Questions and Answers on Dynamic Activities of Agents

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Abstract. In a multiagent and multi-cultural world, the fine-grained analysis of agents' dynamic behaviour, i.e. of their activities, is essential. Dynamic activities are actions that are characterised by an agent who executes the action and by other participants of the action. Wh-questions on the participants of the actions pose a difficult particular challenge because the variability of the types of possible answers to such questions is huge. To deal with the problem, we proposed the classification of the participants of activities that is inspired by linguistic classification of verb valency verbs. The application of these results to the analysis of processes and events and to questioning and answering about these activities is a novelty of the paper.

Keywords: Activity · Communication of agents · Transparent Intensional Logic · Wh-questions and answers

1 Introduction

The primary goal of this paper is to *logically* analyse *processes* and *activities* so that the agents in a multiagent and multicultural world can ask on the participants of such activities. To this end, we have defined different kinds of possible participants of an activity; this classification is inspired by linguistic verb valency frames. Hence, different kinds of Wh-questions and plausible answers can be derived, as each specialised subtype of a Wh-question conveys specific information for an agent on how and where to seek the corresponding direct answer. In addition, by applying TIL deduction system, the agents can infer even more detailed answers, if needed. Thus, we wish to provide not only direct answers extracted from natural-language texts or agents' knowledge bases just by keywords; rather, we also want to derive logical consequences of such answers. Currently, the need of a hyperintensional approach to natural-language processing is broadly recognised. For these reasons, we vote for Transparent Intensional Logic (TIL) as our background theory.[1] Duží and Fait introduce in [7] Genzen's system of natural deduction adjusted for TIL and

[1] See, for instance, [5], [15], [14], [8].

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natural-language processing. The analysis of Wh-questions results into λ-terms with a free variable x ranging over entities of type α, which is the type of a possible direct answer. The system provides answers by suitable substitutions of the α-entities extracted from input sentences, the constituents of which match a given λ-term. It also makes it possible to derive as an answer even more information by applying the semantic rules rooted in the rich semantics of a natural language. In particular, the agents can make use of the relations of requisites and pre-requisites between intensions.

The rest of the paper is organised as follows. Section 2 introduces the basic principles of Transparent Intensional Logic (TIL) that is my background logical system. Section 3 introduces the main results of this paper; it deals with the TIL technique of answering Wh-questions, and concentrates in particular on the dynamic activities of agents. Concluding remarks can be found in Section 4.

2 Basic principles of TIL

Pavel Tichý, the founder of Transparent Intensional Logic (TIL) was inspired by Frege's semantic triangle.[2] However, while Frege did not define the sense of an expression but only characterised it as the 'mode of presentation', Tichý ([21], [22]) defined the sense of an expression, i.e. its *meaning*, as an abstract, algorithmically structured *procedure* that produces the object denoted by the expression, or in rigorously defined cases fails to produce a denotation if there is none.[3]

Tichý in [25] defined six kinds of meaning procedures and called them *constructions*. There are two kinds of atomic constructions that present input objects to be operated on by molecular constructions. They are *Trivialization* and *variables*. Trivialisation of an object X presents the object X without the mediation of any other procedures. Using the terminology of programming languages, the Trivialisation of X, denoted by '${}^0X$', is just a pointer or reference to X. Trivialization can present an object of any type, even another construction C. Hence, if C is a construction, ${}^0C$ is said to present the construction C, whereby C occurs *hyperintensionally*, i.e. in the *non-executed* mode. Variables produce objects dependently on valuations; they are said to *v-construct*. The execution of a Trivialisation or a variable never fails to produce an object. However, since TIL is a logic of *partial functions*, the execution of some of the molecular constructions can fail to present an object of the type they are typed to produce. When this happens, we say that a given construction is *v-improper*. This concerns in particular one of the molecular constructions, namely *Composition*, $[XX_1 \dots X_m]$. It is the very *procedure of applying a function f* produced by X (if any) to the tuple argument $\langle a_1 \dots a_m \rangle$ (if any) produced by the procedures $X_1, \dots, X_m$. A Composition is v-improper as soon as f is a partial function not defined at its tuple argument, or if one or more of its constituents $X, X_1, \dots, X_m$ are v-improper. Another molecular construction is *λ-Closure*, $[\lambda x_1 \dots x_m X]$. It is

[2] See [25].

[3] A similar philosophy of meaning as a 'generalized algorithm' can be found in [18]; this conception has been further developed by Loukanova, see [17].

the very *procedure of producing a function* with the values v-produced by the procedure X, by abstracting over the values of the variables $x_1, \dots, x_m$ to provide functional arguments. No Closure is v-improper for any valuation v, as a Closure always v-constructs a function (which may be, in an extreme case, a degenerate function undefined at all its arguments). Each construction C can occur not only in execution mode designed to produce an object (if any) but also as an object in its own right on which other (higher-order) constructions operate. The Trivialisation of C causes C to occur just presented as an argument, as mentioned above. Yet sometimes, we need to cancel the effect of Trivialisation and trade the mode of C for execution mode. Double Execution, ^2C, does just that; it executes C twice over. If C v-constructs a construction D that in turn v-constructs an entity E, then ^2C v-constructs E. Otherwise, ^2C is v-improper. Hence, the following ^{20}–Elimination rule is valid; for any construction C, $^{20}C=C$.

TIL is a typed λ-calculus. Hence, each entity, even a construction, receives the type to which it belongs. The inductive definition of the *ramified hierarchy of types*, as any inductive definition, consists of a base, inductive steps and the closure. For the purposes of natural-language analysis, we are usually assuming the following *base of ground types*: o (the set of truth-values true **T** and false **F**), ι (the set of individuals, i.e. the universe of discourse),[4] τ (times or real numbers) and ω (possible worlds). From these types of *non-procedural* objects, on the ground level of types of order 1, partial functions of type $(\alpha_1 \dots \alpha_m)$ are defined inductively. Second, constructions of order n are defined as those procedures that produce objects of a type of order m, where $1 \leq m \leq n$. However, these constructions form a higher-order type $*_n$, which is a type of order $n+1$. Finally, partial functions belonging to a type of order $n+1$ are of type $(\alpha\alpha_1 \dots \alpha_m)$, where at least one of the types $\alpha, \alpha_1, \dots, \alpha_m$ is equal to $*_n$.

Empirical expressions denote *empirical conditions*, which may or may not be satisfied at the world/time pair selected as points of evaluation. These empirical conditions are modelled as (PWS-)*intensions*. Intensions are entities of type $((\alpha\tau)\omega)$, or $\alpha_{\tau\omega}$, for short. *Extensional entities* are entities of a type α where $\alpha \neq (\beta\omega)$ for any type β.

Notational conventions. The outermost brackets of Closures are omitted whenever no confusion can arise. Furthermore, 'X/α' means that an object X is (a member) of type α, and '$X \to \alpha$' means that X is typed to v-construct an object of type α. Throughout, it holds that the variables $w \to \omega$ and $t \to \tau$. If $C \to \alpha_{\tau\omega}$ then the frequently used Composition $[[Cw]t]$, which is the *extensionalization* of the α-intension v-constructed by C, is encoded as 'C_{wt}'.

3 Wh-questions and answers

3.1 Technique of answering Wh-questions

From the logical point of view, *empirical questions* denote α-intensions and the direct answer to such a question is the value of type α of this intension in the

[4] We assume that the universe of discourse is a multi-valued set consisting of at least two elements, though we leave aside the cardinality of this basic type.

actual world and time.[5] Hence, the type of possible answer dictates the type of empirical question. Empirical Yes-No questions denote *propositions* of type $o_{\tau\omega}$, where o is the type of truth-values.[6] However, the variety of possible answers to Wh-questions is much greater depending on the type α of an α-intension. For instance, one can ask for the value of an *individual office* (or role) of type $\iota_{\tau\omega}$, like "Who is Miss World 2021"? A possible answer to such a question is a unique individual (an object of type ι who happens to play a given role). Another frequent type of intensions is the *property of individuals*, an object of type $(o\iota)_{\tau\omega}$. For instance, the direct answer to the question "Which Czech ladies are among the first fifty players in WTA ranking singles?" should convey a set (of type $(o\iota)$) of individuals. Currently (written 2021/11/12), they are Barbora Krejčíková, Karolina Plíšková, Petra Kvitová, Karolína Muchová, Marketa Vondroušová. Hence, the question denotes a property of individuals, namely that of being a female Czech tennis player among the first fifty in WTA ranking singles. One can also ask for the value of an attribute at an argument like the salary of somebody. The possible answer to the question "What is John's salary?" is some number of type τ. Hence, the question denotes a magnitude of type $\tau_{\tau\omega}$.

Duží and Fait in [7] introduce a useful logical technique of answering Wh-questions. The answers are obtained by suitable substitutions, i.e. unifications known from the general resolution method. For a simple example, assume that in an agent's knowledge base, there are these formalised sentences.

(1) $\lambda w \lambda t\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ ^0\mathit{Barty}] = {}^01]$
(2) $\lambda w \lambda t\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ ^0\mathit{Sabalenka}] = {}^02]$
(3) $\lambda w \lambda t\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ ^0\mathit{Krejcikova}] = {}^03]$
(4) $\lambda w \lambda t\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ ^0\mathit{Pliskova}] = {}^04]$
(5) $\lambda w \lambda t\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ ^0\mathit{Muguruza}] = {}^05]$
And so on ...

The answer to the question "Who are the first three players in WTA tennis singles"?, i.e.

$$\lambda w \lambda t\, \lambda x\, [[^0\mathit{WTA\text{-}ranking}_{wt}\ x] \leq {}^03]$$

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[5] Duží and Číhalová [6] distinguish between *direct* and *complete* answer to an empirical question. Direct answer is an object X of type α that is the value (in the world and time of evaluation) of the α-intension asked for, while complete answer is the proposition that the value of the asked intension is the object X. The authors deal with presuppositions of questions. Their main thesis is this. If a presupposition of a given question is not true, then there is no direct answer. Instead, a plausible complete answer is the negated presupposition.

[6] For details on TIL analysis of questions and answers see [9, §3.6].

is derived like this. Question (raised in a given w and t)[7]

(6) $\lambda x\, [[{}^0WTA\text{-}ranking_{wt}\, x] \leq {}^03]$

(7) $[[{}^0WTA\text{-}ranking_{wt}\, x] \leq {}^03]$ 6, λ-E

To answer the question, the algorithm searches a given knowledge base for those sentences the constituents of which match with (7). In addition, basic algebraic operations can be applied. Thus, the first matching sentence is (1), as $1 \leq 3$. By substituting ${}^0Barty$ for the variable x, we obtain the answer $x = {}^0Barty$. Since the question concerns the set of three individuals, the algorithm searches for another matching sentence, which corresponds answering the question "Who else"? In the exactly same way, the answers $x = {}^0Sabalenka$ and $x = {}^0Krejcikova$ are conveyed.

Though WTA tennis ranking is changing frequently, as these are empirical facts, from the point of view of dynamic behaviour of agents, the analysis of their activities is the most important issue.

3.2 Dynamic activities

A large number of Wh-questions concerns the participants of activities. Yet, these participants often belong to just one logical type, which is too coarse-grained. We need more detailed classification of their types. Linguistic classifications of Wh-questions are mostly based on the types of question pronouns, i.e. descriptors of interrogative sentences, for example, why, where, how, etc.[8] Descriptors refer to objects of various types. In other words, Wh-questions can ask for time, reason, manner, individuals, the definition of something, etc. Hence, a significant amount of different types of queries belong under the umbrella of Wh-questions.

Our specification of *activities* is based on the linguistic theory of *verb valency frames* and on their logical analysis.[9] From the logical point of view, we deal with the verb phrases as denoting a *function* that is applied to its arguments. The number of arguments is controlled by the content verb valency.[10] Verb valency frames determine the obligatory and facultative arguments, i.e. thematic roles of a given verb, together with their types. Linguists have developed many classifications based on verb valency frames, for instance, VALLEX or Verba Lex.[11] Sowa [19] distinguishes several types of thematic roles, for instance, Agent, Beneficiary, Destination, Duration, Effector, Experiencer, Instrument, Location, Matter, Patient and so on (ibid., pp. 508-510). Thematic role or the

[7] When applying a proof in TIL, the first steps eliminate the left-most $\lambda w \lambda t$, which corresponds to two β-conversions. They apply the empirical assumptions to the world w and time t of evaluation to obtain a truth-value. Similarly, Wh-question transforms into a procedure producing an object of type α. For details, see [7].

[8] See, for instance, [11] and [27].

[9] For the linguistic theory of verb valency frames, see [13]; see also [2] for the proposal of an ontology of events based on the theory of verb valency frames.

[10] For details, see [3].

[11] See, for instance [16] and [12].

type of participant expresses the role that a noun phrase plays with respect to the activity described by a governing verb. From the viewpoint of logic, it is the relation between two entities where one of them is an activity (expressed by the verb), and the other is a participant (expressed mostly by a noun, adverb or adjective). The number and the categories of participants depend on the respective domain of interest and the functions of the system of agents. Being inspired by these ideas, we primarily use the following frequent kinds of participants:

Pat; object affected by the activity
Ben; beneficient (somebody who has a benefit from the activity)
Manner; the manner of the activity execution (measure, speed etc.)
Inst; instrument
Time; when the activity takes place
Time1; when the activity begins
Time2; when the activity ends
Loc; the place of activity
Dir1; the direction of activity, from where
Dir2; the direction of activity, which way
Dir3; the direction of activity, where to

If needed, other kinds of attributes can be specified; we only must keep the selected keywords fixed.

Questions concerning activities can be on the process itself (what is going on?), questions on the primary agent (who or what is doing so and so) and on other participants of a given activity. For instance, assume we have the sentence "John (the agent) is going (the activity) to Brussel (Dir3) by car (Inst) at an average speed of 60 miles per hour (Man)." Then we can ask, "What is John doing?", "Who is going to Brussel?", "How quickly does John go to Brussel?", etc. Our classification enables an agent to look for sentences that might provide a plausible answer at an appropriate component of the agent's knowledge base provided this piece of knowledge is there, or ask their fellow agents, or look for the answer in the huge amount of natural-language texts available.

The basic idea of logical analysis of activities and events is due to Tichý [24]. Its adjustment and simplification have been introduced in [1]). Tichý draws a distinction between *episodic* and *attributive* verbs. Attributive verbs ascribe properties to individuals. Their structure is usually a copula followed by an adjective or noun; for instance, 'is happy', 'is red', 'looks speedy', 'is a student' are attributive verbs. On the other hand, episodic verbs express actions performed by entities. For instance, if John is getting up, it does not suffice to analyse this activity by assigning the property of getting up to John. Instead, John is *doing* the activity of getting up, and one can ask, for instance, "When does John get up?".

Each activity can be specified by a verb *Do*, and by *Who* (the actor), *What* (the activity that is being done), possibly with the attributes of the activity like objects to be operated on, resources, etc. Using a general place holder π for the type of activity and $\alpha^{Part\text{-}i}$ for an attribute/participant of a kind *Part-i*, the type of

Do is $(o\iota\pi)_{\tau\omega}$, and the assignment of participants to the activity is then an entity *Ass* of type $(o\pi\alpha^{Part\text{-}i})_{\tau\omega}$. To simplify the notation and make the formulas easier to read, we will use '${}^0X^{Part\text{-}i}$' instead of '$[{}^0Part\text{-}i\ {}^0X]$' to signify that X belongs to the class of participants *Part-i*. Thus, we obtain a general pattern for analysing an activity $P \rightarrow \pi$ with the actor $a \rightarrow \iota$ and participants $X_1^{Part\text{-}1}, \ldots, X_n^{Part\text{-}n}$.

$$\lambda w\lambda t\,[[{}^0Do_{wt}\ a\ P] \wedge [{}^0Ass_{wt}\ P\ {}^0X_1^{Part\text{-}1}] \wedge \ldots \wedge [{}^0Ass_{wt}\ P\ {}^0X_n^{Part\text{-}n}]]$$

For instance, the analysis of the sentence "*John builds a house in Bali*" comes down to this construction.

$$\lambda w\lambda t\,[[{}^0Do_{wt}\ {}^0John\ {}^0Build] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0House^{Pat}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Bali^{Loc}]]$$

It may happen that in another time John would build a house in Rome. Then we have

$$\lambda w\lambda t\,[[{}^0Do_{wt}\ {}^0John\ {}^0Build] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0House^{Pat}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Rome^{Loc}]]$$

For this reason, the relation *Ass* between an activity and its participant is the relation-in-intension rather than in extension.

If there are two or more actors of the activity, we apply the relation-in-intension $Do/(o\iota \ldots \iota\pi)_{\tau\omega}$. For instance, the sentence "*John and Tom build a house in Rome*" is furnished with this analysis.

$$\lambda w\lambda t\,[[{}^0Do_{wt}\ {}^0John\ {}^0Tom\ {}^0Build] \wedge \\ [{}^0Ass_{wt}\ {}^0Build\ {}^0House^{Pat}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Rome^{Loc}]]$$

If an agent *b* has in their ontology the specification of all the possible participants of activity, and *b* obtains an incomplete message concerning the activity, then *b* can ask his fellow agents for completing their pieces of knowledge. For instance, when receiving the first message about John's building a house in Bali, the agent can ask *when* and for *whom* does John build the house. To this end, we use variables $when \rightarrow (o\tau)$ and $whom \rightarrow \iota$, the valuation of which would be the answer. The content of the query is then this.

$$\lambda w\lambda t\,\lambda when\lambda whom\,[[{}^0Do_{wt}\ {}^0John\ {}^0Build] \wedge \\ [{}^0Ass_{wt}\ {}^0Build\ {}^0House^{Pat}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Bali^{Loc}] \wedge \\ [{}^0Ass_{wt}\ {}^0Build\ when^{Time}] \wedge [{}^0Ass_{wt}\ {}^0Build\ whom^{Ben}]]$$

A possible direct answer to agent *b* is $when = {}^0November\text{-}2021$, $whom = {}^0Marie$.

Another advantage of this approach is this. Since in TIL we have two modal parameters, time and possible worlds, we can easily analyse the activities executed in *past* or *future* and model dynamic behaviour and reasoning of agents. For instance, the question "*When did John build a house in Bali for Marie*"? receives this analysis.

$$\lambda w\lambda t\,\lambda when\,\exists t'\,[[[{}^0Do_{wt'}\ {}^0John\ {}^0Build] \wedge [t' \leq t]] \wedge \\ [{}^0Ass_{wt}\ {}^0Build\ {}^0House^{Pat}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Bali^{Loc}] \wedge \\ [{}^0Ass_{wt}\ {}^0Build\ when^{Time}] \wedge [{}^0Ass_{wt}\ {}^0Build\ {}^0Marie^{Ben}]]$$

The situation gets more complicated if a sentence in past or future comes with a *time reference T* when this or that happened or will happen. In such a case, the sentence is associated with a *presupposition* that the current time t is in the proper relation with respect to the reference time T. Roughly, it means that for sentences in future t comes before the reference time T, while for sentences in past t comes after T; if it is not so, then the proposition has a truth-value gap. Moreover, the sentence can also convey information on the *frequency* of the activity to be executed in the reference time T like twice, always, all the time since, for the whole year. Duží in [4] demonstrates the method of a fine-grained analysis of such sentences in past and future with a reference time interval T. In the paper, a general analytic schema for sentences that come associated with a presupposition is presented. To this end, the author utilises a strict definition of the *If-then-else-fail* function that complies with the compositionality constraint.

For instance, the truth conditions of the sentence "*John has built a house in Bali in 2020*" presuppose that the current time t in which the truth conditions are being evaluated comes after the end of 2020. If it is not so, the sentence has *no truth value*. Thus, we have

$$\lambda w \lambda t\ [\mathit{If}\ [t \geq_\tau {}^0 2020]\ \mathit{then}$$

$$[\exists t'\ [[{}^0 \mathit{Do}_{wt'}\ {}^0 \mathit{John}\ {}^0 \mathit{Build}] \wedge [{}^0 2020\ t']] \wedge$$
$$[[{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ {}^0 \mathit{House}^{\mathit{Pat}}] \wedge [{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ {}^0 \mathit{Bali}^{\mathit{Loc}}] \wedge [{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ {}^0 2020^{\mathit{Time}}]]]$$

$$\mathit{else\ fail}]$$

Additional types. $2020/(o\tau)$; $\geq_\tau /(o\tau(o\tau))$: the relation between the evaluation time t and time interval of the year 2020 such that t comes after the end of the year 2020.[12] The path with the statement 'else fail' means that the denoted proposition evaluates to *no truth value*.

However, if an agent asks without time reference, "*When did John build a house in Bali*?", then the test on the temporal presupposition validity is not applied, of course. Thus, we have $(\mathit{when} \to (o\tau))$

$$\lambda w \lambda t\ \lambda \mathit{when}\ [\exists t' [[{}^0 \mathit{Do}_{wt'}\ {}^0 \mathit{John}\ {}^0 \mathit{Build}] \wedge [t' \leq t]] \wedge$$
$$[[{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ {}^0 \mathit{House}^{\mathit{Pat}}] \wedge [{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ {}^0 \mathit{Bali}^{\mathit{Loc}}] \wedge [{}^0 \mathit{Ass}_{wt}\ {}^0 \mathit{Build}\ \mathit{when}^{\mathit{Time}}]]]$$

By applying the above-described method of unification, the direct answer is $\mathit{when} = {}^0 2020$.

The method of analysis takes also account of the *frequency* of the activity to be executed in the reference time interval *In-Time*. The general analytic schema for sentences S in past tenses is this.

$$\lambda w \lambda t\ [{}^0 \mathit{Past}_t\ [{}^0 \mathit{Frequency}_w\ S]\ {}^0 \mathit{In\text{-}Time}] =$$

$$\lambda w \lambda t\ \mathit{If}\ [{}^0 \mathit{In\text{-}Time} \leq_\tau t]\ \mathit{then}\ [[{}^0 \mathit{Frequency}_w\ S]\ {}^0 \mathit{In\text{-}Time}]\ \mathit{else\ fail}$$

[12] More on dealing with time and calendars can be found in [10].

Here $\leq_\tau$ means that the reference interval *In-Time* comes before time t, or, in general, in a proper relation with respect to time t. Past receives the same type as Future (which is applied for sentences in future), that is $((o(o(o\tau))(o\tau))\tau)$; S is the proposition to be evaluated and *Frequency* of type $((o(o\tau))o_{\tau\omega}\,\omega)$ is the frequency of time intervals in which the proposition S takes the truth-value **T** in world w. The schema for sentences in future tenses differs only by applying the constituent *Future* instead of *Past*.[13]

If John often built houses in Bali since 2007, then by applying the above schema, we obtain this construction.

$$\lambda w\lambda t\,[{}^0Past_t\,[{}^0Often_w\,\lambda w\lambda t\,[[{}^0Do_{wt}\,{}^0John\,{}^0Build] \wedge$$
$$[{}^0Ass_{wt}\,{}^0Build\,{}^0House^{Pat}] \wedge [{}^0Ass_{wt}\,{}^0Build\,{}^0Bali^{Loc}]]]\,{}^02007]$$

The frequency modifier *Often* denotes a world-dependent function that takes a proposition $p \rightarrow o_{\tau\omega}$ to the class of those intervals $d \rightarrow (o\tau)$ which are contained in the chronology of p (i.e. $p_w \rightarrow (o\tau)$). Letting aside vagueness of the term 'often', be it twice or three times a year, if these intervals are frequent since 2007, the proposition is evaluated to **T**.

4 Conclusion

In this paper, I dealt with logical analysis of Wh-questions and its utilisation in intelligent communication and reasoning of agents in a multiagent world. I introduced logical analysis of Wh-questions and the way of their answering by applying Gentzen's natural deduction system adjusted to natural-language processing in TIL. I concentrated on the dynamic aspects of agents' reasoning, in particular questions on participants of activities specified in different tenses with reference time and frequency when this or that activity happened or will happen to be done.

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[13] A detailed analysis of particular kinds of tenses can be found in [9, §2.5.2] or in [24].

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