A Method to Derive The Probabilities of Computational Verb Events

Yi Guo and Tao Yang
Department of Electronic Engineering
Xiamen University
Xiamen, 361005, P.R. China
E-mails: xmulala@gmail.com & taoyang.yangsky@gmail.com

***Abstract*—The probability of a conventional event that consists of a static verb such as be, stay, remain and its contexts can be easily found. However, to derive the probability of a verb event stated by a non-static verb is not as simple as conventional events. In the paper, we introduce a type of evolving function called observation function and address a measure to attain the probability of the verb event via observation functions.**

***Keywords*-computational verb event; evolving function; computational verb observation function; elementary verb event; probability**

I. INTRODUCTION

Static verbs [1] have an ability that they can extend the static perceptions along time. For example, the following statement

$$\text{Tom is } \texttt{tall}, \quad (1)$$

is usually modeled by a computational verb evolving function [1] shown by Fig. 1, in which V_{tall} is an attribute value of Tom.

However, it's difficult to observe the dynamics of static verbs within limited time. In this paper, a type of evolving functions called *observation function* that shows the dynamics of static verbs is introduced and the probabilities of verb events are found based on the observation function.

The organization of this paper is as follows. In Section II the differences and the relationship between fuzzy events and computational verb events will be presented. In Section III observation functions will be defined. In Section IV the measure to find the probabilities of verb events through observation functions will be given. In Section V concluding remarks are including.

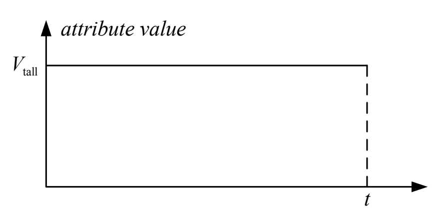


Figure 1. A commonly applied evolving function of the static verb.

II. FUZZY EVENTS AND COMPUTATIONAL VERB EVENTS

Consider the following events:

$F1$: The weather is `a little bit hot`.
$F2$: The weather stays `hot`. (2)
$F3$: The weather remains `very hot`.

Observe that deleting the verbs of the events does not hurt the meanings of the statements, thus the descriptions can be transformed into follows:

`A little bit hot.`
`Hot.` (3)
`very hot.`

The verbs such as be, stay and remain are called *trivial (static) verbs*, which are used to describe a *conventional events (BE-events)* [1]. Fuzzy membership functions are effective tools to model static perceptions. When implementing the fuzzy numbers into modeling events in Eq. (2), the fuzzy membership functions $\mu(T)$ are shown by Fig. 2. Then the events can be called *fuzzy events*.

Naturally, a non-static or non-trivial verb sentence usually describes a *computational verb event* (*verb event* for short). Some examples of verb events are given as follows:

$V1$: The weather becomes a little bit hot.
$V2$: The weather becomes hot. (4)
$V3$: The weather becomes very hot.

Instead of using fuzzy theory, we implement computational verb evolving functions into modeling those dynamic perceptions in Eq. (4). The common way to do that is shown by

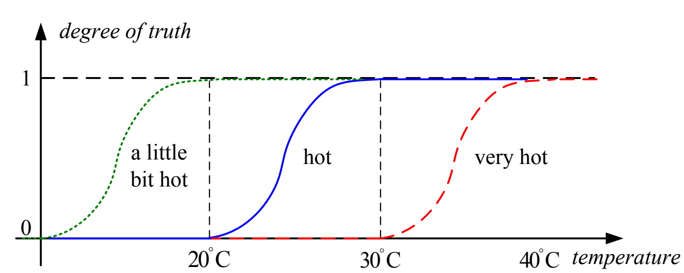


Figure 2. Fuzzy membership functions of "a little bit hot" (green dotted), "hot" (blue solid) and "very hot" (red dashed).

Fig. 3. The *canonical forms* [2] of become for corresponding events are given by

become (cooler than current, a little bit hot)
become (cooler than current, hot)
become (cooler than current, very hot)

III. Observation functions

Let's get the evolving functions through another way. Similarly, observe the truth value of perceptions as the increase in temperature. Under different context, some possible evolving functions describing event V_2 are shown in Fig. 3. Fig. 4(b) shows become we commonly use, of which canonical form is given by

become (not hot at all, definitely hot).

Notice that the curves shown in Fig. 4 are some part of the blue solid curve of Fig. 2 because of the same mapping from a universe of discourse into the truth value of a perception that the weather is hot. We call such type of evolving functions shown by Fig. 4 *observation functions*. To distinguish the fuzzy membership function, universe of discourse is called *universe of observation*. In fact, the observation function has been used in design of verb PID-controllers [2]. When the observation function has the same mathematical expression as the membership function, it characterizes a verb event having a sentence description like one of those in Eq. (2). Whereas the verbs such as is, stay are not trivial verbs but non-trivial verbs that have dynamics.

In practice, membership functions usually take on one of the following different standard shapes: triangular, trapezoidal and Gaussian. Let's take the trapezoidal function for example

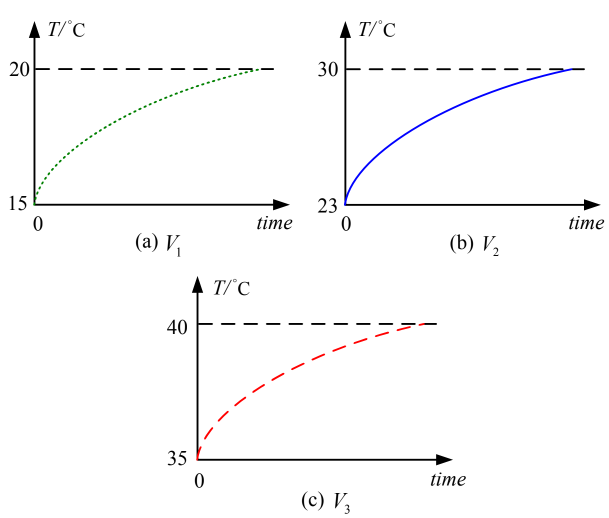


Figure 3. Commonly employed evolving functions to describe verb events in Eq. (4).

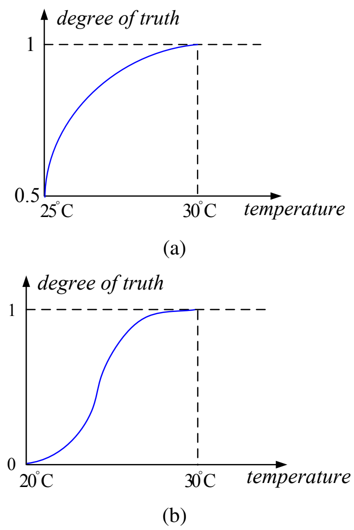


Figure 4. Two possible evolving functions to describe the verb event: "The weather becomes hot".

and its mathematical formula is given by

$$\mu(x) = \begin{cases} \frac{x-l}{x_l-l}, & \text{if } x \in (l, c_l]; \\ 1, & \text{if } x \in (c_l, c_r]; \\ \frac{r-x}{r-c_r} & \text{if } x \in (c_r, r]; \\ 0, & \text{otherwise.} \end{cases} \tag{5}$$

A trapezoidal function $\mu(T)$ shown in Fig. 5 can characterize following fuzzy event.

$$F1\text{: The weather is hot.} \tag{6}$$

Also, it can be an observation function $\mathcal{O}(T)$ characterizing a verb event stated by a non-trivial verb is.

$$V\text{: The weather is hot.} \tag{7}$$

For different segments of dynamics of is, we have a set of verb events as below.

V_1: The weather doesn't stay hot at all. $x \in (-\infty, l]$
V_2: The weather becomes hot. $x \in (l, c_l]$
V_3: The weather stays hot. $x \in (c_l, c_r]$
V_4: The weather leaves hot. $x \in (c_r, r]$
V_5: The weather doesn't stay hot at all. $x \in (r, +\infty)$
(8)

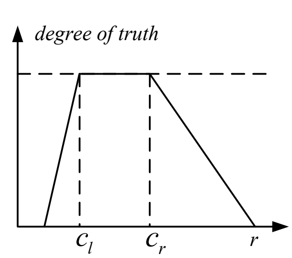


Figure 5. A trapezoidal shape function.

where the verbs' corresponding canonical forms in become are given by

$$\begin{aligned}\mathsf{stay} &= \mathsf{become}\,(0,0)\\ \mathsf{become} &= \mathsf{become}\,(0,1)\\ \mathsf{stay} &= \mathsf{become}\,(1,1)\\ \mathsf{leave} &= \mathsf{become}\,(1,0)\\ \mathsf{stay} &= \mathsf{become}\,(0,0)\end{aligned} \tag{9}$$

in which 0 and 1 are the degrees of truth of the perception "hot".

Since $\mathcal{O}(T)$ represents a verb that is composed of five verbs shown in Eq. (9), the events in Eq. (8) are called *elementary verb events* of event V. V_1 and V_5 can be excluded from our focus on the perception about "hot" since we have attained sufficient information about "hot" by V_2, V_3 and V_4. Fig. 6 illustrates the relation between the verb event V and the related elementary verb events.

IV. The Probabilities of Computational Verb Events

Since a BE-event can be more easily observed and recorded than a verb event, in this section, we introduce how to derive the probabilities of related elementary verb events from the probabilities of BE-event and how to get the probabilities of verb events derived from the *benchmark verb event* [1].

Without losing generalization, we only discuss the event described by a non-trivial verb having canonical form in become: become$(0,1)$ or become$(1,0)$ $(0,1$ are truth values of an object), which are usually used in common life. Fig. 4(b) give an example of become$(0,1)$.

A. Probabilities of the Fuzzy Events and Verb Events

Definition IV.1 (Probability space) *[1] A triple $(\Omega,\mathcal{S},P)$, which consists of a space Ω, a σ-field $\mathcal{S}$ of subset of Ω and a positive, countably additive measure P on $(\Omega,\mathcal{S})$ satisfying $P(\Omega)=1$, is called a probability space. P is called a probability measure. For a countable sequence of disjoint sets $A_1, A_2, \ldots \in \mathcal{S}$, we have $P(\bigcup_{i=1}^{\infty} A_i) = \bigcup_{i=1}^{\infty} P(A_i)$. An event is a member of $\mathcal{S}$.*

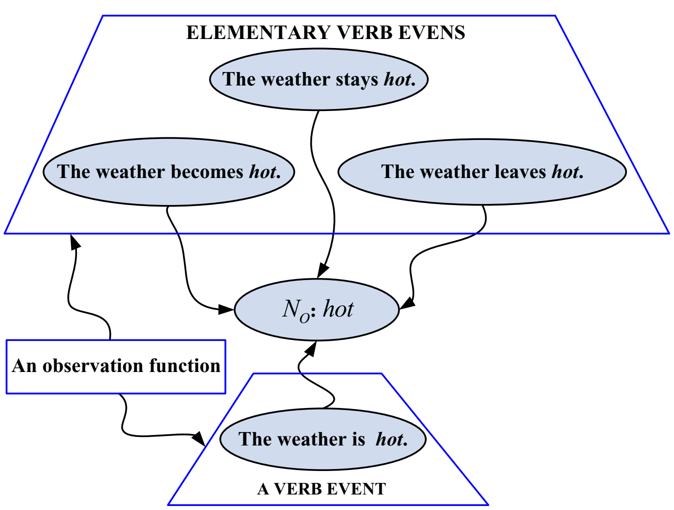


Figure 6. The relation between the verb event V and the related elementary verb events.

If A is an event, then the probability of A, $P(A)$ can be given by:

$$P(A) = \frac{\int_{\Omega}\mu_A(\omega)d\omega}{\int_{\Omega} d\omega} \tag{10}$$

where Ω is the *outcome space*, $\omega\in\Omega$ is called an *elementary event* and $\mu_A(\omega)\in[0,1]$ is the characteristic function of A [1]. If we view $\mu_A(\omega)$ as the membership function of A, then A is called a *fuzzy event*. If we view $\mu_A(\omega)$ as the observation function $\mathcal{O}_A(\omega)$, then A is also called a verb event.

B. Get the Probability of the Related Verb Event When Given the Probability of a BE-event

Suppose that we have the probability of the BE-event F, $P(A)$:

$$F\text{: The weather } \mathsf{is}\ \mathtt{hot}. \tag{11}$$

Our goal is finding the probability of an related event such as:

$$V_2\text{: The weather } \mathsf{becomes}\ \mathtt{hot}. \tag{12}$$

Based on section III, the goal is readily achieved in following steps.

1) Choose a proper fuzzy membership function $\mu_F(\omega)$ to characterize the event F.
2) View $\mu_F(\omega)$ as an observation function $\mathcal{O}_F(\omega)$. Then V_i is an elementary verb event of event V characterizing by $\mathcal{O}_F(\omega)$, employing Eq. (10) yields
$$P(F) = P(V) = \sum_{i=1}^{n} P(V_i) \tag{13}$$
where n is the total number of the elementary verb events decided by $\mathcal{O}_F(\omega)$.
3) Get the relation between $P(F)$ and $P(V_i)$: $P(V_i)/P(F)$.
4) Given the probability $P(F)$, we derive the probability $P(V_i)$.

Let's follow the steps to find $P(V_2)$. We choose a trapezoidal function as $\mathcal{O}_A(\omega)$, and subjectively choose the parameters for the event A as:

$$l = 20°\mathrm{C} \;\; c_l = 25°\mathrm{C} \;\; c_r = 35°\mathrm{C} \;\; r = 40°\mathrm{C} \tag{14}$$

According Eq. (13), we have

$$P(F) = P(hot) = P(V) = P(V_2) + P(V_3) + P(V_4) \tag{15}$$

where V_2, V_3, V_4 are the events in Eq. (8). The relation between $P(V_2)$ and $P(F)$ is that

$$\begin{aligned} p &= \frac{P(V_2)}{P(F)}\\ &= \frac{P(V_2)}{P(V_2)+P(V_3)+P(V_4)}\\ &= \frac{\int_{\Omega}\mathcal{O}_{V_2}(\omega)d\omega}{\int_{\Omega}\mathcal{O}_F(\omega)d\omega}\\ &= \frac{1}{6}\end{aligned} \tag{16}$$

Suppose that the probability of being hot ($P(hot)$) is 0.5 such that

$$P(V_2) = p \cdot P(F) = p \cdot P(hot) = \frac{0.5}{6} = 0.083. \quad (17)$$

C. Probabilities of the Verb Events Derived from the Benchmark Events

Let's study the probability of a verb event derived from a benchmark event V_2 in Eq. (12), which is stated by following sentence:

Verb-event v: The weather becomes hot *very soon*? (18)

The adverbial "very soon" is an operator which is a time scaling factor ($\epsilon \in (0, 1]$) that scales our time perception [3]. And the modifying function is given by:

$$\text{very soon} \circ \text{become} \quad (19)$$

Choosing 0.5 as the value of ϵ means that with the half time the weather becomes hot, namely, the temperature increases from 25°C to 30°C.

However, the observation function ($\mathcal{O}_A(\omega)$) of become we select in Eq. (12) doesn't contain the time information. Therefore, we can't scale our time perception through speeding up become as usual. Our measure is implementing a perception scaling factor α to make it percept the whole process of becoming hot within the time ϵt. In view of the complexity of the evolving process, we choose a linear evolving function commonly used to model become shown by the solid curve in Fig. 7(a), namely, assume it evolves at an average speed such that

$$\alpha = \epsilon. \quad (20)$$

The procedure to gain the evolving function of become in Eq. (18) is shown by Fig. 6, in which

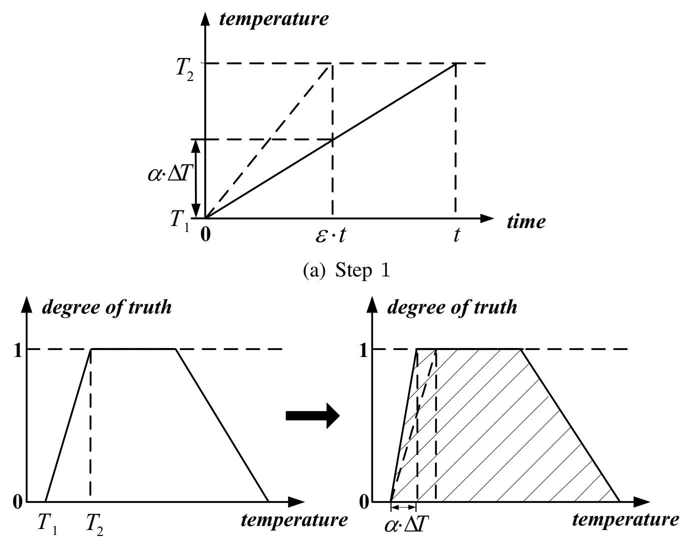
$$\Delta T = T_2 - T_1. \quad (21)$$

Notice that the result is in accord with our perception because we can also say "the weather becomes hot very soon" when we feel hotter than before at the same temperature.

Now let's study the probability of v, which is calculated by:

$$\begin{aligned} P(v) &= P(V_2)\frac{P(v)}{P(V_2)} \\ &= P(V_2)\frac{\int_\Omega \mathcal{O}_v(\omega)d\omega}{\int_\Omega d\omega} \cdot \frac{\int_\Omega d\omega}{\int_\Omega \mathcal{O}_{V_2}(\omega)d\omega} \\ &= P(V_2)\frac{\alpha\Delta T}{\Delta T} \\ &= \alpha P(V_2) = \epsilon P(V_2) \\ &= \frac{0.5\epsilon}{6} \end{aligned} \quad (22)$$

We can find a more precise evolving function to substitute the one in Fig. 7(a) through the corresponding membership function using *computational verb extension principle* [4]. Since an attribute value can be transformed into many action values, for simplicity, we only choose a linear function. When the universe of observation is the time, the method shown in Fig. 7(b) shows its feasibility.



(a) Step 1

(b) Step 2

Figure 7. The procedure to gain the evolving function of become in Eq. (18).

Notice that employing a perception scaling factor increases the probability of "hot" as Fig. 7(b) shows. It's because that the range of temperature where people feel definitely hot is enlarged.

V. Conclusions

In previous work [1], another method to get the probabilities of verb events is presented. To find the probability of the verb event V_2 in Eq. (12), an event modifier Ψ_{become} is applied. The modified membership function has the same shape as the original one for it's an observation function that emphasizes the degree of truth value of the verb event V_2 itself. Thus, it's different from the method provided by this paper where the observation function of V_2 which is a part of the observation function of V in Eq. (7) emphasizes the truth value of the object "hot". Compare to the measure in reference [1], it's more convenient for us to derive the probability of verb events and more flexible to choose different type of observation functions under different conditions.

Computational verbs are effective tools to model the dynamics of the world. Therefore, knowing the probabilities of computational verb events are quite helpful for us to make decisions in daily life.

References

[1] T. Yang, The mathematical principles of natural languages, T. Yang, Ed. Tucson: Yang's scientific research institute, LLC, 2007.

[2] ——, "Architectures of computional verb controllers: towards a new paradigm of intelligent control," International Jouranl of Computational Cognition, vol. 3, no. 2, pp. 74–101, June 2005.

[3] ——, "Computational verb systems:averbs and adverbials as modifiers of verbs," Information Sciences, vol. 121, pp. 39–60, December 1999.

[4] ——, "Bridging computational verbs and fuzzy membership functions using computational verb collapses," International Jouranl of Computational Cognition, vol. 4, no. 4, pp. 47–61, December 2006.