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Datasheet for the decision of 22 June 2021

Case Number: T 0614/15 - 3.4.01

Application Number: 09153358.8

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Language of the proceedings: EN

Title of invention:
Method and apparatus for ultrasound synthetic imaging

Applicant:
SuperSonic Imagine

Headword:
Ultrasound synthetic imaging /SUPERSONIC IMAGINE

Relevant legal provisions:
EPC Art. 56

Keyword:
Inventive step - effect not made credible within the whole scope of claim

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Case Number: T 0614/15 - 3.4.01

D E C I S I O N
of Technical Board of Appeal 3.4.01
of 22 June 2021

Appellant: (Applicant)
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Decision under appeal:
Decision of the Examining Division of the European Patent Office posted on 14 November 2014 refusing European patent application No. 09153358.8 pursuant to Article 97(2) EPC.

Composition of the Board:

Chairman P. Scriven
Members: P. Fontenay
D. Rogers

Summary of Facts and Submissions

I. The appeal is against the Examining Division's decision to refuse European patent application 09153358.

II. The application was refused because the Examining Division did not consent to the new set of claims, replacing all previous requests on file, which was filed during the oral proceedings (Rule 137(3) EPC).

III. Concretely, the Examining Division held that independent claims 1 and 9 were not clear, and that the description did not provide the information required for implementing the equation defining the coherent data in the independent claims. The objection relied on the findings that the weighting function $B(\alpha)$ that appeared in the definition of the coherent data was not sufficiently specified (Article 84 EPC) and that the raw data appearing in the equation could not be derived from the $RFraw(x,z,\alpha)$ data referred to in the description (Article 83 EPC).

IV. The appellant requested that the decision be set aside, and that a patent be granted on the basis of a main request, or, in the alternative, an auxiliary request. Both requests were annexed to the statement of grounds.

V. In a communication under Article 15(1) RPBA, the appellant was informed of the Board's preliminary view.

VI. While the Board acknowledged that the claimed subject-matter, despite various shortcomings affecting its clarity, defined new subject-matter, it also expressed doubts with regard to the existence of an inventive step under Article 56 EPC. In this respect, reference was made to document

D4: US-B-6 551 246,

considered to illustrate the closest prior art.

VII. In the Board's understanding, the method according to claim 1 of the main request differed from the method disclosed in D4 only in the sequence of the calculating steps carried out to obtain the final image. In the absence of any recognisable technical effect in terms of image quality or of frame rate, the two methods appeared to be equivalent.

VIII. The additional features in claims 1 and 9 according to the auxiliary request, regarding the correction of delays by estimating aberrations in the imaged region, were considered to reflect a straightforward measure, insufficient as such to justify the existence of an inventive step. Reference was made, in this respect, to D1 (US-A-2004/0006272) which, in a similar context, addressed the problem of aberrations resulting from different tissue types.

IX. In reply to the Board's communication, the appellant filed a new main request and auxiliary requests 1 to 4. During oral proceedings before the Board, auxiliary requests 3 and 4 were withdrawn and a new auxiliary request 3 was filed instead.

X. The main request and auxiliary requests 1 and 2 have been amended with regard to the requests filed with the statement of grounds to address the misgivings of the Board with regard to Article 84 EPC.

XI. With regard to inventive step, the appellant emphasised that the claimed method extended beyond a mere rearrangement of the method steps known from D4. Moreover, D4 only combined data obtained from two transmitted plane waves propagating along directions defined by opposite angles. The synthesis of sets of coherent data from the plurality of sets of raw data, as defined in claim 1 of all requests, was not suggested in the prior art. This was the key feature of the invention. It contributed to improved image quality in terms of signal-noise ratio (SNR) and to an increase in the frame rate.

XII. Claim 1 of the main request reads:

A method for ultrasound imaging comprising at least the following successive steps:
a) a transmission step in which a plurality of N ultrasonic plane waves having different propagation directions are transmitted into an imaged region (1) and a respective set of raw data is acquired by an array of transducers (2) in response to each ultrasonic wave, for each of a plurality of imaged locations in the region (1), each set of raw data representing the

time signals received by the transducers (2) in response to the corresponding ultrasonic plane wave;
b) a coherence enhancing step in which, for each of a plurality of virtual dynamic transmit focusing lines in the imaged region (1), at least one set of coherent data is synthesized from the plurality of N sets of raw data acquired in response to the plurality of N transmitted plane ultrasonic waves having different propagation directions, each set of coherent data corresponding to the backscattered echoes resulting from a given virtual dynamic transmit focusing line;
c) a beamforming step in which, for each of a plurality of locations included in each of the virtual dynamic transmit focusing lines, an image pixel is computed by receive beamforming, using said at least one set of coherent data, thus computing an image of the imaged region.

XIII. Claim 1 of auxiliary request 1 differs from claim 1 of the main request in that it more specifically recites how each set of coherent data is computed from the collected sets of raw data.Concretely, claim 1 according to auxiliary request 1 reads:

A method for ultrasound imaging comprising at least the following successive steps:
a) a transmission step in which a plurality of N ultrasonic plane waves having different propagation directions are transmitted into an imaged region (1) and a

respective set of raw data is acquired by an array of transducers (2) in response to each ultrasonic wave, for each of a plurality of imaged locations in the region (1), the array of transducers (2) being a linear array, and each set of raw data representing the time signals received by the transducers (2) in response to the corresponding ultrasonic plane wave;
b) a coherence enhancing step in which, for each of a plurality of virtual dynamic transmit focusing lines in the imaged region (1), at least one set of coherent data is synthesized from the plurality of N sets of raw data acquired in response to the plurality of N transmitted plane ultrasonic waves having different propagation directions, each set of coherent data corresponding to the backscattered echoes resulting from a given virtual dynamic transmit focusing line, and wherein the set of coherent data RFcoherent for each of said virtual dynamic transmit focusing lines is computed by applying delays to the raw data for performing a virtual dynamic transmit focusing on said virtual dynamic transmit focusing line, assuming that the speed of sound c is homogeneous in the imaged region (1), each set of coherent data being computed by the following formula:

$$RFcoherent\left(x_1, x, z\right) = \sum_{\alpha} B\left(\alpha\right) RFraw\left(x, \tau\left(\alpha, x_1, x, z\right), \alpha\right)$$

where x, z are coordinates, respectively along an axis X of the linear transducer array (2) and along an axis Z perpendicular to the axis X,

x_1 is a lateral position of each virtual dynamic transmit focusing line along axis X,
α are the respective angles of inclination of the direction propagation of the plane waves with regard to axis Z,
RFcoherent(x_1, x, z) is a set of coherent data corresponding to one virtual dynamic transmit focusing line of lateral position xl,
RFraw(x, t (a, xl, x, z), a) are data from the sets of raw data RFraw,
B(α) is a weighting function for each angle contribution,
τ(α, x_1, x, z) is a travel time computed according to the following formula :

$$\tau(\alpha, x_1, x, z) = \frac{1}{c}\left[(z\cos\alpha + x_1\sin\alpha) + \sqrt{z^2 + (x - x_1)^2}\right];$$

c) a beamforming step in which, for each of a plurality of locations included in each of the virtual dynamic transmit focusing lines, an image pixel is computed by receive beamforming, using said at least one set of coherent data, thus computing an image of the imaged region.

XIV. Claim 1 of auxiliary request 2 differs from claim 1 of the main request in that it more specifically recites how in a first substep each set of coherent data is computed from the collected sets of raw data and in that it incorporates a second substep in which the delays to be considered in the expression of the coherent data are corrected by an estimation of aberrations in the imaged region.

XV. Claim 1 of auxiliary request 3 differs from claim 1 of the main request in that it incorporates the additional features introduced in claim 1 of auxiliary request 2 and further specifies how the estimation of aberrations is performed.

Reasons for the Decision

Admissibility of the main request and auxiliary requests 1 and 2

1. In the Board's judgement, the objections which led to the refusal of the application, raised by the Examining Division under Rule 137(3), were not justified in their substance.

2. Equation 4 in the description defines how coherent data are obtained from the various raw data.

$$RFcoherent\left(x_1, x, z\right) = \sum_{\alpha} B\left(\alpha\right) RFraw\left(x, \tau\left(\alpha, x_1, x, z\right), \alpha\right)$$

where B(α) is a weighting function for each angle contribution.

3. The application as a whole focuses on the elaboration of the coherent data, that is, on the manner in which the raw data received by the transducers of the array are aligned on the time axis by appropriately shifting the time signals by a delay corresponding to the travel time required for a planar wave to reach a scatterer and then be reflected back to each transducer. In this respect, the concrete definition of the weighting function is not essential for the coherence step. It could, in its simplest implementation, be a constant,

as put forward by the applicant during the oral proceedings before the Examining Division.

4. The delay appearing as a variable in the expression of *RFraw* in equation 4 is actually the travel time for a plane wave moving along a propagation direction defined by angle α to reach the scatterer and for the echoes to be received by the transducer at position x along the transducer array. The fact that the time signal received by the transducer at position x incorporates contributions (echoes) from other sources does not affect this. The key element of the invention is, namely, that the contribution originating from the scatterer at location (x_1,z) be present. Since the virtual dynamic transmit focusing lines are defined by the abscissa x_1, the value of the variable $\tau(\alpha,x_1,x,z)$ is thus, for a given pair of propagation angle α and transducer x, directly and unequivocally associated with the ordinate z of the scatterer at location (x_1,z), contrary to what was assumed by the Examining Division.

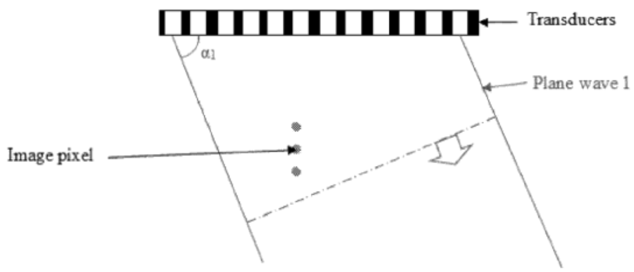
5. The main request and auxiliary requests 1 and 2 were modified in comparison to the requests filed with the statement of grounds, in reaction to the Board's communication. The Board is satisfied that the objections which were raised under Article 84 EPC with regard to the unclear and partly inconsistent terminology in the claims have been satisfactorily resolved.

6. Consequently, in exercising its discretion under Article 12(4) RPBA 2020, the Board decides to admit the main request and auxiliary requests 1 and 2 into the appeal proceedings.

The disclosed invention

7. The disclosed invention relates to a method of imaging with ultrasound.

8. In a first step, a plane wave is transmitted along a selected direction defined by angle α with regard to the transducer axis. The plane wave is obtained by successively firing the transducers with a delay that depends on the angle α. Raw data are collected for each transducer within the array as a time series of reflected signals (echoes) received by the transducers, thus providing, for each firing event defined by angle α_i, a two dimensional matrix of raw data (page 8, lines 22-27 as filed).



In contrast to conventional techniques where the raw data thus obtained are used to calculate image pixels, the method according to the invention repeats the transmission steps for a plurality of propagation directions α_i.

9. According to the invention, for each transducer in the array, the echoes received after the propagation of all plane waves are coherently summed to compute a coherent data set. By "coherently summed together" is meant that the raw echoes reflected from a scatterer at location (x_1,z) and received by a particular transducer are summed with the corresponding raw data obtained for all

propagation directions α_i. This is achieved by first delaying the raw data by the appropriate time delay. The raw data are thus synchronised before they are summed. The process is carried out for each point on the virtual focus line and for each transducer in the transducer array, thus providing a two-dimensional matrix of coherent data (page 9, lines 3-9 of the original application).

10. The coherent data set, obtained by the coherence enhancing step, is the computational equivalent of a data set that would be obtained by emitting a wave focused on a specific focal zone in the region of interest in conventional imaging.

11. The total back-and-forth travel time by which raw data are delayed is the sum of the time needed for the plane wave to reach the scatterer at the virtual transmit focal zone (x_1,z) and the time required for the echo to come back to the transducer at position x. It is expressed by equation 3 in the application.

$$\tau(\alpha, x_1, x, z) = \tau_{ec} + \tau_{rec} = 1/c\left[(z\cos\alpha + x_1\sin\alpha) + \sqrt{z^2 + (x - x_1)^2}\right]$$

12. Finally, a synthetic receive beamforming step is performed. It consists of summing the spatially coherent RF data over all transducers (x) in the array. Synthetic receive beamforming is a well-known technique, used in the prior art synthetically to synchronise, for each transducer of an array, the contribution originating from a selected scatterer in the medium to be imaged. The process is carried out for each pixel of the image.

Main request - the claimed invention

13. According to the claimed invention, the various sets of coherent data are synthesized from the plurality of *N* sets of raw data acquired for the plurality of *N* transmitted plane ultrasonic waves along propagation directions α_i. Each matrix of synthetic coherent data corresponds to the backscattered echoes resulting from a given virtual dynamic transmit focusing line. Concretely, each dynamic transmit focusing line is defined by a plurality of points (x_1, z) extending along a line defined at abscissa x_1 and perpendicular to the transducer axis.

14. While the disclosed invention, as summarised above, shifts the raw data by time delays reflecting the total back-and-forth travel time of the emitted wave and reflected echoes, to obtain the coherent data, the claimed invention is not so specific.

15. The claimed process, in fact, also encompasses a shift by a time delay that is limited to the time required for the plane waves to reach the scatterer, that is by the first term $\tau_{ec} = 1/c(z\cos\alpha + x\sin\alpha)$ in equation 3. (The second term is constant for a given pair of scatterer and transducer, and thus without effect on the coherence). Depending on the time delay effectively considered in the coherence step, the beamforming step could be limited to a simple (possibly weighted) addition of coherent data, as in the main embodiment of the invention, or to the summation of coherent data further shifted according to the time delay required for each reflected echo signal to reach each transducer at location *x*, as usual according in receive beamforming.

Main request - inventive step (Article 56 EPC)

16. The Board concurs with the appellant that the claimed method defines new subject-matter and that document D4 is to be considered as best starting point.

17. Document D4 was acknowledged in the original application. It illustrates one implementation of ultrasound synthetic imaging, commonly referred to as the synthetic plane wave approach. It consists in transmitting plane waves at different angles in the medium to be imaged, beamforming the backscattered signals for each plane wave, and then combining the thus obtained information to obtain the final image (cf. Figure 1).

18. Concretely, each set of raw data collected by a transducer at location *x* is delayed in D4 according to a predefined delay profile dependent on the image locations (scatterers at positions (x_1,z)) actually selected (D4 column 6, lines 23-35) and the position of the transducer within the array. In order to synchronise the arrival of the echoes from a given image point, a channel-independent delay offset is defined for each image point (column 6, lines 30-35).

19. In the absence of any detail as to the definition of the channel-independent delay offset in D4, the Board acknowledged that the reference to a channel-independent delay offset, while corresponding to a transducer independent delay offset, could not be equated, with certainty, with the first term τ_{ec} of the delay defined in equation 3 of the application.

20. Contrary to the appellant's assertion, more than two steering angles can be used in D4 (column 2, lines 61,

62; column 4, lines 50-53; column 10, lines 32-61; column 12, lines 19-33; column 16, lines 21-46). The process is also not limited to angles of opposite values (column 8, lines 20-39).

21. The claimed method differs thus from the method disclosed in D4 by the recited sequence of steps (b) and (c), i.e. in that the coherence enhancing step (b) in which,

> *for each of a plurality of virtual dynamic transmit focusing lines in the imaged region (1), at least one set of coherent data is synthesized from the plurality of N sets of raw data acquired in response to the plurality of N transmitted plane ultrasonic waves having different propagation directions, each set of coherent data corresponding to the backscattered echoes resulting from a given virtual dynamic transmit focusing line,*

is followed by a beamforming step (c), in which

> *for each of a plurality of locations included in each of the virtual dynamic transmit focusing lines, an image pixel is computed by receive beamforming, using said at least one set of coherent data, thus computing an image of the imaged region.*

22. The claimed method goes beyond a mere reordering of the various calculations, contrary to the assertion in the Board's provisional opinion.

23. In the appellant's view, the recited features lead to a better image quality and an improved (increased) frame rate.

24. However, the appellant could neither provide evidence of these effects, compared to the method disclosed in D4, nor produce a convincing explanation as to why the image quality would be improved or the frame rate increased.

25. The final synthesis step in D4 requires the information to be provided by the beamformers. This is only possible after N plane waves have been transmitted along the propagation directions α_i (cf. figure 3).

26. Hence, no improvement in the frame rate can be seen in the claimed method compared to that of D4. Both methods appear to be equivalent since they both require all raw data matrices for all steering angles α_i to be available before carrying out the subsequent calculations leading to the final ultrasound image.

27. The appellant could also not persuade the Board that the claimed method would lead to an improved signal to noise ratio (SNR) in the final image.

28. Effects in terms of quality of the obtained image can only be assessed on the basis of the calculations actually carried out for the determination of the pixel value. The passage of the description on page 12, lines 18-29 is the only one relating to this aspect of the invention. It reads:

> *After step b), a receive beamforming is then performed on each of the M coherent RF data matrices to compute the final*

ultrasonic image. The delay law used is the one calculated by the aberration correction method:

A point (x_1,z) of the image is obtained by adding coherently the contribution of each scatterer, that is to say delaying the $RF_{x1}(x,t)$ signals by τnew(x_1,x,z) and adding them in the array direction X:

$$s(x_1,z) = \int A(x_1,x)\, RF_{x_1}(x, \tau new(x_1,x,z))\, dx \qquad (6)$$

where A *is the receive apodization function as a function of* x *for the building of line x_1 in the final image.*
The image thus comprises M lines.

29. The appellant stressed that equation 6 defined the theoretical background for the acoustic field and that the integral, in reality, had to be construed as a discrete summation over the transducers in the array. It was further stressed during oral proceedings that the *$RF_{x1}(x,t)$* data referred to in equation 6 corresponded to the coherent data referred to previously. They define time series and not specific values at predetermined times, as had been assumed by the Board.

30. The appellant's arguments did not persuade the Board.

31. Even if it were assumed that $RF_{x1}(x,t)$ should correspond to the RFcoherent data of equation 4,

$$RFcoherent(x_1,x,z) = \sum_{\alpha} B(\alpha)\, RFraw(x, \tau(\alpha,x_1,x,z), \alpha)$$

it is noted that the time does not appear as a variable in the expression of *RFcoherent* in left-hand side of equation 4, suggesting that the terms RFraw appearing in the discrete summation on the right-hand side are not time series but specific values of the *RFraw* previously received. Concretely, $RFraw(x,\tau(\alpha,x_1,x,z),\alpha)$ on the right side of equation 4 refer, according to this interpretation, to the values of the raw data obtained at $t = \tau(\alpha,x_1,x,z)$.

32. Even if the appellant's view were accepted, it is observed that the passage on page 12 of the original application, reproduced above, does not elaborate on how the pixel values are obtained from $s(x_1,z)$ data, or even whether $s(x_1,z)$ should be considered, as such, as providing the sought information (pixel value).

33. All in all, the skilled person would not be in a position to derive, from equation 6 and the definition of the coherent data in equation 4, how the value of the pixel, which reflects the properties of scatterer at (x_1,z), is obtained. Whether envelope detection is to be performed on a time series of $s(x_1,z)$ data, as submitted during the oral proceedings, whether alternative processing of the $s(x_1,z)$ data is to be performed, or whether said data constitutes as such the basis of the sought information cannot be determined on the basis of the patent application and common general knowledge.

34. In conclusion, the patent application as a whole is not sufficient to persuade the Board either that an improvement of the image quality can be obtained, or that it would apply over the whole ambit of the claim.

35. In the absence of any recognisable technical effect in terms of frame rate or image quality, distinguishing the claimed method from the method known from D4, the

existence of an inventive step in the sense of Article 56 EPC is to be denied.

Auxiliary request 1 - the claimed invention

36. Claim 1 of auxiliary request 1 specifies which corrections in terms of time delay are to be applied to the raw data in order to obtain sets of coherent data. By specifying that the raw data are aligned by taking into account both the delay required for each planar wave to reach a scatterer and the time required for the reflected echo to reach a given transducer, the claimed method better reflects the content of the disclosed invention. The beamforming step in receive appears to be limited to a mere addition of said coherent data without the need for any additional delay to be considered at this final stage.

37. As stressed above with regard to claim 1 of the main request, the calculations to produce $s(x_1,z)$ still require all data to be available before starting with said calculations and are, thus, without any bearing on the frame rate.

38. Similarly, in the absence of any clear indication as to how an image pixel is to be obtained from the $s(x_1,z)$ data, the skilled person is unable to recognise any improvement in the quality of the image thus obtained.

39. In the absence of any identifiable technical effect distinguishing the claimed method from the method known from D4, the existence of an inventive step is to be denied.

Auxiliary request 2

40. Claim 1 differs from claim 1 of auxiliary request 1 in that it specifies that the claimed imaging method comprises a substep in which delays are corrected by an estimation of aberrations in the imaged region.

41. The thus obtained time delays better reflect reality in that they take into account the fact that ultrasound does not propagate at a constant velocity, but with velocities that depend on the elastic properties of the propagation medium. In the context of the invention, the added features contribute to more precise delays.

42. It follows that the coherent data on the basis of which the pixel values are to be calculated are better synchronised. This applies independently of whether a single value at $t = \tau$ is to be selected as basis of the relevant information, or a time series of said raw data.

43. The claimed features contribute to an improvement of the image quality compared to methods where such aberrations are not corrected.

44. The skilled person would recognise that a method of imaging which relies on the determination of travel times to elaborate coherent data would be directly affected by propagation velocities varying in the imaged region. The claimed method does not appear to extend beyond merely specifying that the time delays are to be corrected by an estimation of the aberrations.

45. In the Board's judgement, independently of the source of the information to be considered for the correction, an estimation of aberrations is a straightforward measure to be envisaged under the circumstances for which the existence of an inventive step is to be denied.

Auxiliary request 3 - Admissibility

46. Auxiliary request 3 was filed during the oral proceedings before the Board; that is, at a particularly late stage of the appeal proceedings.

47. According to Article 12(4) RPBA 2020,

> *Any part of a party's appeal case which does not meet the requirements in paragraph 2 is to be regarded as an amendment, unless the party demonstrates that this part was admissibly raised and maintained in the proceedings leading to the decision under appeal. Any such amendment may be admitted only at the discretion of the Board.*

48. The Board notes that the appellant had been informed, in the Board's communication under Article 15(1) RPBA 2020, of the issues to be addressed during the oral proceedings. In its reply, the appellant had already amended the requests on file, in an attempt to resolve theses issues. The reasons which lead to the main request and auxiliary requests 1 and 2 being considered as unallowable had been explicitly addressed in the Board's communication. Finally, the Board is not persuaded, that the amendments carried out in claim 1

of auxiliary request 3, would be sufficient to render the claimed method inventive.

49. As a consequence, in the exercise of its discretion under Article 12(4) RPBA 2020, the Board does not admit auxiliary request 3 in the proceedings.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

H.Jenney P. Scriven

Decision electronically authenticated