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Datasheet for the decision of 8 May 2024

Case Number: T 1526/22 - 3.5.06

Application Number: 17208647.2

Publication Number: 3502976

IPC: G06N3/08, G06N3/04

Language of the proceedings: EN

Title of invention:
A STATE ESTIMATOR

Applicant:
Arriver Software AB

Headword:
Neural network-based state estimator/ARRIVER

Relevant legal provisions:
EPC Art. 84, 52(1), 56
RPBA 2020 Art. 12(4)

Keyword:
Amendment to case - amendment admitted (yes)
Clarity - all requests (no)
Inventive step - all requests (no)

Decisions cited:

T 0032/82, T 1055/92

Beschwerdekammern

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Case Number: T 1526/22 - 3.5.06

D E C I S I O N
of Technical Board of Appeal 3.5.06
of 8 May 2024

Appellant: (Applicant)	Arriver Software AB c/o Veoneer Sweden AB Datalinjen 3C 583 30 Linköping (SE)
Representative:	Loveless, Ian Mark Reddie & Grose LLP The White Chapel Building 10 Whitechapel High Street London E1 8QS (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 13 December 2021 refusing European patent application No. 17208647.2 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	M. Müller
Members:	M. Domingo Vecchioni
	A. Jimenez

Summary of Facts and Submissions

I. The appeal is against the decision of the examining division issued on 13 December 2021 to refuse European patent application no. 17 208 647.2.

II. The examining division refused the application on the basis that claims 1 and 12 did not meet the requirements of Article 84 EPC and claims 1 to 12 did not meet the requirements of Articles 52(1) and 56 EPC in view of the following prior art documents:

D1: B. Kim et al., "Probabilistic vehicle trajectory prediction over occupancy grid map via recurrent neural network", 2017 IEEE International Conference on Intelligent Transportation Systems (ITSC), 16-19 October 2017, pages 399-404, XP033330586,

D3: D. Mitrovic, "Short term prediction of vehicle movements by neural networks", 1999 Third International Conference on Knowledge-Based Intelligent Information Engineering Systems, 31 August - 1 September 1999, pages 187-190, XP010370945.

III. With the statement of grounds of appeal, the appellant requested that the decision of the examining division be set aside and that a patent be granted on the basis of the application documents according to the main request or the auxiliary request filed with the statement of grounds of appeal. The board understands from the notice of appeal, page 1, and the statement of grounds of appeal, section 1.3, that the appellant requested as further alternative that the case be remitted to the first instance for further prosecution.

IV. In a communication sent with the summons to oral proceedings, the board presented its preliminary opinion on the appeal. The following prior art documents were introduced, Article 114(1) EPC:

D7: C. Lundquist et al., "Joint ego-motion and road geometry estimation", Information Fusion, vol. 12, 2011, pages 253-263, XP093131958,

D8: S. Krebs et al., "A survey on leveraging deep neural networks for object tracking", 2017 IEEE International Conference on Intelligent Transportation Systems (ITSC), 16-19 October 2017, pages 411-418, XP033330551.

V. With a letter received on 2 March 2024, the appellant indicated that it would not be represented at the oral proceedings and had no further submissions to make.

VI. The oral proceedings were thereupon cancelled.

VII. Claim 1 of the main request reads as follows:

"An apparatus for a motor vehicle driver assistance system for an ego vehicle, the apparatus being configured to:

implement a state estimator configured to use a first state of the ego vehicle to calculate a subsequent second state of the ego vehicle, wherein calculating the second state from the first state includes a prediction element and an update element, wherein:

the prediction element includes implementing a prediction model to estimate the second state from the first state;

the update element includes implementing an update model to refine the estimated second state, wherein the update model refines the estimated second state on the basis of at least one value corresponding to a measurement of the second state, the at least one value being determined from a sensor measurement, and;

wherein calculating the second state from the first state includes using an artificial neural network ("ANN");

wherein the first state and the second state each include at least one ego vehicle attribute describing an aspect of a motion of the ego vehicle,

and the first state and the second state each include at least one local object attribute describing a local object located in the vicinity of the ego vehicle, wherein the local object is a local vehicle."

Claim 12 of the main request reads as follows:

"A method for estimating a state of an ego vehicle, the method being implemented on a compute module, the state being for use in a motor vehicle driver assistance system for the ego vehicle, the method including the steps of:

implementing a state estimator to use a first state of the ego vehicle to calculate a subsequent second state of the ego vehicle, wherein calculating the second state from the first state includes a prediction element and an update element, wherein:

the prediction element includes implementing a prediction model to estimate the second state from the first state;

the update element includes implementing an update model to refine the estimated second state, wherein the update model refines the estimated second state on the basis of at least one value corresponding to a measurement of the second state, the at least one value being determined from a sensor measurement, and;

wherein calculating the second state from the first state includes using an artificial neural network ("ANN") wherein the first state and the second state each include at least one ego vehicle attribute describing an aspect of a motion of the ego vehicle, and the first state and the second state each include at least one local object attribute describing a local object located in the vicinity of the ego vehicle, wherein the local object is a local vehicle."

VIII. Claim 1 of the auxiliary request differs from claim 1 of the main request in the following additional features:

(a) "wherein the at least one local object attribute includes a location of the local object";

(b) "wherein the apparatus is configured to output an output variable from the second state for use by an active driver assistance device or a passive driver assistance device".

Claim 10 of the auxiliary request differs from claim 12 of the main request in the additional features (a) and

(b') "outputting an output variable from the second state for use by an active driver assistance device or a passive driver assistance device".

Reasons for the Decision

The application

1. The application relates to a method (and a corresponding apparatus) for estimating a "state" of an ego vehicle, for use in a motor vehicle driver assistance system for the ego vehicle (original description, page 1, lines 2-3).

2. A driver assistance system needs to maintain a situational awareness about the current real-world situation of the ego vehicle. The situation of the ego vehicle "may include various categories of information: ego vehicle information (e.g. location, speed, heading, etc.), the surrounding environment information (e.g. position of lane markings, road signs, geographical markers, landmarks, etc.) and/or local object(s) information (e.g. position and velocity of local vehicle(s))" (page 2, lines 25-29).

   A mathematical representation of this real world situation at a single point in time is referred to as the "state" of the ego vehicle (page 2, lines 30-36).

3. An ego vehicle may be fitted with a number of different sensors and sensor systems. The information from the sensors may have an associated uncertainty (page 2, lines 20-24). The sensor measurements may be only indirectly related to the state to be estimated (page 8, lines 27-28).

4. The application first describes the conventional Kalman filter approach to the state estimation problem: "In general, a Kalman filter takes a first state and calculates a second state by a) predicting the second state

based on a physical model to form an intermediate state, and b) updating the intermediate state based on measurements of the second state (or parts of it)" (page 9, lines 22-24). It is illustrated in figure 2:

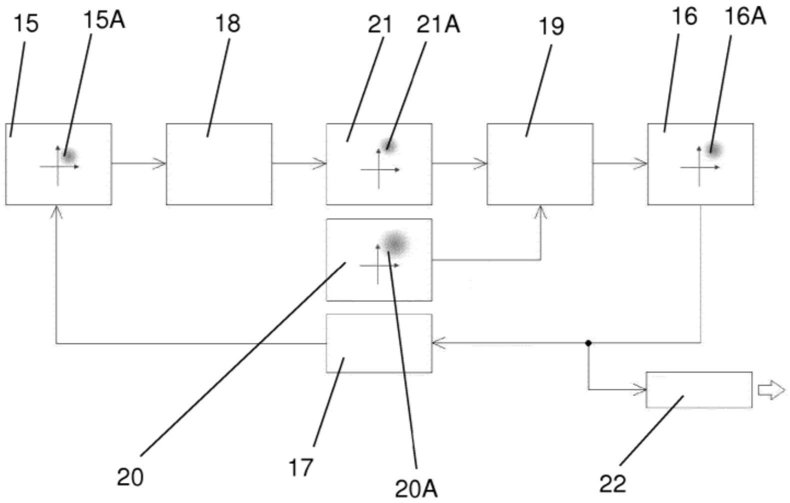

Fig.2

The state in a point in time k ("second state 16") is computed from the state in a previous point in time k-1 ("first state 15") and from measurements (20) taken at point in time k. The computation involves two stages: a "prediction" 18 (using a "prediction model"), yielding an intermediate estimate of the state in point in time k ("intermediate state 21"), followed by an "update" 19 (using an "update model"). The prediction and update models are typically defined by matrix operations designed based on domain knowledge (page 8, lines 1-33).

5. The present application proposes to use an artificial neural network (ANN) in this method (page 10, lines 11-12).

An ANN may, for instance, implement the prediction stage 18 (first embodiment, figures 4 and 5) or the update stage 19 (second embodiment, figures 6 and 7).

It is also proposed to use an ANN to replace the combined prediction and update stages (third embodiment, figures 8 and 9). This ANN may be a recurrent neural network (fourth embodiment, figures 10 and 11).

Using an ANN is said to have, inter alia, the advantage of allowing for nonlinear models and unknown or only partly known modelling equations; relationships between variables can be described that are highly nonlinear and may be of arbitrary complexity (page 10, lines 11-13; page 11, lines 9-10).

6. The present application also proposes that the first and second states of the ego vehicle each includes "at least one ego vehicle attribute" describing an *aspect of motion of the ego vehicle* and "at least one local object attribute" describing a vehicle ("local vehicle") in the vicinity of the ego vehicle, in particular describing the *location of a local vehicle* (original claims 6-8; page 17, lines 7-9).

7. The calculated (current) state of the ego vehicle may be used as an input to driver assistance functionalities, active or passive ones. In the case of a passive driver assistance system, the calculated state of the ego vehicle could be merely output for presentation to the driver (page 1, lines 21-26; page 3, lines 4-8; page 7, lines 1-4).

Main request - Claim interpretation and Article 84 EPC

8. The examining division objected that claims 1 and 12 failed to meet the requirements of Article 84 EPC for two reasons:

(1) the wording "the first state and the second state each include at least one local object attribute describing a local object located in the vicinity of the ego vehicle, wherein the local object is a local vehicle" did "not allow to unambiguously derive the meaning of an attribute describing a local object, for example whether it is limited or not to a color of said local vehicle" (decision, point 12.1); and

(2) the wording "for a motor vehicle driver assistance for an ego vehicle" suggested that an effect supporting motor vehicle assistance is to be produced, which was however not apparent from the wording of the claim (decision, point 12.2).

In both cases, it was said that claims 1 and 12 had to be further limited in order for the claimed subject-matter to be in agreement with the effect and problem argued by the appellant. Reference was made in that respect to the Guidelines for Examination in the EPO ("EPO Guidelines", presumably March 2021 edition) F-IV, 4.5.1.

8.1 As regards (1), the board considers the recited feature to be broad but not unclear: the "at least one local object attribute" may be any attribute of the local vehicle that is suitable for use by a driver assistance system. It could be, for instance, the local vehicle's position or velocity or even its color (e.g. as it could be relevant for a classification of that vehicle). The claim is clearly not limited to the attribute being a color of said local vehicle. Hence, this objection is not convincing.

8.2 As regards (2), the board interprets the wording of claim 1 "an apparatus for a motor vehicle driver assistance system for an ego vehicle" as meaning an apparatus *suitable for* a motor vehicle driver assistance system for an ego vehicle, as is usual for a purpose feature in an apparatus claim in the form "apparatus for ...". Claim 1 does not require the claimed apparatus to be configured to provide the output of the state estimator as input to a driver assistance system. The board does not see a lack of clarity of claim 1 in that respect.

Claim 12 is directed to "a method for estimating a state of an ego vehicle, the method being implemented on a compute module, the state being for use in a motor vehicle driver assistance system for the ego vehicle". The last statement appears to define an *intended use* of the calculated state obtained by the claimed method. This is not a purpose feature of the kind "method for...", which may in certain circumstances be considered to imply a corresponding method step, but rather of the kind "data for...". The claim does not specify any method step in which the calculated state would be actually used for that purpose, nor does the claim comprise any other feature that would establish that said use is part of the claimed method, be it explicitly or implicitly. The board tends to consider that also this feature is to be understood as merely requiring the calculated state to be *suitable for* use in a motor vehicle driver assistance system for the ego vehicle, in which case there would be no clarity problem. However, in view of the other objections, this issue may be left open.

8.3 As regards the lack of agreement of the claims with the "effect and problem argued by the appellant", the board notes that the examining division has not indicated which concrete effect and problem are being referred to. In any case, if the effect and problem put forward by the appellant in its argumentation were not derivable from the claim, this would per se not imply a lack of clarity of the claim but would rather be an issue to be considered when assessing inventive step.

The passage of the EPO Guidelines F-IV, 4.5.1, cited by the examining division relates to essential features of the invention. According to the board of appeal decisions cited in that passage, an objection that essential features are missing in an independent claim would have required a consideration of either the technical problem said to be solved in the description (see T 32/82, point 15: "As essential features have to be regarded all features which are necessary to obtain the desired effect or, differently expressed which are necessary to solve the technical problem with which the application is concerned."; see also EPO Guidelines F-IV, 4.5.2, first sentence) or which features were explicitly presented as essential in the description (see T 1055/92, point 5). The examining division has not referred to any specific passage of the description in support of its objection. Hence, the board does not see that the cited passage of the EPO Guidelines supports the objection.

9. The board considers that claims 1 and 12 lack clarity, Article 84 EPC, for the following further reasons:

According to claim 1, the claimed apparatus is configured to calculate the second state from the first state, wherein "calculating the second state from the first state includes a prediction element and an update element", where "the update element includes implementing an update model to refine the estimated second state" obtained by the prediction element. A priori, this would imply that separate prediction and update calculations are carried out.

However, according to the third and fourth embodiments (figures 8-11 and corresponding description), reflected in dependent claim 5, the prediction model and the update model are "combined into a combined ANN". In these embodiments, the combined ANN carries out an estimation of the second state taking as input the first state and the measurements of the second state but without necessarily performing separate prediction and update calculations, as suggested by claim 1.

This casts doubt as to how the features of claim 1 related to the prediction and update elements are to be interpreted, rendering claim 1 unclear, Article 84 EPC. Similar considerations apply to claim 12.

10. The board notes that claim 1 refers to "a state estimator configured to use a first state of the ego vehicle to calculate a subsequent second state of the ego vehicle" and specifies that these calculations include refining an "estimated second state [obtained by the prediction element] on the basis of at least one value corresponding to a measurement of the second state, the at least one value being determined from a sensor measurement".

The board interprets "state estimator" as not encompassing the prediction of a *future* state (with respect to the point in time in which the calculations and measurements are carried out), because the term "state estimation" (as opposed to "state prediction") commonly refers, in the relevant technical field, to estimating a current state and because it would not be clear how a value corresponding to a "measurement of the second state" could be determined by sensor measurements if that second state were a future state.

It is noted that the "prediction element" recited in claim 1 predicts the second state from a past (first) state, as is common in the Kalman filter approach to estimate a current state. In the context of claim 1, this prediction is not a prediction of a future state.

Main request - Articles 52(1) and 56 EPC

11. The examining division objected that claims 1 to 12 lack an inventive step starting from D1 and in view of D3 (decision, points 13 and 14).

12. *Document D1 as starting point*

12.1 D1 discloses a method for *predicting* the future location of vehicles surrounding the ego vehicle using recurrent neural networks (LSTM structures in figure 1).

The input consists of an estimate of the current and past positions and velocities of the surrounding vehicles as obtained from sensor measurements, the positions being expressed by coordinates relative to the ego-vehicle, as well as the current yaw rate and velocity of the ego-vehicle, so as to compensate for a coordinate change due to the movement of the ego vehicle (abstract; section I, third paragraph; section II; section IV.A, first paragraph; figures 1 and 2).

The output may be expressed as probabilities of presence of a surrounding vehicle in grid elements of an occupancy grid map ("probabilistic prediction" -

section II.B and IV.A; figure 3) or, alternatively, predicted coordinates of each surrounding vehicle relative to the ego vehicle ("deterministic prediction" - section IV.A, last paragraph; section IV.B, second paragraph).

The disclosed trajectory prediction method may be used for path planning and collision avoidance in an autonomous vehicle (section I, first paragraph).

D1 states that the proposed approach outperforms previous approaches based on the Kalman filter and using sophisticated vehicle behaviour models by learning complex behaviour of the vehicles from recorded trajectory data during the training phase (abstract; section I, second paragraph; section V.C).

12.2 In the terms of claim 1, the method of D1 uses thus a "first state of the ego-vehicle", comprising an attribute describing an aspect of motion of the ego vehicle as well as an attribute describing the location of a local vehicle, to predict a future "second state of the ego-vehicle", comprising an attribute describing the location of a local vehicle.

The board considers that the predicted state in D1 may be considered to be a "state of the ego-vehicle" even though it only describes attributes of surrounding vehicles, which is also coherent with the broad definition of that notion given in the description (page 2, lines 25-35).

12.3 The board considers however that claim 1 differs from the teaching of D1 *at least* in the following:

(i) the apparatus of claim 1 is configured to carry out a state *estimation* ("state estimator"), whereas the method of D1 is for *predicting* a *future* state;

(ii) the state estimation calculations in claim 1 involve "a measurement of the second state", which is absent in the method of D1, precisely because in D1 the second state is a future one;

(iii) the state to be estimated (the second state) in claim 1 includes not only an attribute describing a local vehicle (as in D1) but also "an ego vehicle attribute describing an aspect of motion of the ego vehicle".

12.4 The examining division acknowledged essentially only difference (iii) (decision, point 13.1.1).

12.5 As regards (i), it is noted that the method of D1 involves an estimation of the current positions and velocities of surrounding vehicles and of motion-related parameters of the ego vehicle (see e.g. section IV.A, first paragraph: "the ego-vehicle estimates the current coordinates and velocities of the N surrounding vehicles"), without however going into the details of that estimation. There is no disclosure in D1 that a neural network is used for that estimation, which provides only the input to the prediction method illustrated in figure 1.

As regards (ii), there is no disclosure in D1 that the method illustrated in figure 1 involves a measurement of the *future* position of the vehicles (how could it be?).

12.6 For the "prediction element" and the "update element" according to claim 1, the examining division referred, respectively, to sections IV.A and IV.B of D1, without providing any further detail regarding the feature mapping.

While section IV.A describes the prediction of the future locations of surrounding vehicles as summarised above, section IV.B describes the *training* of the LSTM networks, not the operation of the prediction method *per se*.

The examining division might have considered that the features of claim 1 were realised during the training of the LSTM networks, insofar as a training typically involves iteratively carrying out a prediction of a state x_k from state x_{k-1}, using the prediction method described in section IV.A, followed by a comparison of the predicted state x_k with the actual state x_k as recorded in the training data (section IV.B, first paragraph: "the training data containing the trajectory of each individual vehicle is used to train the single LSTM").

While the first of these two steps could be mapped to the "prediction element" feature of claim 1, the second one does not involve "refin[ing] the estimated second state [which would be the predicted state x_k] on the basis of the at least one value corresponding to a measurement of the second state [which would be the recorded actual state x_k]", as required by the "update element" feature of claim 1, as in that training step the parameters of the LSTM networks might be refined but there is no disclosure of refining the predicted state itself.

The board is thus not convinced by the examining division's feature mapping.

12.7 The board notes in passing that the appellant's argument in the statement of grounds of appeal for the non-obviousness of claim 1 starting from D1 focuses on the alleged improvement in accuracy of the state of the ego vehicle that is achieved by the invention by the *combined* estimation of the ego vehicle motion and of an attribute of a local vehicle, the use of an ANN in that combined estimation allowing "to account for complex and non-deterministic interrelationships between ego vehicle parameters and local vehicle parameters to derive a more accurate ego vehicle state".

The board is not convinced that this alleged effect is achieved over the whole scope of claim 1. Indeed, claim 1 encompasses that two separate ANNs are used in the state estimator, one for estimating ego vehicle motion and one for estimating the attribute of the local vehicle, without consideration of possible inter-relationships between them. Such an arrangement is explicitly envisaged in the description: "there may be different prediction ANNs, each corresponding to a different part of the state" (page 13, lines 17-19; see also page 14, lines 27-32, for a corresponding statement in respect of the update element).

12.8 Still, the board recalls that D1 concerns a different task than that implemented by the apparatus of claim 1 (prediction of future state instead of (current) state estimation) and therefore prefers starting its inventive step analysis from a different document.

13. *Document D7 as starting point*

13.1 In its preliminary opinion, the board noted that the invention appeared to lack an inventive step starting from D7. The appellant did not reply in substance to this objection.

13.2 D7 discloses *jointly* estimating the motion of the ego vehicle and of a local vehicle: the equations (1a) and (1b) in section 1, first paragraph, involve a state vector which comprises attributes describing "the dynamics of the ego vehicle, the road geometry [and] leading vehicles" (see also section 1, second paragraph, last sentence; section 2, second paragraph; section 3, first paragraph; section 3.1, first paragraph; section 3.4, first paragraph). They are jointly estimated based on sensor measurements using a conventional extended Kalman filter (section 1, first paragraph, last sentence; section 2, third and fifth paragraphs, section 3.5, first paragraph), which implies the use of a prediction element and an update element as specified in claim 1. D7 elaborates then on hand-crafted physical models to be used in that context. The benefits of a joint estimation are emphasised (section 1, third and fifth paragraphs).

13.3 Claim 1 differs from D7 essentially only by the feature that "calculating the second state from the first state includes using an artificial neural network".

13.4 The board considers that it would have been obvious to a skilled person at the filing date of the present application (19 December 2017) that a prior art method such as D7 involving a physical model may be simplified and possibly improved by using a suitably trained neural network instead of the physical model. This was already a technological trend at the time, as evidenced, for instance, by document D8.

13.5 D8 provides a survey of the use of deep neural networks for object tracking (a state estimation task), in particular in the automotive driving context (see abstract and figure 1). D8 describes in section III the traditional approaches to object tracking, including the extended Kalman filter, which involve prediction and update phases, as illustrated in figure 2. In section IV.A, fourth and fifth paragraphs, it is noted that deep neural networks may be used to capture non-linear dependencies directly from data, to learn to predict the movement of objects (and thus to replace physical models hitherto used). Alternatively, the tracking may be formulated "as end-to-end problem" to "jointly optimize the whole tracking process". The board notes that this latter approach corresponds to that used in the third and fourth embodiments in the present application, while the former approach suggests the first and second embodiments.

13.6 Hence, claim 1 lacks an inventive step, Articles 52(1) and 56 EPC, starting from D7 in view of common general knowledge as evidenced by D8. Similar considerations apply to claim 12.

Auxiliary request - Admittance

14. This request was first filed with the statement of grounds of appeal. The differences (a) and (b)/(b') between claims 1 and 10 of the auxiliary request compared to claims 1 and 12 of the main request are indicated at point VIII of the facts. The amendments are based on original claims 8 and 12, respectively.

15. The board notes that in the present case the decision under appeal at least implicitly contained the position of the examining division on the auxiliary request, as the amendments were anticipated in the objections under Article 84 EPC (decision, points 2.1 and 2.2) and reasons were given as to why the examining division considered the corresponding dependent claims not inventive (decision, point 13.3).

16. The boards exercised therefore its discretion under Article 12(4) RPBA to admit the auxiliary request, as its consideration was not prejudicial to procedural economy.

Auxiliary request - Articles 84, 52(1) and 56 EPC

17. The board tends to consider the limitations on the scope of claim 1 and 10 implied by the expression "for use by" in features (b) and (b'), respectively, to be not clear for essentially the same reasons as those given at point8.2 above, second paragraph. However, this may be left open as, in any case, the objections under Article 84 EPC raised at point 9 above applies as well to claims 1 and 10.

18. Furthermore, claims 1 and 10 lack an inventive step, Articles 52(1) and 56 EPC, in view of the reasons given in point 13 above, the position of a local vehicle being an obvious choice for an attribute describing the dynamics of a leading vehicle, and the method of D7 being obviously for use in driving assistance.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

L. Stridde Martin Müller

Decision electronically authenticated