishing a proposition in a type of circumstance and (ii) the relation of one accomplishment property being a way of for another accomplishment, property, in a type of circumstance. We now bring these together in an analysis of the by relation. We do things by doing other things; that is, we perform some actions by performing others. Our analysis of actions involves two categories: executions and accomplishments. So, too our analysis of the *by* relation involves two subrelations. Consider:

(4) John flipped the switch to the *on* position by moving by flicking.

(5) ."John turned on the light by flipping the switch to the *on* position.

We offer definitions of two relations involving agents and times, that of an agent bringing it about, that *P by* executing a movement of a certain type in a circumstance at a time, and that of an agent, at a time, bringing if about that *P by* bringing it about that *Q,* in a circumstance. These two relations together comprise our analysis of the *by* relation. We use the notation VO (to suggest, *in virtue of)* for the first and PER. for the second.

$\mathbf{VO}(\alpha,t,C,\mathcal{E}M,BP)$ iff
$\exists m$ such that

1. $\mathcal{E}M(\alpha,t,m)$
2. $C(m)$
3. $\mathbf{MO}(C,\mathcal{E}M,BP)$

Thus (4) is true iff (roughly):

(4') John effected a movement of the flicking type, in circumstances such that any movement of that, type, in that kind of circumstance, would have as a result that the switch directly in front of which that