

Kohei Arai *Editor*

Intelligent Systems and Applications

Proceedings of the 2022 Intelligent
Systems Conference (IntelliSys) Volume 3



Springer

Lecture Notes in Networks and Systems

Volume 544

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Kohei Arai
Editor

Intelligent Systems and Applications

Proceedings of the 2022 Intelligent Systems
Conference (IntelliSys) Volume 3

Editor
Kohei Arai
Saga University
Saga, Japan

Editor's Preface

It gives me immense pleasure and privilege to present the proceedings of Intelligent Systems Conference (IntelliSys) 2022 which was held in a hybrid mode on 1 and 2 September 2022. IntelliSys was designed and organized in such a wonderful manner in Amsterdam, the Netherlands, that in-person and online delegates shared their valuable research in an engaging discussion, and hence, we were able to take advantage of the best that the two modalities can offer.

IntelliSys is a prestigious annual conference on artificial intelligence and aims to provide a platform for discussing the issues, challenges, opportunities and findings of its applications to the real world. This conference was hugely successful in discussing the erstwhile approaches, current researches and future areas of study in the field of intelligent systems. The researches managed to give workable solutions to many intriguing problems faced across different fields covering deep learning, data mining, data processing, human–computer interactions, natural language processing, expert systems, robotics, ambient intelligence, to name a few. They also let us see through what the future would look like if artificial intelligence was entwined in our life.

One of the meaningful and valuable dimensions of this conference is the way it brings together researchers, scientists, academicians and engineers on one platform from different countries. The aim was to further increase the body of knowledge in this specific area by providing a forum to exchange ideas and discuss results and to build international links.

Authors from 50+ countries submitted a total of 494 papers to be considered for publication. Each paper was reviewed on the basis of originality, novelty and rigorousness. After the reviews, 193 were accepted for presentation, out of which 176 (including 8 posters) papers are finally being published in the proceedings.

We would like to extend our gratitude to all the learned guests who participated on site as well as online to make this conference extremely fruitful and successful and also special note of thanks to the technical committee members and reviewers for their efforts in the reviewing process.

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-3-031-16074-5 ISBN 978-3-031-16075-2 (eBook)
<https://doi.org/10.1007/978-3-031-16075-2>

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We sincerely believe this event will help to disseminate new ideas and inspire more international collaborations. We kindly invite all to continue to support future IntelliSys conferences with the same enthusiasm and fervour.

Kind Regards,
Kohei Arai

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Implementation of Two-Layered Dynamic Pragmatics

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Abstract. The paper presents a program that models information exchange in natural language via a multiagent system in which – parallel to a changing model of the outside world – relevant segments of information states of Agents communicating with each other can be monitored by Users from step to step. The theoretical background is provided by ℑeALIS, ‘Reciprocal and Lifelong Interpretation System’: a two-layered dynamic pragmasemantic theory. The software executes generalized truth evaluation in a set of possible-world-like objects partially ordered via a label system defined by a recursive technique. The dynamic character is captured as follows: the program essentially models intensional profiles associated with Agents’ Utterances as transition rules of finite-state automata, the states of which are Phases, sums of moments of information states of the Agents thinking about the world outside and each other. It is also a crucial feature of ℑeALIS that it is a two-layered interpretation system: the Agents who can function as Speakers and Hearers take conventionalized Addresser and Addressee roles, defined in ℑeALIS as complex intensional profiles. As for practical applications of programs implementing the ℑeALIS model of human communication, it is of great importance in several areas of life and work to store information so that not only the pieces of information themselves be saved but, for each piece of data, information on such circumstances as who knows it, who knows about whom that the latter person knows or does not know it, who is authorized to reveal it, and who is assumed to be interested in its modification. It is worth learning from human ways of storing and organizing information as much as possible.

Keywords: Two-layered dynamic pragmatics · Formal semantics · Types of automaton · C#

1 The Main Purpose: Modeling Information Exchange in Hungarian via a Multiagent System

The program to be presented in the paper and the two-layered dynamic pragmatics project in its background pursue similar objectives to a program and project presented four years ago in Hungary [1, 2], but follow a new programmatic conception and rely on the current results of the NeALIS-approach [3] and the international dynamic pragmatics literature [4], see [5–8]. The program intends to model information exchange in natural language (Hungarian, in particular, at least initially) via a multiagent system [9] in which – parallel to a changing model of the outside world – relevant segments of information states of Agents communicating with each other can be monitored by Users from step to step, in Topics elaborated by themselves.

2 Topics, Events, Standings, Phases

A Topic consists of temporally arranged Events (or, more precisely, ‘eventualities’, including ‘states’, which can be characterized a simpler internal event structure than ‘events’ in the restricted sense). Claims can be made about temporary Standings of Events, on the basis of the general event structure presented in Fig. 1 [10]. If this scheme is applied to a man’s Event of traveling home, the Standings (in the sense ‘the way things stand’) that belong to the four phases can be formulated in English/Hungarian as follows (among others), from left to right:

- *he will travel home/haza fog utazni* ‘home will to-travel’,
- *he is going/about to travel home/hazautazófélben van* ‘home-traveling-towards-in’,
- *he is traveling home/utazik haza* ‘travel home’,
- *he has traveled home/(már) hazautazott* ‘(already) home-traveled’.

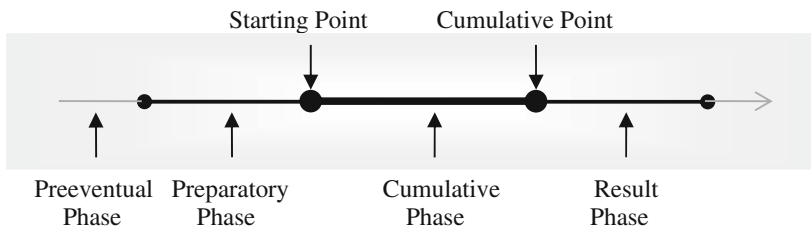


Fig. 1. General event structure

The sum of momentary Standings constitutes a temporary outside-world model, with which, in favor of a uniform treatment of steps of communication, an Oracle is worth „trusting”: a distinguished Agent of the multiagent system who is assumed to have solid knowledge on the truth values of all Standings at each moment taken into consideration. Other Agents do not (necessarily) have solid knowledge on the Standings but truth-evaluate them in (essentially Montague-style) alternative possible worlds [11], which are to be regarded as collection points of their (more or less strong) hypotheses, wishes, intentions. An Agent’s temporary information state can be captured as a (Kamp-style) representation [12] of a potential discourse in which he or she would summarize his/her thoughts concerning the Standings taken into consideration, classified according to attitude types [13]. The classification according to attitude types’ typically means that a Standing is assigned to more than one attitude, e.g.

- *I am almost confident in this,*
- *but it does not make me happy,*
- *so I wish I could modify it,*
- *through raising another Agent’s intention to carry out its modification.*

Inside a Topic, the Users can monitor the Standings in a few Phases of the Events that belong to the given Topic; in particular, they typically monitor the procedure in the course of which the Agents’ sentence-size Utterances – as actions by speech [14] – produce successive Phases. On the basis of this, a Phase is a relation in which Standings are associated with possible-world-like objects called ‘worldlets’ in ReALIS, having regard to the typically minor information content of these objects. A Phase can also be interpreted as the complex truth evaluation of the relevant Standings in the Oracle’s and all the other Agents’ worldlets. An Utterance concerns a Standing, modifying the Phase so that the Agents participating in it as Speakers or Hearers associate the given Standing with worldlets in the output Phase in another way than in the input Phase.

Let us consider the following simple example about the Utterance ‘Barça won last night’. Suppose an Agent, who could not watch the match in question (and has all confidence in the speaker), gets a Hearer of this Utterance. While, in the input Phase, his relevant possible-worldlet-evaluations concerning the victory can be formulated as, say, [he *longs for* this victory] and [*considers* it more or less *probable*], the output Phase can be characterized by worldlet-evaluation which can be expressed as follows: [he *considers* Barça’s victory to be *a fact*] [and (he considers to be a fact that the Speaker also considers Barça’s victory to be a fact), etc.].

3 Methods I (First Approximation): Finite-State Automata to Formulate Transitions from Phase to Phase

Phases can be captured (at least as a first approximation) as states of finite-state automata [15], with transition rules understood as the “reading off” of Utterances concerning States. Put simply, a transition is a Speaker Agent telling a Hearer Agent an Utterance. The input condition for a transition rule is that the Addresser role and the Addressee role defined in the *intensional profile* of the given Utterance can be *unificated* (in the

sense the term of ‘unification technique’ is used in Prolog) with the information states in the given Phase of the Speaker and the Hearer, respectively. The term of an *intensional profile* is illustrated by the three fundamental intensional profiles presented in Table 1. First of all, however, it is necessary to clarify that two-layeredness, which appears even in the title of the paper, is a crucial property of the underlying dynamic-pragmatics stance: the ‘Speaker’ as an Agent (with a mind containing an information state) is not a terminological alternative to ‘Addresser’ but the latter is a role that is set as part of linguistic convention [16]. Similarly, the ‘Hearer’ as an Agent (with a mind containing an information state) is not a terminological alternative to ‘Addressee’, either, but the latter is another role that is set as part of linguistic convention [16].¹ By his/her Utterance, the Speaker Agent has ‘taken the Addresser role’, which essentially corresponds to Searlean *illocutionary act* [17]. The Speaker also typically offers, by an Utterance, an Addresser role to the Hearer Agent, who can ‘accept this role’; some parts of these moments already belong to the mechanism of Searlean perlocutionary effect. In our approach, thus, acting by speech is captured as a transition rule between states of a finite-state automaton as follows. The input condition for the transition is ability for unification between the conventionalized roles and the interlocutors’ current information states. The output situation is the new pair of information states that the execution of the given unification results in, or more precisely, the Phase version the modified part of which (relative to the input Phase) is exactly the renewed pair of information states.

The series of examples below is devoted to present the sentence types with the three fundamental conventionally specified uses: the *declarative*, *imperative* and *interrogative*

¹ Oishi [16] offers (p. 338) a (terminological re-) interpretation of Austin’s [14 felicity conditions (pp. 14–15) as follows: “To clarify how an illocutionary act is performed felicitously and brings about an effect, let us specify the terminology. A particular speaker in a given case who makes an utterance... is distinguished from the performer who performs a particular illocutionary act..., whom we call the *addresser* of the act. The hearer to whom the speaker speaks... is also distinguished from the person to whom the illocutionary act is performed..., whom we call the *addressee* of the act. The circumstances of the situation in which an utterance is made... Are distinguished from the *context* of the act... The illocutionary act brings about its conventional effect when (i) the speaker, the hearer, and the circumstances of the speech situation are assumed to be the addresser, the addressee, and the context of the act, respectively..., (ii) the speaker follows the procedure correctly..., (iii) the hearer ratifies the act (or the speaker makes a specific sequel) for the procedure to be completed..., (iv) the speaker has the thought or feeling, or intention of the addresser of the act..., and (v) the speaker or the hearer conducts her/himself subsequently as is specified for the addresser/addressee of the act.”.

conventions [19].² An intentional profile assigned to a sentence type practically consists of the worldlets concerned with the truth valued defined in them.

DECLARATIVE SENTENCE TYPE: He has traveled home. (1a)

IMPERATIVE SENTENCE TYPE: Travel home! (b)

INTERROGATIVE SENTENCE TYPE: Has he traveled home? (c)

The profiles given in Table 1 are shown, having regard to the fact that this paper is not a linguistic paper, chiefly in favor of the mere illustration of the build-up of the relevant data types with meager reference to their linguistic/pragmatic content. The interested reader is referred to the cited references listed in [20] for detailed description of pragmatic and semantic details.

It is by a label system that worldlets are identified and arranged in a partially ordered network. A simple label shows whose attitude is considered (i: *I*, u: *you*, o: *other person*), and what kind of attitude it is (B: *belief*, D: *desire*, I: *intention*, A: *authority*, E: *experience*). It also shows the moment when the given truth evaluation is carried out. The type of truth evaluation we use contains, besides the traditional values ‘false’, marked with -5 , and ‘true’, marked with $+5$, further in-between values, which has begun to

² Lauer’s formal-semantics based Dynamic Pragmatics [19] has the same point of departure as that of ReALIS, in contrast to less formal branches of pragmatics (pp. 4–5): “There is surprisingly little work on the conventional link between clauses of different types and their use, at least in the formally-oriented semantics literature. There was some early work on this issue in philosophy ..., but soon, it seems, researchers abandoned the issue. In part this was likely due to the fact that the dominant paradigm in speech act theory ... made the project of assigning a conventionally-specified use to sentences based on their type seem hopeless: Sentences of any given type can be used to perform acts of almost any given Searlean illocutionary type. Developing a systematic framework for studying the conventionally specified use of sentences of different types is thus a very timely project. Secondly, it is this conventional connection between sentences and their use that connects semantic content, as it is studied in linguistics, with language use, and inferences about utterance choice. As I just pointed out, the classical Gricean account of implicatures [18] starts from the assumption that a speaker utters a (declarative) sentence in order to convey information, and thus... Presupposes an answer to the question of how sentences are conventionally associated with a certain use. And if we want to take a Gricean perspective more generally – if we want to investigate how interlocutors reason about each other’s action choices – we need to know how the contents we study in linguistic semantics relate to the use of sentences. An understanding of clause typing thus is central to developing a formal framework that lets us take a pragmatic perspective in general.” Lauer qualifies his approach (p. 1) as “pragmatics, in a broadly Gricean sense. It is not... About conversational implicatures, at least not in the classical sense of the term. [It concentrates]... on a question that may seem quite un-Gricean, due to its focus on linguistic convention: What kind of linguistic convention makes it so that sentences of different types – such as declaratives, interrogatives and imperatives – are used in different ways, and support different kinds of pragmatic inferences? This question, however, will be addressed from a very Gricean angle. Pragmatic inference is construed as language users’ reasoning about utterance events. Or, more precisely, as language users’ reasoning about how utterance events are chosen. A central aim... is to show that consistently taking such a perspective is fruitful, indeed, necessary if we want to understand language use.”

Table 1. Intensional profiles of the three major sentence types [5], as a generalization of the Gricean maxims of cooperative agents' actions by speech [18].

GOAL-ORIENTED MENTALIZATION	DECLARATIVE	IMPERATIVE	POLAR INTERROGATIVE
	BASIC	BASIC	BASIC
For e : iB	$iB=+5_\alpha$	$iB=-5_\gamma$	$iB \in "0"$
$iBuB \in "+5$	$iBuB \in "0"$	$iBuB = "+5 \bullet \gamma$	$iBuBiB \in "+5 \bullet +5 \bullet "0"$
For e' : $\dots \bullet W$, $r \in R \subseteq \{i, u, o\}$,	$W = uB \uparrow$	Default: $e' = res_e$	$W = iB \uparrow$
$(\Sigma iBrD \cdot iBrD) / (5 \cdot R)$ $\in "+5$	$iBrDuB \uparrow = 5$ β	For e' : $iBrD$	$iBrDiB \uparrow = \beta$
$iBuA \in "+5 \bullet "+5$	$iBuAuB \uparrow = \beta$	For e' : $iBuA$	$iBuAiB \uparrow = \beta$ crucial component: $iBuB = \xi \in \beta = 5$
For e'' : $iIuI \uparrow \in "+5 \bullet +5$	$iIuI \uparrow uB \uparrow = \alpha$	For $e'' = e$: $iIuI \uparrow$	$iIuI \uparrow iB \uparrow = \xi$
$iAiIuI \uparrow \in "+5$	$iAiIuI \uparrow uB \uparrow = \alpha$	$iAiIuI \uparrow$	$iAiIuI \uparrow iB \uparrow = \xi$

be an established practice in dynamic pragmatics [4]. In dimension B, the epistemic dimension of beliefs of different strength degrees, for instance, value zero refers to the total lack of information (and bias), whilst values +1, +2, +3 and +4 express that a Standing is probably true, with the corresponding values -1, -2, -3 and -4 expressing its false status. The knowledge of the Addresser of a (pragmatically unmarked) declarative sentence (iB : "I believe"), for instance, can be characterized by +5: by the Utterance in (1a), one expresses that, at least according to his/her momentary information state (marked with ' $iB0$ ', or simply ' iB ', with no reference to anteriority or posteriority), the person referred to in the sentence *has* traveled home, with no doubts. In the case of an imperative sentence (1b), the Addresser commits him-/herself to the stance that the given Standing does not exist (-5), since he/she just expresses that it is desirable to take steps to achieve the Standing. In the case of a polar question (1c), the expressed knowledge of the Addresser can be characterized by the values in set $\{-4, -3, -2, \dots, +4\}$, marked with "0" in the table ('a set of numbers around zero'); this expresses that the Addresser considers the given Standing to be neither true nor false. The traditional two-valued truth evaluation thus has been generalized in a way that not only the eleven values of set $\{-5, \dots, +5\}$ are exploited but also its subsets.

It is worth at this point exemplifying the concept of 'ability for unification', mentioned in the first paragraph of Sect. 3. If Utterance (1c) has come from a Speaker who assigns probability +2 to the result state of the event of traveling home (see Fig. 1) as the Standing concerned, that is, he/she thinks that the person referred to in the sentence is *likely* to have traveled home, then he/she has legitimately taken the interrogative Addresser role, since $+2 \in \{+1, +2, +3 \text{ and } +4\}$. The relevant segment of the intensional profile of the conventional Addresser role thus could be unified with the assumed information state of the Speaker. Note in passing that there are only two B-values at the Oracle's disposal: +5 (true) and -5 (false), the two traditional truth values, because it is unequivocally defined in which Standing an Event "stands" in a particular Phase (see Fig. 1).

In order to make the linguistic picture somewhat less obscure, we discuss, relative to the epistemic background concerning Beliefs (sketched above), the criteria concerning Intentions, held to be crucial in classical pragmatics. The shared initial segment of the relevant labels in Table 1 is $[i|u|↑]$, which can be formulated in English as follows: “I intend you to intend to ... (as an output effect of my Utterance as an action by speech).” In the case of the imperative type, there is an Addresser who considers the non-existence of a particular Standing to be a shared knowledge with the Addressee; he/she thus intends the Addressee to intend to realize the existence of the given Standing. In the case of a question, the Addressee is expected to make his or her piece of information, assumed to be reliable by the Addresser ($uB=ξ \in \beta=5$, where symbol 5 marks the set $\{-5, +5\}$), available to him/her, the Addresser ($iB↑=ξ$, that is, “the Addressee is expected to strive for a Phase in which both interlocutors are aware of the truth value of a the given Standing). A declaration functions inversely: the output shared knowledge depends on the Addressee’s inclination for accepting ($uB↑=+5$) what is offered by the Addresser as part of his/her “input knowledge” ($iB = +5$).

In all three cases, the basic version of the output of the Utterance (as a transition rule of an automaton) is a Phase in which the Hearer Agent, as part of his/her Addressee role, has “already” *have* the expected intention (to carry out something / to give or accept a piece of information). A further *default* modification of Phases is the replacement of the triggered intention with the accomplishment of the action itself that the given intention concerns. What is referred to as ‘the accomplishment of the action’ can entirely uniformly be treated in the three fundamental intensional profiles, due to the building of the Oracle into our model of communication. It is obvious that the given Phase, in the case of questions and declarations, can uniformly be characterized by the assignment of one of the truth values $+5$ and -5 to a Standing in a certain worldlet in the appropriate interlocutor’s information state. In the case of the imperative profile, it is the Oracle whose appropriate information state is regarded as getting updated with the assignment of one of the classical truth values to a Standing of an Event. If someone had been instructed to travel home, for instance, as in (1c), and he/she *has* traveled home as an accomplishment of the instruction, then the achievement of the given result phase of the traveling-home Event – as an assignment of $+5$ to the corresponding Standing – appears in a certain Phase in the Oracle’s information state.

The model of human communication sketched so far, however, is still insufficient: an instance of ability for unification (as an input condition defined in the intensional profile that belongs to an Utterance) must not be understood as *deterministically* leading to the successful execution of the unification (as part of an output Phase). Instructions may remain undone, questions unanswered, declarations unaccepted. Fortunately, all this can be accounted for due to the two-layered character of our ReALIS-based model of communication. As for the implementation, Users are authorized to give Agents more freedom than automatically executing the available transition rules of finite automata along intensional profiles, characterized as ‘default’ above. This topic will be returned to in Sect. 5.

4 Methods II: Integration of Discourse Markers as Transition-Rule Modifying Linguistic Elements

This section presents the crucial components of the intensional profiles of four Hungarian discourse markers/particles. It is held to be the definitive element of being a *discourse marker* [21] that the insertion of a discourse marker in a sentence does not influence the descriptive content – that is, the truth-conditionally characterizable content – of the sentence; by which we can mean nothing else but truth evaluation according to the world outside. In the worldlets of interlocutors, the output of truth evaluation *does* change due to a discourse marker compared to that of the sentence-type hosting it; that is the task of discourse markers: to provide insight into complex attitudes in human minds. Linguist Users of the software should define intensional profiles for discourse markers by modifying the sets of worldlet labels of the host profiles. The resulting intensional profiles then function as new transition rules between Phases.

Let us now consider the four Hungarian discourse markers, italicized below, which are devoted to the illustration of the intensional influence of discourse markers.

Valószínűleg hazautazott. (2a)
likely home-traveled
'He is likely to have traveled home.'

CSAK hazautazott! (b)
only home-traveled
cca. 'He *did* travel home (as had been expected, contrary to opposite beliefs).'

Szerintem utazzon haza! (c)
according-to-me travel-should home
'He should travel home, that is my advice.'

Hazautazott, *ugye?* (d)
home-traveled QUESTION TAG
'He has traveled home, hasn't he?'

The contribution of the insertion of *ugye* in a polar question is the simplest case to capture (2d). This discourse marker basically *enriches* the host profile, without deleting its original components. It *adds* to the interrogative host profile that the Addresser is biased towards the positive variant of the answer, and he/she imparts this piece of information to the Addressee. In the next section, this profile will get a more thorough overview.

The contribution of *valószínűleg* to the basic declarative profile can be understood as the resetting of a "generator value", namely that of the Addresser's knowledge concerning the given Standing (2a). The degree α' of this knowledge is different from the original degree in the host profile, which is +5, so there is rather only a *hypothesis* at the Addresser's disposal. Nevertheless, he/she thinks that its reliability is still valuable compared to the degree of reliability of the Addressee's corresponding piece of information ($iBuB \leq \alpha'$), it is thus worth sharing with the Addressee (cf. $uB \uparrow = \alpha'$). The concept of a

Table 2. Contribution of discourse markers [5, 6, 7] to the three major intentional profiles

DECLARATIVE		IMPERATIVE	POLAR INTERROGATIVE
<i>valószínűleg</i>	METACOGNITIVE <i>CSAK</i>	<i>szerintem</i>	<i>ugye</i>
$iB=\alpha' \in '+4$	$iB=+5$	$iB=-5_{\gamma}$	$iB=\eta \in '+4$
$iBuB\leq\alpha'$	$iBuB=+5$	$iBuB\in''+5\bullet\gamma$	$iBuBiB\in''+5\bullet'+5\bullet\eta$
	$iB\geq iB\downarrow\downarrow>iB\downarrow$		
$iBrDuB\uparrow=5_{\beta}$	$iD\downarrow\downarrow\sim iD\downarrow\sim iD\in'+5$	For e': $iBrD$	$iBrDiB\uparrow\in\beta=5$
$iBuAuB\uparrow=\beta$		For e': $iBuA$	$iBuAiB\uparrow\in'+5\bullet\beta$ crucial factor: $iBuB=\xi\in\beta$
$iIuI\uparrow uB\uparrow=\alpha'$		$iIuI\uparrow\in'+4_{\chi}$	$iIuI\uparrow iB\uparrow\in'+5\bullet\xi$
$iAiIuI\uparrow uB\uparrow=\alpha'$		$iAiIuI\uparrow=\chi$	$iAiIuI\uparrow iB\uparrow\in'+5\bullet\xi$

‘generator value’ has been mentioned above due to the fact that the resulting profile due to the contribution of *valószínűleg* is described just like that of the host profile with the difference that a piece of information at the Addresser’s disposal regarded as a parameter in the two profiles is evaluated and transferred filled with another value.

Our software can capture the communication strategy of collecting information concerning a particular Standing from several different Agents, with the purpose of making the final decision on the basis of the sum of the information cumulated. It can also be taken into consideration which Agents can be regarded as ‘independent sources of information’ in the relevant respect: the Agents’ (permanently changing) relational networks in the world outside are stored in the Oracle’s (also permanently changing) information states. A finite-state automaton is insufficient to capture this strategy of communication; it should be equipped with some sort of memory to store the definitive properties of the pieces of information concerning the given Standing coming in several waves, for instance, minimal and maximal degrees of certainty.

The contribution of discourse marker *szerintem* [6] placed in a declarative sentence is similar to that of *valószínűleg*: the Addresser offers valuable but not fully reliable information, which does not come from immediate experience. In (2c), *szerintem* is placed in an imperative sentence, in which, instead of mitigating the degree values in the Belief-dimension, it mitigates the degree of Intention ($iIuI\uparrow\in'+4$). It softens pragmatically unmarked imperative sentences with a commending character to advices.

The stressed discourse marker *CSAK* illustrated in (2b) has an intensional profile in which three temporal variants of the Addresser’s permanently changing information state are referred to [7, 8]. The particular sentence presented in (2b), for instance, can plausibly be interpreted as follows. At the current moment it is claimed to be a fact that someone has traveled home. There was also an old moment when this traveling-home event seemed to be likely or sure to come true ($iB\downarrow\downarrow$). This Hungarian discourse marker, however, also expresses that there was at least one moment when the given travel seemed to be uncertain or it seemed that it would never happen ($iB\downarrow$; and the change in expectations can be expressed by relations between the numeral degrees assigned to the worldlet segments iB , $iB\downarrow$ and $iB\downarrow\downarrow$). This discourse marker can thus be called ‘metacognitive’ as the Addresser refers back to earlier states of his/her mind. In order to capture this metacognitive character, the originally proposed finite-state automaton is

obviously insufficient. Some kind of memory is required to store maximal and minimal epistemic values of certainty associated with certain Standings in certain worldlets in Phases changing in time.

5 Methods III: Automata Equipped with a Memory Stack to Capture Users' Complex Decision-Making Mechanisms

In this section, we follow the argumentation in favor of modeling human communication with automata which are necessarily to be equipped with memory stacks in order to store, in each Phase, information concerning earlier Phases. The argumentation is based on a coherent series of analyses of pragmatic phenomena in the theoretical framework of *ReALIS* [5].

Let our point of departure be the observation that certain sentence types, for instance, *optative* and *exclamative* sentences (being of reflexive, hesitative character) are *ab ovo* having intentional profiles containing no reference to an Addressee role. If, however, the intensional profile opted for by the Speaker is such that an Addressee role is defined in it, then there are criteria to decide not only whether the Speaker is suitable for the Addresser role on the basis of his/her information state but also whether a potential Hearer is suitable for the Addressee role, also on the basis of his/her information state. The technical background is always essentially the checking of ability for unification and then the execution of unification. Nevertheless, both steps can be overridden by potential Hearers, and hence by Users of our software who are assumed to intend to simulate real situations of human communication by using the Agents as their avatars. As for 'ability for unification', it is a well-known fact in pragmatics that a Hearer who is only partially suitable for an offered Addressee role has a certain amount of freedom to *accommodate* the Speaker's expectations concerning his/her information state. The given Hearer can act as if he/she matched the role. Or, oppositely, a Hearer can ignore certain elements of a Speaker's intensional profile by *creating* an Addressee role in the case of an exclamation, for instance, re-interpreting by this the exclamation as a declaration; simply saying, he/she exploits a piece of information not meant to him/her. Our permanently developing software can simulate more and more pragmatic phenomena of these types by ensuring Users the freedom of overriding what are offered *as default* by instances of ability for unification.

Let us now systematically overview four methods available to a Hearer of an Utterance in the area of developing his/her information state in the output Phase or in later Phases, with some delay.

The first method can be called *compliance with Addressee role*. In a *ReALIS*-style description, it can simply be captured, when a particular profile is considered, by collecting all worldlet labels of the profile with an initial segment *iB* – that is, labels with build-up *iB•W* with arbitrary label segments *W*, with the single criterion that *u* (referring to 'you', the Addressee) be referred to in *W* (as a string of symbols), and then by practically executing the given unification on all evaluations of *W*. The simple question in (3a), in English, for the sake of simplicity, will serve as illustration, but the analyses will rely on the intensional profile of the Hungarian *ugye*-question, presented in Table 2 in Sect. 4, see (3b-e).

Suppose the Speaker of the question in (3a) is a man who is taking part in a conference abroad and is calling his teenage daughter on mobile phone. This way the girl has been selected to be the Addresser of the Utterance. It should be known about her that she is now at an infamous festival with her disreputable boyfriend, by exploiting the week's absence of her father, contrary to her promise not to do such things instead of studying.

a. Zoe, at home, are you? (3)

b. $iBuB=5 \rightarrow iBuB=5 \rightarrow uB \in 5$ (in particular, $uB=-5$)

b'. $iBuBiB \in '+4 \rightarrow iBuBiB \in '+4 \rightarrow uBiB \in '+4$

b''. $iBuDiB \uparrow=? \rightarrow uDiB \uparrow=-5 \bullet 5$

c. $iIu \uparrow iB \uparrow = \beta' \in 5 \rightarrow iIu \uparrow iB \uparrow = \beta' \rightarrow uI \uparrow iB \uparrow = \beta' \rightarrow uI \uparrow iB \uparrow = \beta' (= -5)$

d. $iB \in '+4 \rightarrow uB \uparrow iB(\uparrow) \in '+4$

e. $iB \in '+4 \rightarrow uB \uparrow iI \uparrow uB \uparrow iB(\uparrow) \in '+4$ (factually, $uB \uparrow iB \uparrow = -5$)

In (3b-b''), three components of the intensional profile of *ugye*-question with reference to an Addressee are considered, and what is referred to above as 'execution of unification' is represented in (3b-b'') as a simple deletion of the shared *iB* worldlet-label segments.

By the given deletion, the profile element of the Addresser expressing that "the Addresser considers it to be a fact or at least likely that the Addressee knows the answer to the question" is replaced with a profile element expressing that "the Addressee knows the answer" (3b). Because of the special character of the question, except for fantastic or horroistic situations, it trivially holds for an arbitrary Hearer that he/she is completely suitable for this part of the expected Addressee role. Anyone necessarily knows whether he/she him-/herself is at home, or not. As for Zoe, she is completely suitable for the Addressee role on the basis of the easy criterion sketched: she is exactly aware of the fact that she is *not* at home (as for unification, $-5 \in 5$ in our special arithmetic as 5 marks the two-element set $\{-5, +5\}$). Nevertheless, she is not happy with this instance of compliance.

The criterion scrutinized in (3b') is the expectation towards the Addressee that she does not get surprised at the Utterance, namely the *ugye*-question (NB: as a question is practically an instruction, the interlocutors are assumed, as a point of departure, to share some knowledge concerning a "negative situation", which is the Addresser's incomplete knowledge concerning a certain Standing). That is, she must not be surprised at either the fact that the Speaker does not know whether she is at home or not, or the fact that she considers it likely that she is at home. As for the latter part, Zoe has made a promise not to go away during her mother's absence, so she must essentially be at home according to her mother; but a week is a period longer than the mother can expect that during it her daughter should never open the door at all, in order to do the shopping, for instance. Zoe is obviously suitable for this double criterion; she will not be happy with the question but she cannot be surprised at it.

The labels shown in (3b'') concern desires/interests towards the updating of the Addresser's information state with some piece of information at the Addressee's disposal. The reference to an *arbitrary* Agent by symbol r in Table 1 in Sect. 3 and Table 2 in Sect. 4 is intended to express the observation by experts of pragmatics that answering a question may serve the interest of not (only) the Addresser but, in general, members of a set R potentially to different extents. The Speaker thus decides whose desire/interest he/she thinks that his/her updating serves. Technically a weighted mean can measure the sum of desires, on the basis of which the Speaker should decide whether he/she is worth taking the Addresser role at all; but let us now restrict our attention to the particular story. If the father takes the Addresser role in a way that it is taken that $R = \{i\}$, that is, he considers only his own curiosity (which should be offered by the software as the *default* case), then the question of Zoe's suitability for the Addressee role does not emerge at all at this point. If, however, the father is hoping that his daughter will *proudly* say 'yes' to the question ($R = \{i, u\}$, and $iBuDiB\hat{+}=+4\bullet+5\bullet5$), he has been mistaken, since Zoe does not desire to inform him about the truth ($uDIB+= -5\bullet5$). In this latter case, thus, if the father is distrustful, Zoe is not an ideal Addressee, while in the former case, in which the father is naive, Zoe is a perfect Addressee on the basis of the calculations. There is no contradiction; what the different calculations provide is a complex analysis of the situation, including the consideration of the opposite interests.

The second method for a Hearer to build his/her output information state on the basis of the Addressee role offered to him/her can be called the *Realization of the central Intention*. As shown in (3c), the core of the calculation is the deletion of an iI worldlet-label segment from the single worldlet label including this segment. In the given case, what is calculated in the case of an *ugye*-question is the same as would be calculated in the case of a pragmatically unmarked basic polar question: "the Hearer, having taken the Addressee role, (already) intends to inform the Speaker about the truth value of a given Standing." As also shown in (3c), the *default* next Phase can also be calculated via deleting the initial segment of a worldlet label. This way the Addressee's triggered Intention is replaced with the result of the realization of what is intended: "the Speaker has received the answer to his/her question, which is a truth value already in his/her information state."

In our story, Zoe is at a crucial crossroads at this point. By taking the Addressee role, she starts the chain reaction just sketched, the final Phase of which is one in which his father has learned that she is not at home ($iB\hat{+}= \beta' = -5$), having broken her promise. It is up to the User whose avatar is Zoe how he/she sets the truth value of the worldlet-label segment $uI\hat{+}$ ("whether the Hearer comes to the decision to get inclined to tell the truth, or not"). Taking the Addressee role means the satisfaction of the Speaker's expectations by telling the truth. Telling a lie, however, means that the Speaker's expectations defined in the Addresser role have not been satisfied, so the Hearer has not taken the Addressee role. The Speaker cannot notice, at least immediately and purely on the basis of the false answer, that the Hearer has not taken the Addressee role; it is in this way that a lie can function effectively.

Compliance with Addressee role and *Realization of the central Intention* are obligatory parts of (the taking of) the expected Addressee profile. This does not mean that it is obligatory to take the Addressee role but it means that the Addressee role is to be

regarded as having been completely taken only if these two methods have been completely executed. There are two further methods, however, which are factually *optional*. They make it possible to calculate *implications* on the basis of the Addresser's intensional profile, which has been *exhibited* by the Utterance and hence has turned into the basis of revealing the Speaker's information state in the given Phase.

The third method can be called *Raising awareness of profile elements*. Any element of the intensional profile exhibited by the Speaker via the Utterance can be regarded as having made publicly available, and hence can be built in the Hearer's output information state as a generalization of the unificational procedure executed on the Addressee's role. As shown in (3d), the technical realization of the application of this method consists of the adjunction of a worldlet-label segment $_{uB}\uparrow$ to the given input profile element together with the degree value assigned to it ("from now on, it also belongs to the Addressee's knowledge that...").

In (3d) it is illustrated how awareness of the Speaker's profile element concerning his/her knowledge on a Standing can be raised. Zoe can draw the conclusion by this method that "my father considers it likely that I am at home (so he trusts my words)."

Even an *ugye*-question can serve as the source of information, say, for a slow learner. Suppose that a slow learner pupil is hearing the question *Finnland's capital is Helsinki, isn't it?* from a good pupil. He or she can then store the piece of information according to which Finland's capital is Helsinki. He is aware of the fact that this is not necessarily a true fact (as a piece of information is taken over together with its certainty degree) but "better than nothing". It is possible, thus, that someone who has no answer to a biased question, and hence is not suitable for an Addressee role, re-interprets the Utterance type from question to declaration and obtains a more or less valuable piece of information from the Utterance. Modeling human communication thus requires more complex a tool than a deterministic finite-state automaton, which can capture the steps of communication in the course of which unified interlocutors' roles push forward Phases; certain pragmatic phenomena can be modeled in a way in which Hearers have recourse to other methods than what come as a *default*.

The other accommodation-based strategy is *Suspicion*, the essence of which can be elucidated by providing the technical detail that the Addresser's profile element opted for by the Hearer should be completed with the complex worldlet-label segment $_{uB}\uparrow i\uparrow_{uB}\uparrow$ as an initial part (3e). The method can be regarded as an extraordinarily cautious alternative to raising awareness of the profile element opted for: instead of taking over a piece of information, the Hearer reaches the conclusion that "the Speaker intends me to take over the given information by acting as if it were part of his/her information state".

It is sketched in (3e) that Zoe begins to suspect that her father has left the conference earlier in order to check his daughter's reliability, and he has already been at home and attempted to figure out where Zoe can be found. Meanwhile he wants his daughter to think that he is still at the conference and trusting her words.

The four methods may lead to the proliferation of worldlets in interlocutors' information states. As they rely on simple, exactly defined operations on worldlet labels (practically concatenation between series of symbols), their local treatment by the software is unproblematic. It is highly problematic, however, to cope with the global problem

of the proliferation of worldlets; instead of which Users should be “entrusted” with the task of deciding from Phase to Phase which subset of the entire set of available steps (sketched in this section) should be carried out. The automaton modeling human communication, however, should save, in each Phase, the relevant data characterizing a few earlier Phases, in order to make it possible to carry out later what could have been carried out earlier. This requires automata equipped with memories.

6 A Few Comments on the Functioning of the Program

The program is written in C#, and it has two major parts considering its functioning.

One part was established for data management, as one of the main goals is filtering the data concerning mental states, eventualities, worldlets. Thus, an SQLite database for datastore is used for this purpose and for handling the linkage between data models.

The other part is responsible for reaching and using data. Different mental states can be edited and assigned to different referents. A visual surface makes possible data

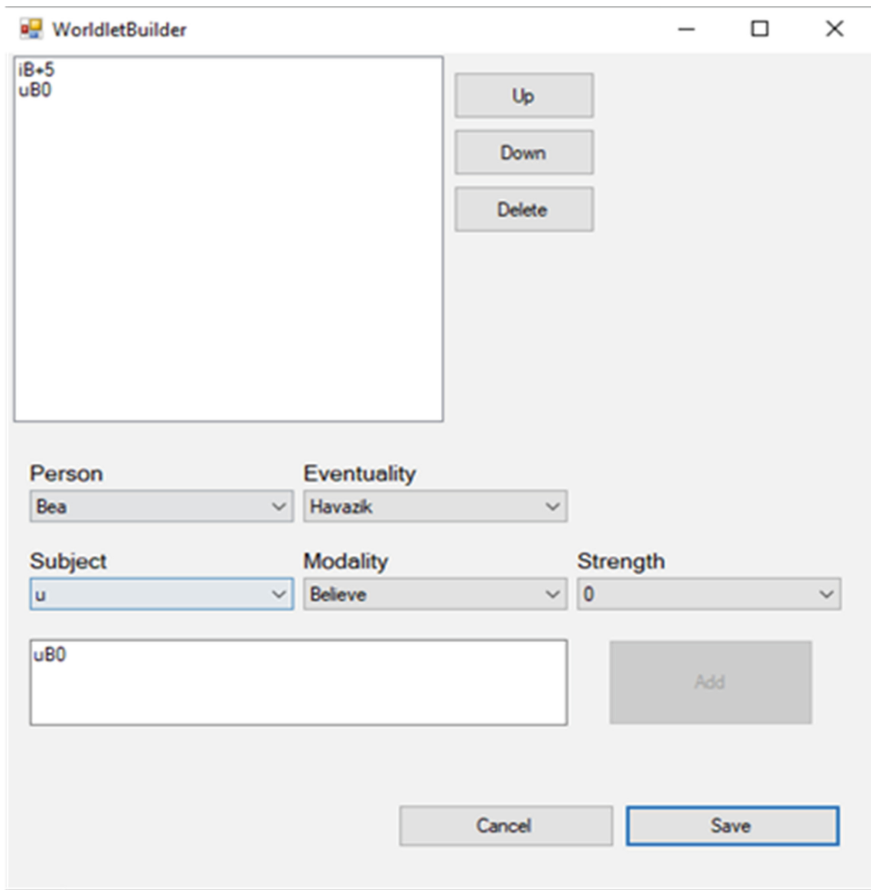


Fig. 2. Visual surface for editing worldlet labels

upload for linguists (see Fig. 2) and the usage of basic functions for all the users (see Fig. 3). Based on the stored data a truth-evaluation of the appropriateness is possible considering the speaker and the listener both.

This two-layered structure enables to establish a multiplatform system in the later stages of the modeling.

Addresser	Addressee	Oraculum	Anna	Bea
Anna	Bea	Havazik: +5 Anna: IB+5 · Havazik Anna: IB+5uB0 · Havazik (u:Bea) Bea: IB0 · Havazik	IB+5 · Havazik IB+5uB0 · Havazik (u:Bea)	IB0 · Havazik

Fig. 3. Visual surface for the basic functions

7 Summary, Improvement, Applications, Future Research

As a first step, we would like to take advantage of the software in the legitimation of *ReALIS*, ‘Reciprocal and Lifelong Interpretation System’, which can be characterized within the world of formal linguistics and within the world of cognitive sciences as a two-layered representationalist dynamic pragmasemantic theory [1, 3, 6, 8, 20]. The software executes generalized truth evaluation in a set of possible-world-like objects partially ordered via a label system defined by a recursive technique; that is how it serves as an implementation of *ReALIS*, which is to be regarded as a Montague-style *interpretation system* [11]. The chief way of the verification of the legitimacy of a formal theory is to prove that algorithms can be based on its toolkit, then programs can be written on the basis of the algorithms, which are capable of simulating the phenomena described by the theory. The *reciprocity* of *ReALIS* is captured by the system of these *worldlets*, which are to store a multiagent system’s [9] Agents ‘thoughts concerning, besides the world outside, each other’s’ thoughts. The *dynamic* character is captured as follows: the program essentially models intensional profiles associated with Utterances of the Agents as transition rules of finite-state automata, the states of which are Phases, sums of moments of information states of the Agents thinking about the world outside and

each other (and each other's thoughts on each other's, etc.). It is also a crucial feature of *ReALIS* that it is a *two-layered* interpretation system: the Agents who can function as Speakers and Hearers take conventionalized Addresser and Addressee roles [16], defined in *ReALIS* as complex intensional profiles. The profiles, on one hand, serve as criteria checking in the input Phase of Utterances whether interlocutors' roles can be unified with their momentary information states, and on the other hand, determine the output Phase, via updating the information states concerned with the results of the successful unification.

A finite-state automaton is obviously insufficient to capture the immense freedom by which Speakers can choose between several intensional profiles as well as Hearers can also decide whether they take the Addressee role offered by the Speakers, or refuse it, or accommodate certain profile elements, or create new profile elements by conventionally determined methods. The software can reward the optimal selection of profiles and roles in the given Phases, or punish incompatible selections of actions by speech, including telling bluffs or lies. This makes it possible to use the software as a game in which the Agents of the multiagent system modeling human communication can be used as avatars by its Users. They can work on the fulfilment of secret missions, selected randomly, as in *Risk* (e.g. "Zoe's father should be sure that his daughter is at home while Zoe's boyfriend should simultaneously think that Zoe does not tell lies so her father is aware of the fact that Zoe is not at home"), while permanently taking care of not collecting too many penalty points as a result of lies, bluffs and other instances of mismatch between intensional-profile components and information states.

As for potential ways to proceed, the *lifelong* character of *ReALIS* should also be built into the software. Let us consider the following case: someone arrives at home and tells his sister, who has been at home, *Are you at home?* Obviously, this is not the type of question which can be characterized by the basic polar interrogative intensional profile, sketched in Sect. 3. The Speaker must be aware of the fact that his sister is at home. Nevertheless, the Utterance can serve as some kind of question: *How is it possible that you are at home?* [8] Ideal answers, beyond the mere legitimation of the given type of question in the given situation, are to rely on *interpersonal* knowledge ("Well, I have said, indeed, that I want to take part in a conference; but yesterday the organizers sent me a message that it will be done on-line") or general *world knowledge* ("It is weekend. Are you aware of this fact?"). In the approach of *ReALIS*, Agents' information states are defined by *simultaneous recursion* from their birth, in a way that such concepts as episodic and semantic memory are also captured. As minds are permanently being fed by discourse representations [12], information states are plausibly to represent gigantic discourse representations, which serve as rich sources of interpersonal knowledge and general world knowledge. Processing each Utterance can potentially activate the entire content of interlocutors' information states. Events have not only well defined internal structures, sketched in Sect. 2, but also well-defined relational network, through which such pieces of general information are available that 'people do not work at weekend,' 'someone taking part in a conference means him or her not being at home,' but nowadays 'a conference can also be done on-line,' as well as such interpersonal knowledge as 'my sister is a research who often takes part in conferences.' The program should practically

gain such information by re-interpreting representations of episodic information as general semantic relations, via detaching particular stories with particular Agents as their participants from these Agents.

As for practical applications of programs implementing the *ReALIS* model of human communication, it is of great importance in several areas of life and work to store information so that not only the pieces of information themselves be saved but, for each piece of data, information on such circumstances as.

- who knows it,
- who considers it only likely,
- who thinks that it is false,
- who knows about whom that the latter person knows or does not know it,
- who is authorized to reveal it,
- and to whom,
- who is assumed to be interested in its modification,
- who is capable of executing some modification,....

It is worth learning from human ways of storing and organizing information as much as possible [22]. Alternative dynamic possible-world based interpretation systems [23], instead of this pragmatic aspect, exclusively concentrate on logicosemantic aspects of information organization.

Acknowledgment. Supported by the ÚNKP-21–2-I New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund.

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