

The believability of Road Runner cartoons: logical consistency conquers unreality

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The rules and disciplines are properly difficult to identify. But there are—there must be—rules. Without them, comedy slops over at the edges. Identity is lost.

—Chuck Jones

Abstract

Entertainment has always involved fictional characters in artificial settings. Effective use of artificial worlds and characters demands that the agents and worlds be believable and understandable. We examine the world and characters in the Road Runner cartoons, and show how the world, while not realistic, is internally consistent. We argue that the consistency of both the world and the actions of the agents relative to their motivations are important factors in the success of the series, and provide a model for developing believable agents and worlds in general.

Introduction

Drama and comedy have a long history as human entertainment, with an oral tradition that predates written history in those cultures that predate written history. The meaning of such performances, whether for entertainment, affirming cultural values, or challenging the status quo, depends to some degree on the believability of the characters and their situations. The characters need not be human, and the environment in which they act need not be earth, but the actions and situations must seem reasonable in the context of the environment.

In this paper, we consider the artificial world presented in the Road Runner and Coyote Cartoons, forty-two of which were produced between 1949 and 1980 [Beck, 1989]¹ While the world presented in these cartoons seems quite unrealistic, most actions within this world are quite predictable, and the unpredictable ones, largely those that are funny, seem reasonable in the context of the cartoons. We present this world as an example of an artificial world that is effectively used

to entertain, and hypothesize that this effectiveness is due in part to a believable environment populated by actors with recognizable motivations.

The structure of this paper is as follows. We discuss how Road Runner and Coyote world is an amalgam of features from the real world, other commonly used cartoon features, and particular more specific features having to do with the Coyote's beliefs. Next, we present a set of logical axioms designed to support formal commonsense reasoning in this world—if a world is logically consistent, we should be able to formalize its commonsense underpinnings in ways similar to those used for commonsense reasoning about the real world. Next, we use these axioms in an example proof that the logical formalization supports; in particular we present a proof that would not hold in the real world. Finally, we consider how the creators of this world used an alternative mechanism (a set of rules) to keep logical consistency, and argue that this logical consistency contributes much to the entertainment value.

The world of Road Runner and Coyote

As drama, the Road Runner–Coyote cartoons are quite simple:

- only two characters are involved,
- there is no dialogue,
- the interaction between characters is simply one of pursuit and avoidance,
- the environment is consistent and minimal, and
- the theme is persistent across the entire series.

The environment of the Road Runner–Coyote cartoons is an idealization of the southwest American desert: rugged terrain, with few plants (other than cactus), wires strung on poles, and lots of two-lane highway. These roads play a central part in this world, since the Road Runner spends his time traveling along them, and the improbable concentration of bridges, tunnels, and roads cut into cliffs makes for an interesting environment for the Coyote to try various ploys to catch the Road Runner.

¹A 43rd cartoon, *Chariots of Fur* was released late in 1994. This world has also been used, with less success, in advertising automobiles and soft drinks.

The theme: the Coyote (*Eatibus Almost Anythin-gus*) is hungry and sees the Road Runner (*Tastyus Supersonicus*) as his only chance for a decent meal but the Road Runner is too fast for the Coyote simply to chase and catch. His only chance is somehow to trap the Road Runner and, for the duration of the series, his planning and scheming bring him pain, suffering, and indignity ... but no Road Runner! The Road Runner spends his days, appropriately, merrily running along the road and has little interest in the Coyote and his doings. His sole contribution to the affair is a few well-placed “beep-beeps” that startle the Coyote into compromising positions.

While many things in the environment have real-world analogs, other features are typical of cartoons—a common cliché is a character who walks off a cliff or steps out of a window to not fall toward the ground until he notices that he is not supported by anything, or a character who does not feel pain when set on fire until he *sees* that he is burning. The abstraction here seems to be that physics is affected by the knowledge or belief of the involved characters. This notion is very common in these cartoons, where much of what happens seems to depend on the beliefs and intentions of the Coyote.

If this world is believable and understandable, it should be describable by some set of axioms, as has been done for commonsense reasoning about things in the world. The differences between this world and the real world complicate the job of axiomatizing this world, but such an axiomatization provides evidence that the world is in general logically consistent, and the efforts could lead to a greater understanding of the sorts of differences that an artificial world might exhibit without becoming too alien to be understood.

Road Runner-Coyote according to formal logic

The basis for the axiomatization of the Road Runner - Coyote Microworld is sorted modal temporal logic [Davis90]. Included in the axiomatization are a number of necessary modal belief and knowledge axioms and axioms required for reasoning about the physical objects used by the Coyote in his never-ending quest of Road Runner Tartare. The axiomatization of this microworld is to the end of proving that, no matter what situation they find themselves in, the Coyote will never catch the Road Runner.

The approach taken by the current work is to axiomatize a subset of situations that are portrayed in the series of cartoons such that an interesting set of axioms can be developed. Further, this set of situations has been chosen such that inconsistent and anomalous situations are avoided, allowing for a simpler, consistent set of axioms. This is a necessary tack because not all behavior in this microworld is logically consistent. For example, at least once the Coyote sets up a trap that requires the Road Runner to stop and read

RRC.17. $\text{occurs}(I, \text{fall}(A)) \Leftrightarrow$
 $\text{knows}(A, \neg \exists Y$
 $\text{true_in}(\text{start}(I), \text{support}(Y, A)), \text{start}(I))$
(Toonville Cliché I: Agent A will only fall if A knows that nothing supports A.)

RRC.18. $\text{occurs}(I, \text{burn}(A)) \Leftrightarrow$
 $\text{knows}(A, \text{true_in}(\text{start}(I), \text{burning}(A)), \text{start}(I))$
(Toonville Cliché II: Agent A will only suffer the pain of burning when A knows that A is burning.)

RRC.19. $(\text{occurs}(I, \text{make}(\text{coyote}, X))$
 $\wedge \text{believes}(\text{coyote}, \text{true_in}(\text{end}(I), \text{representation}(X, O, B)), \text{end}(I))) \Rightarrow$
 $\text{true_in}(\text{end}(I), \text{instance}(X, O))$
(Coyote’s Dilemma I: If Coyote believes something he made is a representation then it is an instance of that type.)

RRC.20.
 $\text{believes}(\text{coyote}, \text{true_in}(S2, \text{instance}(X, O)), S2) \wedge \text{believes}(\text{coyote}, \text{true_in}(S1, \text{representation}(X, O, B)), S1) \wedge \text{precedes}(S1, S2) \Rightarrow$
 $\text{true_in}(S2, \text{representation}(X, O, B))$
(Coyote’s Dilemma II: If Coyote believes that something is an instance, and he previously believed it to be a representation, then it is a representation.)

Figure 1: Axioms pertaining to belief and state changes

a sign. When the Road Runner zips by the sign and trap without even looking at it, the Coyote is stupefied. In a few moments, the Road Runner returns to the scene sporting a sign that reads “Road Runners Can’t Read!” This statement is close to the classic liar sentence “This sentence is false.” How can the Road Runner be using written language if he can not read it?

A number of sorts are defined to constrain portions of the logic to pertain to only certain groups of entities. Sorted predicates include state and event predicates, interval predicates, and domain dependent predicates that are true or false independently of situations. The predicate $\text{true_in}(S, T)$ where state fluent T holds in situation S functions as the state predicate. The predicate $\text{occurs}(I, E)$ where event type E occurs in interval I functions as the event predicate. Various states and events are defined that hold in certain situations and are used as arguments to the true_in and occurs predicates. Standard interval predicates are also defined [Allen83].

Agents’ beliefs, knowledge and goals are represented as modal operators with a temporal dimension. These operators include: $\text{believes}(A, \phi, S)$ where agent A believes statement ϕ in situation S , $\text{knows}(A, \phi, S)$ where agent A knows statement ϕ in situation S , and $\text{goal}(A, \phi, S)$ where agent A has goal ϕ in situation S . Three axioms – Arrogance of Belief (RRC.5),



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Figure 2: The painted tunnel ploy.

Knowledge is Belief (RRC.6), Arrogance of Knowledge (RRC.7) – are used to define the relationships between belief, knowledge, and actual fact [Davis90].

Some of the more interesting aspects of this microworld involve the interaction between an agent's belief and the world he inhabits. An agent's belief seems to 1) affect the state of physical objects, 2) require some interval of time to engage, and 3) affect the operation of mechanisms. The following sections present these aspects in more detail.

Belief and State Change

Figure 1 details a number of axioms that are unique to the cartoon domain. The Toonville Clichés (RRC.17, RRC.18) seem to be applicable in a wide range of animated series. The first simply states that a cartoon character will not fall until he notices that he is falling. Since knowledge implies belief that is in fact true, the character falls when he knows that he is not supported. If simple belief were used, the character might be mistaken (say, if he is standing on a two-dimensional representation of the ground below him) and should not fall. The second Toonville Cliché is similar but applies to the situation in which the character is burning. Burning has no ill effect upon the character until the character knows that he is burning which is the case only after he smells smoke or sees flames.

The Coyote's Dilemmas (RRC.19, RRC.20) apply only to the Road Runner-Coyote animated series (although they have analogs in other cartoons). They both pertain to an often repeated situation in which the Coyote attempts to fool the Road Runner with a two-dimensional representation of a tunnel or bridge. Two predicates used in the Coyote's Dilemmas require explanation. representation (X,O,B) is true when en-

tity X is simply a representation (painting, drawing) of type O (tunnel, bridge) and exists on substrate B (cliffside, canvas). instance(X,O) is true when X is an instance of an entity of sort O. Unfortunately for the Coyote, the cards are stacked against him by these axioms. If he believes that one of his creations is simply a representation, a seemingly safe assumption, the tunnel or bridge becomes an actual instance of that tunnel or bridge! If he then reverses himself and believes that the structure is truly an actual instance, the structure reverses itself and becomes a representation of the structure! Needless to say, these simple axioms wreak havoc in the Coyote's life and prevent him from fulfilling his goals in such a devious manner.

This selection of axioms highlights a unique quality of this artificial domain: the interaction of belief and state change. Since such a domain has never before been the subject of such formal study, the fact that current commonsense formalisms can be used to axiomatize it is remarkable. More of the logic is presented in the Appendix.

Examples of logical consistency: a proof

One particularly classic example of one of the Coyote's ploys is seen for the first time in the very first episode of the series entitled "Fast and Furry-ous" (1949). The Coyote paints a tunnel on a cliff side in hopes that the Road Runner will smash into the cliff as he attempts to pass through the trompe l'oeil tunnel. We wish to infer that the Coyote does not catch the Road Runner and suffers a loss of dignity thereby thwarting both of his goals as formalized in the Coyote Goal axiom (RRC.3). It is a classic use of the Coyote's Dilemmas.

The proof is given in Figure 3. The Coyote paints a representation of a tunnel and, quite appropriately, be-

Prove:

$\exists_I \text{true_in}(\text{end}(I), \text{free}(\text{roadrunner})) \wedge \text{true_in}(\text{end}(I), \text{undignified}(\text{coyote})) \wedge \text{meets}(i2, I)$	
1. $\text{occurs}(i1, \text{make}(\text{coyote}, T1))$	(Given)
2. $\text{believes}(\text{coyote}, \text{true_in}(\text{end}(i1), \text{representation}(T1, \text{Tunnel}, C1)) \wedge \text{instance}(C1, \text{Cliffside}), \text{end}(i1))$	(Given)
3. $\forall_{S \in i2} \text{true_in}(S, \text{free}(\text{roadrunner}))$	(Given)
4. $\text{occurs}(i2, \text{use}(\text{roadrunner}, T1))$	(Given)
5. $\text{occurs}(i2, \text{observe}(\text{coyote}, \text{roadrunner}))$	(Given)
6. $\text{meets}(i1, i2)$	(Given)
7. $\text{true_in}(\text{start}(i2), \text{instance}(T1, \text{Tunnel}))$	RRC.19, IAS.1, 1, 2, 6
8. $\neg \text{true_in}(\text{end}(i2), \text{clobbered}(\text{roadrunner}))$	RRC.14, 4, 7
9. $\text{believes}(\text{coyote}, \text{true_in}(\text{end}(i2), \text{instance}(T1, \text{Tunnel})), \text{end}(i2))$	RRC.12, 4, 5, 8
10. $\text{true_in}(\text{end}(i2), \text{representation}(T1, \text{Tunnel}, C1))$	RRC.20, IAS.1, 2, 6, 9
11. $\exists_I (\text{meets}(i2, I) \wedge \text{occurs}(I, \text{chase}(\text{coyote}, \text{roadrunner})))$	RRC.3, RRC.10, 5
12. $\text{meets}(i2, i3) \wedge \text{occurs}(i3, \text{chase}(\text{coyote}, \text{roadrunner}))$	EI, 11
13. $\text{occurs}(i3, \text{use}(\text{coyote}, T1))$	RRC.11, IAS.2, 4, 12
14. $\text{true_in}(\text{end}(i3), \text{clobbered}(\text{coyote}))$	RRC.13, IAS.1, 10, 12, 13
15. $\neg \text{occurs}(i3, \text{catch}(\text{coyote}, \text{roadrunner}))$	RRC.16, 12, 14
16. $\text{true_in}(\text{end}(i3), \text{free}(\text{roadrunner}))$	RRC.15, IAS.1, RRC.2, 3, 12, 15
17. $\text{true_in}(\text{end}(i3), \text{undignified}(\text{coyote}))$	Clobbered Axiom, 14
18. $\exists_I \text{true_in}(\text{end}(I), \text{undignified}(\text{coyote})) \wedge \text{true_in}(\text{end}(I), \text{free}(\text{roadrunner})) \wedge \text{meets}(i2, I)$	EG, 12, 16, 17

Figure 3: The painted tunnel proof

lieves it simply to be a representation. Unfortunately, because of his belief and the Coyote's Dilemma I, the tunnel becomes a real transportation structure. The Road Runner runs through the tunnel, unscathed, and this convinces the gullible Coyote that the tunnel is indeed real which this time, due to the Coyote's Dilemma II, causes the tunnel to become a representation. The Coyote attempts to use the tunnel representation, runs smack dab into the cliff wall it is painted on, and is clobbered by it. This clobbering leaves the Coyote undignified and the Road Runner remains free thereby thwarting the Coyote's goal of capturing and eating him.

To show the generality of our axioms, a proof along similar lines can be constructed that demonstrates yet another ruse attempted by the Coyote fails miserably. In this case the Coyote paints a representation of a bridge on canvas and places it in front of a bridge that is currently out of commission. The representation immediately becomes an instance of a bridge and, true to form, the Road Runner takes advantage of it by running over it. This convinces the Coyote that the bridge is indeed real which causes it to revert back to a representation of a bridge. As he gives chase to the Road Runner, he attempts to run over the illusionary bridge only to rip through the canvas and fall into the canyon spanned by the out-of-commission bridge. Needless to say, he is subsequently left road runner-less and undignified.

Related work

We have found no previous work in commonsense theories of artificial worlds as we define them. Traditionally, artificial worlds have been viewed as carefully constructed models in which knowledge is complete and common sense plays no part (e.g. the blocks world). We have extended this view to include a class of artificial worlds that seems to develop its own set of commonsense rules.

The Oz project [Bates-et-al92] includes a model for emotions for its actors, which is a primary motivator of behavior. This provides a consistency of behavior that might otherwise be lacking. One question raised by this work is how formal an axiomatization is necessary (or desirable) to attain believability.

Work in belief and knowledge formalisms is legion [Halpern86, Vardi88] as is work in naive physics [Gentner83, Bobrow85, Weld89] and time [Allen83, Allen85] but the interaction between belief and the other concepts seems to manifest itself strictly in the domain of artificial worlds (with the notable exception of time) and, therefore, has not previously been considered for study.

Conclusions

In this paper, we presented a partial axiomatization of the Road Runner-Coyote world. An interesting feature of this work is that it parallels some of the work done by Chuck Jones, the creator of the Road Runner-Coyote cartoons: he presented a set of "rules" that characterize this world (and provide a framework for producing more cartoons in this world) [Jones89]:

- The Road Runner cannot harm the Coyote except by going “beep-beep!”
- No outside force can harm the Coyote—only his own ineptitude or the failure of the ACME products.
- The Coyote could stop anytime—if he were not a fanatic.
- No dialogue ever, except “beep-beep!”
- The Road Runner must stay on the road—otherwise, logically, he would not be called Road Runner.
- All the action must be confined to the natural environment of the two characters—the southwest American desert.
- All materials, tools, weapons, or mechanical conveniences must be obtained from the ACME corporation.
- Whenever possible, make gravity the Coyote’s greatest enemy.
- The Coyote is always more humiliated than harmed by his failures.

It is arguable that the long-term popularity and quality of these cartoons are based in large part on the recognizable logical consistency of the product – in fact, the fact that the world is well understood by the audience allows the authors to occasionally push the logical limits a bit for effect (such as with the aforementioned “Road Runners can’t read” sign).

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Appendix: The Road Runner - Coyote Microworld (highlights)

Nonlogical Symbols

Constants

roadrunner	: (<i>Tastyus Supersonicus</i>)
coyote	: (<i>Eatibus Almost Anythingus</i>)

States

supports(X,Y)	: X is under (and supporting) Y
free(X)	: X is free to move
clobbered(A)	: agent A is harmed
burning(X)	: X is burning
instance(X,O)	: X is an instance of sort O
representation(X,O,B)	: X is a representation of sort O on substrate B

Predicates

true_in(S,T)	: state T holds in situation S
occurs(I,E)	: event E occurs in interval I
before(I1,I2)	: end(I1) < start(I2) (intervals)
meets(I1,I2)	: end(I1) = start(I2)
precedes(S1,S2)	: situation S1 precedes situation S2

Functions

value_in(S,F)	: value of fluent F in situation S
start(I)	: situation at start of interval I
end(I)	: situation at end of interval I

Modal operators

believes(A, ϕ ,S)	: agent A believes statement ϕ in situation S
knows(A, ϕ ,S)	: agent A knows statement ϕ in situation S
goal(A, ϕ ,S)	: agent A has goal ϕ in situation S

Selected Axioms

- RRC.1** $\text{sort_of}(X) = \text{Agent} \Rightarrow X = \text{roadrunner} \vee X = \text{coyote}$
(Domain Closure)
- RRC.2.** $\text{roadrunner} \neq \text{coyote}$
(Unique Names)
- RRC.3.** $\text{goal}(\text{coyote}, \exists_I \text{occurs}(I, \text{eat}(\text{coyote}, \text{roadrunner})) \wedge \neg \exists_{S1} \text{true_in}(S1, \text{undignified}(\text{coyote})), S)$
(Coyote Goal: At all times the Coyote has the goals to eat Road Runner and to avoid loss of dignity.[Jones89])
- RRC.4.** $\text{goal}(\text{roadrunner}, \neg \exists_I \text{occurs}(I, \text{catch}(\text{coyote}, \text{roadrunner})), S)$
(Road Runner Goal: At all times the Road Runner has the goal to prevent the Coyote from catching him.)
- RRC.5.** $\text{believes}(A, \text{believes}(A, \phi, S) \Rightarrow \text{true_in}(S, \phi), S)$
(Arrogance of Belief: In a given situation, an agent believes that all his beliefs are true.)
- RRC.6.** $\text{knows}(A, \phi, S) \Rightarrow \text{believes}(A, \phi, S)$
(Knowledge is Belief: In a given situation, if agent knows something, he believes it.)
- RRC.7.** $\text{knows}(A, \phi, S) \Rightarrow \text{true_in}(S, \phi)$
(Arrogance of Knowledge: In a given situation, if agent knows something, it is true.)
- RRC.8.** $\text{true_in}(S, \text{instance}(X, O)) \Leftrightarrow \neg \text{true_in}(S, \text{representation}(X, O, B))$
(In a given situation, an object cannot be both an instance and a representation—state coherence)
- RRC.9.** $\text{true_in}(S, \text{clobbered}(A)) \Rightarrow \text{true_in}(S, \text{undignified}(A))$
(Clobbered Axiom: If an agent gets clobbered the agent has suffered loss of dignity.)
- RRC.10.** $\text{goal}(A1, \exists_I \text{occur}(I, \text{eat}(A1, A2)), I1) \wedge \text{occurs}(I1, \text{observe}(A1, A2)) \Rightarrow \exists_{I2} (\text{meets}(I1, I2) \wedge \text{occurs}(I2, \text{chase}(A1, A2)))$
(Chase Causal Axiom: If A1 wants to eat A2 and A1 observes A2 then A1 chases A2.)
- RRC.11.** $\text{occurs}(I2, \text{chase}(A1, A2)) \wedge \text{occurs}(I1, \text{use}(A2, X)) \wedge \text{sort_of}(X) = \text{Trans_Struct} \wedge \text{before}(I1, I2) \Rightarrow \text{occurs}(I2, \text{use}(A1, X))$
(Follow Causal Axiom: If agent A1 chases agent A2 across a transportation structure, A1 uses that structure.)
- RRC.12.** $\text{occurs}(I, \text{use}(A1, X)) \wedge \neg \text{true_in}(\text{end}(I), \text{clobbered}(A1)) \wedge \text{occurs}(I, \text{observe}(A2, A1)) \Rightarrow \text{believes}(A2, \text{true_in}(\text{end}(I), \text{instance}(X, \text{sort_of}(X))), \text{end}(I))$
(Seeing Is Believing: If agent A1 observes another agent successfully use something A1 believes the thing is real.)
- RRC.13.** $\text{occurs}(I, \text{use}(A, X)) \wedge \text{true_in}(\text{start}(I), \text{representation}(X, O, B)) \Rightarrow \text{true_in}(\text{end}(I), \text{clobbered}(A))$
(Representation Use: If an agent uses a representation of something, he is clobbered.)
- RRC.14.** $\text{occurs}(I, \text{use}(A, X)) \wedge \text{true_in}(\text{start}(I), \text{instance}(X, T_struct)) \Rightarrow \neg \text{true_in}(\text{end}(I), \text{clobbered}(A))$
(Instance Use: If an agent uses a transportation structure, he is not clobbered.)
- RRC.15.** $\text{true_in}(\text{start}(I), \text{free}(A2)) \wedge \neg \text{occurs}(I, \text{catch}(A1, A2)) \wedge A1 \neq A2 \Rightarrow \text{true_in}(\text{end}(I), \text{free}(A1))$
(Freedom Axiom: If agent A2 is free at the start of an interval and A1 has not caught A2 in that interval, A2 is free at the end of that interval.)
- RRC.16.** $\text{occurs}(I, \text{chase}(A1, A2)) \wedge \text{true_in}(\text{end}(I), \text{clobbered}(A1)) \Rightarrow \neg \text{occurs}(I, \text{catch}(A1, A2))$
(Thwarted Chase: If agent A1 chases agent A2 and gets clobbered in the process, A1 has not caught A2.)
- RRC.17.** $\text{occurs}(I, \text{fall}(A)) \Leftrightarrow \text{knows}(A, \neg \exists_Y \text{true_in}(\text{start}(I), \text{support}(Y, A)), \text{start}(I))$
(Toonville Cliché I: Agent A will only fall if A knows that nothing supports A.)
- RRC.18.** $\text{occurs}(I, \text{burn}(A)) \Leftrightarrow \text{knows}(A, \text{true_in}(\text{start}(I), \text{burning}(A)), \text{start}(I))$
(Toonville Cliché II: Agent A will only suffer the pain of burning when A knows that A is burning.)
- RRC.19.** $\text{occurs}(I, \text{make}(\text{coyote}, X)) \wedge \text{believes}(\text{coyote}, \text{true_in}(\text{end}(I), \text{representation}(X, O, B)), \text{end}(I)) \Rightarrow \text{true_in}(\text{end}(I), \text{instance}(X, O))$
(Coyote's Dilemma I: If Coyote believes something he made is a representation then it is an instance of that type.)
- RRC.20.** $\text{believes}(\text{coyote}, \text{true_in}(S2, \text{instance}(X, O)), S2) \wedge \text{believes}(\text{coyote}, \text{true_in}(S1, \text{representation}(X, O, B)), S1) \wedge \text{precedes}(S1, S2) \Rightarrow \text{true_in}(S2, \text{representation}(X, O, B))$
(Coyote's Dilemma II: If Coyote believes that something is an instance and it is something that he previously believed was a representation then it is a representation.)