Developing a parallelized hyperelastic boundary-element code for the real-time simulation of deformation of a kidney

Reference No : 182018003378

By : Kirana Kumara P

Proposal

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Proposal Details

Project Title :	Developing a parallelized hyperelastic boundary-element code for the real-time simulation of deformation of a kidney		
Scheme :	Core Research Grant		
Broad Area :	Engineering Sciences	**Sub Area :**	Mechanical & Manufacturing Engineering & Robotics
Duration In Month :	36	**Total Cost (in Rs.) :**	*15,93,700*
Name of Principal Investigator :	Kirana Kumara P	**Email ID :**	
Date of Birth :		**Contact No :**	
Category :		**Gender :**	
Nationality :	Indian	**Is differently abled :**	
Designation :	Senior Assistant Professor	**Department :**	Department of Mechanical Engineering
PI Institute :	Madanapalle Institute of Technology and Science		
PI Institute Address :	Post box no. 14,Angallu, madanapalle, chittoor, Chittoor, Andhra pradesh-517325	**Pin Code :**	517325

Project Summary : It is widely believed that just like flight simulators are useful for training pilots, surgery simulators are useful for training surgeons. However, it is a long way for surgery simulators to reach the level of maturity the flight simulators have attained at present. Currently, most of the surgery simulators use models that are not physics based, thus sacrificing fidelity. Although the literature notes that physics based models are superior compared to other models, more work needs to be done before one can have a useful surgery simulator that uses a physics based model in the back-end. Hence the proposed project aims to build a simulator that can train surgeons in eye-hand coordination which is very important for many laparoscopic surgical procedures. Here, deformation of a kidney will be modeled using the Boundary Element Method (BEM) which is a physics based method. Since a kidney may be approximated to be hyperelastic, a hyperelastic BEM code has to be used in the back-end. Unfortunately, no hyperelastic BEM code is readily available. Hence a hyperelastic BEM code will be developed as part of the project. One has to parallelize the code and run the code on a computer cluster to speed up the computations and to achieve real-time performance, so that the simulations would be realistic. This requires a computer cluster with a multi-core processor. In fact, many cores are needed in one and only one processor to minimize the data transfer time. One may note that although BEM has been identified in the literature as a method that could be useful for building surgical simulators, none has attempted to build a surgical simulator based on nonlinear boundary elements. Once the simulator is built, as future work, the simulator may be offered to a

few surgeons for testing/evaluation. If the product turns out to be successful, one can think of commercialization also. Anyway, the nonlinear BEM code may be released as free and open source software so that anyone can use it to solve a hyperelastic problem (even problems that are not related to surgical simulation).

Objective : • To develop a parallelized boundary element code for hyperelasticity, and making the code free and open source software. Also documenting how the code is written (First Year)
• Parallelize the code and do the performance evaluation, and make it suitable for real-time simulations (Second Year)
• Build a surgical simulator based on the above code (Third Year)

Keywords : Boundary, Element, Hyperelastic, Real-time, Simulation

Expected Output and Outcome of the proposal :

1. As of now, no boundary-element based code that can solve hyperelastic problems is readily available. Hence the parallelized boundary element code resulting from this project will be made available free of cost to anyone (it will be released under an open source license also). Once the code is released as open source software, others can use or adapt the code to solve other problems involving hyperelasticity (not only the type of problem addressed in this project).
2. It may be possible to get three journal papers out of the results.
3. Last but not the least, prototype of a surgical simulator will be built. The prototype will be able to simulate the deformation of a kidney in real-time. The simulator could be helpful for training prospective surgeons for eye-hand coordination.
4. The computing facility bought for the project will also be useful for the students/faculty of PI's organization.
5. As future work, surgeons may evaluate/try the simulator.
6. If the surgeons rate the product favorably, commercialization of the product (simulator) may be possible in the future.

Other Technical Details

1. Origin of the Proposal:

Flight simulators are widely used to train prospective pilots before they are trained on real aircraft. Similarly, it is widely agreed that surgery simulators would be useful for training prospective surgeons before they can operate on patients. However, unlike flight simulators, surgery simulators are not widely adopted. The reason for this is that surgery simulators have not yet reached the level of maturity that flight simulators have already achieved.

The main reason surgery simulators are not so widely used is that the simulations realized by them are not as realistic as they should be. Hence there is a need to develop technologies that would enhance the realism offered by surgical simulators.

The simulators currently in use mostly use technologies such as spring-mass models which are not physics-based. It is generally agreed that using physics-based models would result in better realism. But the problem with physics-based models is that they are computationally expensive, and it is not easy to achieve the real-time performance.

Out of physics-based models, the Boundary Element Method (BEM) has already been identified as a good candidate. However, the simulations obtained by using the BEM are not up to the mark so far, since those simulations assume that biological organs (say kidney) are linear elastic while they are closer to hyperelastic solids. Hence there is a need to use nonlinear boundary elements (hyperelastic boundary elements in particular) to get more realistic simulations.

Hence the proposed project aims to simulate the deformation of a kidney by using hyperelastic boundary elements in the back-end. A multi-core computer cluster must be employed to speed up the computations. It is hoped that the use of nonlinear boundary elements for real-time simulations would result in a surgical simulator that is more realistic.

When compared to other surgical procedures, surgery simulators are more useful for training surgeons in laparoscopic procedures. Hence this projects focuses on the eye-hand coordination task which is very essential for performing any laparoscopic surgery, and a kidney is the biological organ considered.

2. Review of status of Research and Development in the subject

2.1 International Status:

The reference [A. C. M. Dumay and G. J. Jense, 1995] discusses the topic of endoscopic surgery simulation in a virtual environment. The paper tries to answer the question: “Can virtual environment technology assist surgeons in training and maintaining endoscopic surgery skills?” The paper opines that virtual environment technology has great potential for surgical training purposes. The reference [Herve Delingette and Nicholas Ayache, n.d.] notes that the development of commercial simulators has proved that there is a demand for products that help to optimize the learning curve of surgeons. The reference mentions that the emergence of medical robotics and more precisely of minimally invasive surgery robots, has reinforced the need for simulating surgical procedures, since these robots require a very specific hand-eye coordination. Reference [Issenberg SB, et al., 1999] mentions that since laparoscopic surgery needs highly skilled surgeons, it is preferable to use a surgical simulator for training and evaluating surgeons.

The reference [Herve Delingette, 1998] surveys existing models of deformation in medical simulation. The reference [U. Meier, et al., 2005] is a review paper that presents a classification of the different deformable models available in literature, makes a comparison of the different deformable models, performs an evaluation of the state of the art, and discusses the future of deformable models. The reference [Ido Badash, et al., 2016] is a recent review paper.

Sources in the literature (e.g., [U. Meier, et al., 2005]) widely agree on the fact that continuum mechanics based models are desirable if one is interested to achieve highly accurate simulations of biological organs. One can note that real-time simulation of three dimensional nonlinear solids is a necessity for the continuum mechanics based real-time computational simulation of biological organs. One can also note that real-time graphics needs about 30 computations per second whereas real-time haptics needs about 1000 computations per second [SensAble technologies, 2005].

The review paper [U. Meier, et al., 2005] identifies BEM as a candidate which could be better than FEM when it comes to the realistic and real-time simulation of biological organs for surgical simulations. References [Ullrich Meier, et al., 2001; C. Monserrat, et al., 2001; P. Wang, et al., 2007] use BEM for simulations. Reference [Ullrich Meier, et al., 2001] uses linear elastostatic boundary elements together with Woodbury formula [Max A. Woodbury, 1950]. Reference [C. Monserrat, et al., 2001] uses linear elastostatic boundary elements together with precomputations to achieve real-time simulations. It also suggests parallel computing to obtain real-time performance but does not implement it. The reference tells that establishing deformable models with BEM is a reliable method to model objects in virtual reality environments for surgical simulations. Reference [P. Wang, et al., 2007] precomputes linear elastostatic boundary element solutions to obtain real-time performance. To simulate cutting, [P. Wang, et al., 2007] uses interpolated presolutions which may not provide accurate solutions every time because cutting changes geometry and hence the solutions obtained from interpolated pre-solutions could be far from accurate at times. Reference [P. Wang, et al., 2007] also suggests parallel computing to obtain real-time performance but does not implement it. Reference [Foster, et al., 2013] achieves real-time performance by using linear elastostatics and updating only part of the boundary element mesh where there is a change in the mesh, and updating the boundary element system of equations for that part of the geometry only. This method may not be suitable every time especially when there is considerable difference between the original mesh and the modified mesh.

However, no one has been able to achieve real-time performance with realistic material behaviour using any nonlinear continuum mechanics based method in a straightforward way. Many have used just linear continuum mechanics based models with highly simplified material behaviour to achieve real-time performance, while some others have not bothered about real-time performance. Some have applied specialized techniques like static condensation to solve only a specialized problem in hand. Many authors have used specialized techniques like precomputations and static condensation even while using a linear elastostatic material behaviour. Still, research groups (e.g., [Salisbury, n.d.; Stephane Bordas, 2008]) are hopeful that, with the ready availability of high performance computing (clusters, supercomputers, GPUs), it could be possible to achieve real-time performance, for a reasonably accurate material behaviour (like hyperelasticity).

2.2 National Status:

The reference [Kirana Kumara P, 2014] discusses about the viability of BEM for the real-time simulation of biological organs. It considers only linear elastostatics only, and hence no nonlinearity is considered.

Apart from the above refence, one does not find any relevant reference (old or new journal papers) from any Indian author.

2.3 Importance of the proposed project in the context of current status

From the international and national statuses discussed above, one can note that none has tried to perform nonlinear simulations in real-time using boundary elements so far. However, probably now is the right time to try incorporating nonlinear BEM into surgical simulations since powerful computer clusters are available now for a reasonable price (which hospitals can afford). Of course, nonlinear BEM codes are not readily available and one has to develop one's own codes for the purpose.

Hence the need of the hours is: (i) to develop a nonlinear BEM code (ii) parallelize the code and make it run on a parallel computer to achieve the real-time performance (iii) to develop a surgical simulator based on the parallel BEM code. In fact, this project proposal aims to achieve these very objectives.

The nonlinear BEM code may be released as free and open source software, so that anyone may use the code to solve different problems (not necessarily problems related to surgical simulators). Finally, it may be possible to commercialize the product developed (surgical simulator) during the course of the project.

2.4 If the project is location specific, basis for selection of location be highlighted:

This project is not location specific.

3. Work Plan:

3.1 Methodology:

Biological organs are inherently nonlinear. Hence the simulation of biological organs that take into account nonlinearity would result in more accurate results. However, whether the simulation would be more realistic after incorporating nonlinearity depends not only on the accuracy of the results obtained but also on how fast the simulations are (whether or not the simulations are real-time, since not just accuracy but the real-time performance also increases realism).

Out of several possible nonlinear models, hyperelasticity is selected because it is very close to the behaviour of many biological organs like kidney, liver etc (those biological organs usually operated using laparoscopic surgery). The model can simulate large deformations while using nonlinear material properties. Many investigators have assumed biological organs like kidney to be hyperelastic and hence hyperelastic material constants are available in the literature for kidney.

However, codes and software packages for hyperelastic BEM are not readily available. This PI is not aware of any nonlinear BEM code that may be useful for the simulation of biological organs (e.g., 3D hyperelasticity). Even the commercial boundary element simulation software BEASY (developed by Prof. Brebbia who is widely considered to be the one who invented the BEM) does not include hyperelasticity. However, the theory behind hyperelastic BEM is fully mature and readily available in the literature. One just needs to write the code oneself, although it would take considerable amount of time.

The references [O. Köhler and G. Kuhn, 2001; G. Karami and D. Derakhshan, 2001; M. Brun, et al., 2003] quite extensively and clearly describe the BEM formulation for hyperelasticity. These formulations may readily be used for the nonlinear BEM-based simulation of biological organs. This PI has planned to use the theory, solution techniques, and formulae from the above three sources. The solution schemes, algorithms, and equations are not explained here since that would need several pages. The three sources above contain almost all the details one needs to know, to be able to write a hyperelastic boundary element code.

One of the differences between a nonlinear BEM code and a linear BEM code is that while carrying out nonlinear simulations, the characteristic matrix has to be calculated using a nonlinear formulation, e.g., the formulation explained in [O. Köhler and G. Kuhn, 2001; G. Karami and D. Derakhshan, 2001]. The other difference is that the system of algebraic equations to be solved to get the final solution is not linear. Hence a solution method that is capable of solving a system of nonlinear algebraic equations has to be employed at the last stage.

The hyperelastic BEM code developed has to be parallelized to make it run faster, with the aim to get the real-time performance (30 computations per second). One needs to use a single processor with many cores for the purpose since the time for data transfer between computing cores for this type of processors is very small if all the cores are present in the same chip (same piece of semiconductor).

Once a parallelized hyperelastic BEM code is ready, one has to test the code and do the performance evaluation by solving dummy problems. If any problems are found, they have to be sorted out. Finally, one should have a code which can give accurate solutions, and which should also offer the real-time performance.

The final task is to build a surgical simulator for a kidney. The geometry of kidney is readily and freely available in the internet. The hyperelastic material properties are readily available in the literature. A GPU is used to render the kidney on the computer screen interactively. Using a GPU would enable fast and real-time (about 30 frames per second for persistence of vision) rendering. Rendering is achieved by using free and open source rendering libraries (software) that are readily available. Of course, it is a standard practice to use free and open source libraries for rendering (they are as good as commercial software, and much of commercial software incorporates these libraries in their products).

The software that integrates the parallelized hyperelastic BEM code, rendering libraries, and other associated software and drivers has to be developed from scratch. This would be completed during the third year.

Linux will be the operating system. Fortran and C/C++ are the programming languages. Software libraries will be used to perform common mathematical operations.

3.2 Time Schedule of activities giving milestones

0-3 month: Hiring JRF, setting up the lab, purchasing equipment, purchasing consumables

4-12 month: Developing a hyperelastic BEM code

13-15 month: Parallelizing the code

16-18 month: Releasing the code, writing a paper that describes the code

19-21 month: Performance evaluation of the code

22-24 month: Writing the second paper, attending a conference

25-27 month: Rendering

28-30 month: Building the simulator

31-33 month: Writing the third paper, attending a conference

34-36 month: Buffer time to account for unforeseen delays, thinking about the future work

3.3 Suggested Plan of action for utilization of research outcome expected from the project

During second year, the code developed during the first year would be released as free and open source software. There are many websites or web-based hosting services that archive codes/software for free. The code may be described in the form of a journal paper also. There are journals that accept this type of papers (e.g., ACM Transactions on Mathematical Software).

Performance evaluation of the code, and building the simulator are also expected to produce one additional journal paper each.

Once the project is over, the simulator would be offered to surgeons for evaluation. Once a few surgeons give positive feedback, one may think about commercialization.

3.4 Environmental impact assessment and risk analysis

There are no environmental impact and risks associated with this project.

4. Expertise:

4.1 Expertise available with the investigators in executing the project:

The PI completed his PhD in the same area. The title of his PhD thesis is: "Studies on the Viability of the Boundary Element Method for the Real-Time Simulation of Biological Organs". In fact, the proposed project could be considered as an extension of the PhD thesis.

The ideas behind the proposed project are already presented in two patent applications filed by the PI. However, the ideas are not implemented yet (no surgical simulator has been built so far). The two patent applications are:

[1] Kirana Kumara P, 2016b, "A surgical simulator for training surgeons in a few tasks related to minimally invasive surgery," Patent Pending, Application Number (Indian patent): 201641031739, Filing Date: September 17, 2016, Date of Publication: September 30, 2016, Official Journal of the Patent Office, Issue Number 41/2016, Page Number 69455

[2] Kirana Kumara P, 2017, "A hyperelastic-boundary-element based surgical-simulator for training surgeons in a few eye-hand-coordination tasks related to minimally invasive surgery," Patent Pending, Application Number (Indian patent): 201741022553, Filing Date: June 28, 2017, Date of Publication: July 7, 2017, Official Journal of the Patent Office, Issue Number 27/2017, Page Number 22533

Some publications by the PI pertaining to the theme of the proposal are listed in Section 4.3 below.

In the proposed project, the task to be completed during the first year is to develop a hyperelastic boundary element code. This task may be considered an extension of PI's earlier works [Kirana Kumara P, 2012] and [Kirana Kumara P, 2014a]. The task to be completed in the second year may be considered to be an extension of [Kirana Kumara P, 2014b], whereas the third-year task is relevant to [Kirana Kumara P, 2016b] and [Kirana Kumara P, 2017].

4.2 Summary of roles/responsibilities for all Investigators:

There is only one investigator who (together with a JRF) would carry out the whole project.

4.3 Key publications published by the Investigators pertaining to the theme of the proposal during the last 5 years

[1] Kirana Kumara P, “A Study of Speed of the Boundary Element Method as applied to the Realtime Computational Simulation of Biological Organs,” Electronic Journal of Boundary Elements, 2014, Vol. 12, No. 2, pp. 1-25.

[2] Kirana Kumara P, “A Study on the Usefulness of Support Vector Machines for the Realtime Computational Simulation of Soft Biological Organs,” Seventh M.I.T. Conference on Computational Fluid and Solid Mechanics - Focus: Multiphysics & Multiscale, June I2-14, 2013, Massachusetts Institute of Technology, USA.

[3] Kirana Kumara P, “A surgical simulator for training surgeons in a few tasks related to minimally invasive surgery,” Patent Pending, Application Number (Indian patent): 201641031739, Filing Date: September 17, 2016, Date of Publication: September 30, 2016, Official Journal of the Patent Office, Issue Number 41/2016, Page Number 69455

[4] Kirana Kumara P, “A hyperelastic-boundary-element based surgical-simulator for training surgeons in a few eye-hand-coordination tasks related to minimally invasive surgery,” Patent Pending, Application Number (Indian patent): 201741022553, Filing Date: June 28, 2017, Date of Publication: July 7, 2017, Official Journal of the Patent Office, Issue Number 27/2017, Page Number 22533

[5] Kirana Kumara P, 2014, “Codes for solving three dimensional linear elastostatic problems using constant boundary elements while ignoring body forces,” Available from: http://eprints.iisc.ernet.in/48088/

[6] Kirana Kumara P, 2015, “A literature survey on the real-time computational simulation of biological organs,” Available from: http://vixra.org/abs/1506.0122

4.4 Bibliography

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Foster, Timothy,Mark, 2013, Real-time stress analysis of three-dimensional boundary element problems with continuously updating geometry, Doctoral thesis, Durham University

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Herve Delingette, Nicholas Ayache, n.d., Soft Tissue Modeling for Surgery Simulation, Online resource from http://www.inria.fr/centre/sophia/

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Kirana Kumara P, 2012, A MATLAB Code for Three Dimensional Linear Elastostatics using Constant Boundary Elements, International Journal of Advances in Engineering Sciences (IJAES), 2 (3). pp. 9-20

Kirana Kumara P, 2013, A Study on the Usefulness of Support Vector Machines for the Realtime Computational Simulation of Soft Biological Organs, Seventh M.I.T. Conference on Computational Fluid and Solid Mechanics - Focus: Multiphysics & Multiscale, June I2-14, 2013, Massachusetts Institute of Technology, USA.

Kirana Kumara P, 2014a, Codes for solving three dimensional linear elastostatic problems using constant boundary elements while ignoring body forces, Available from: http://eprints.iisc.ernet.in/48088/

Kirana Kumara P, 2014b, A Study of Speed of the Boundary Element Method as applied to the Realtime Computational Simulation of Biological Organs, Electronic Journal of Boundary Elements, Vol. 12, No. 2, pp. 1-25

Kirana Kumara P, 2015, A literature survey on the real-time computational simulation of biological organs, Available from: http://vixra.org/abs/1506.0122

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P. Wang, A.A. Becker, I.A. Jones, A.T. Glover, S.D. Benford, C.M. Greenhalgh, M. Vloeberghs, 2007, Virtual reality simulation of surgery with haptic feedback based on the boundary element method, Computers and Structures, 85(2007), pp. 331-339

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SensAble technologies, 2005, OPENHAPTICS™ TOOLKIT version 2.0, PROGRAMMER'S GUIDE

Stephane Bordas, 2008, A Ph.D.+MSc Position on Brain Surgery Simulation by XFEM and FleXFEM, http://imechanica.org/node/3239

U. Meier, O. Lopez, C. Monserrat, M. C. Juan, M. Alcaniz, 2005, Real-time deformable models for surgery simulation: a survey, Computer Methods and Programs in Biomedicine, 77(2005), pp. 183-197, doi:10.1016/j.cmpb.2004.11.002

Ullrich Meier, Carlos Monserrat, Nils-Christian Parr, Francisco Javier Garcia, Jose Antonio Gil, 2001, Real-Time Simulation of Minimally-Invasive Surgery with Cutting Based on Boundary Element Methods, Medical Image Computing and Computer-Assisted Intervention - MICCAI 2001, Lecture Notes in Computer Science, Volume 2208, pp. 1263-1264

5. List of Projects submitted/implemented by the Investigators

No project proposal is submitted, no project is under implementation, and no project is completed.

6. List of facilities being extended by parent institution(s) for the project implementation

6.1 Infrastructural Facilities

Sr. No.	Infrastructural Facility	Yes/No/ Not required Full or sharing basis
1.	Workshop Facility	Not required
2.	Water & Electricity	Yes
3.	Laboratory Space/ Furniture	Yes
4.	Power Generator	Yes
5.	AC Room or AC	Not required
6.	Telecommunication including e-mail & fax	Yes
7.	Transportation	Yes
8.	Administrative/ Secretarial support	Yes
9.	Information facilities like Internet/Library	Yes
10.	Computational facilities	No
11.	Animal/Glass House	Not required
12.	Any other special facility being provided	Not required

6.2 Equipment available with the Institute/ Group/ Department/Other Institutes for the project:

No useful equipment is already available.

7. Name and address of experts/ institution interested in the subject / outcome of the project

Any good hospital (that can perform a laparoscopic surgery) would be interested in trying a simulator that is based on a new and promising technology. As future work, the PI would approach a few good hospitals once the simulator is ready.

Budget Details

Full Summary (in Rs.)

Institute	Manpower Budget	Consumables	Travel	Equipment	Overhead Costs	Total
Madanapalle Institute of Technology and Science, CHITTOOR	*9,00,000*	*25,000*	*50,000*	*5,18,700*	*1,00,000*	*15,93,700*
Total	***9,00,000***	***25,000***	***50,000***	***5,18,700***	***1,00,000***	***15,93,700***

Manpower Budget Breakup

Institute Name : Madanapalle Institute of Technology and Science, CHITTOOR

Summary :

Budget Head	Year-1 Amt (in Rs.)	Year-2 Amt (in Rs.)	Year-3 Amt (in Rs.)	Total (in Rs.)
Manpower Budget	*3,00,000*	*3,00,000*	*3,00,000*	*9,00,000*
Consumables	*15,000*	*5,000*	*5,000*	*25,000*
Travel	*0*	*25,000*	*25,000*	*50,000*
Equipment	*5,18,700*	*0*	*0*	*5,18,700*
Overhead Costs	*50,000*	*30,000*	*20,000*	*1,00,000*
Grand Total (in Rs.)	***8,83,700***	***3,60,000***	***3,50,000***	***15,93,700***

Manpower Budget Detail :

Designation	Year-1 Amt (in Rs.)	Year-2 Amt (in Rs.)	Year-3 Amt (in Rs.)	Total Amt (in Rs.)
Junior Research Fellow (JRF)	*3,00,000*	*3,00,000*	*3,00,000*	***9,00,000***

Justification for Manpower :

1 . Since the PI has to involve himself in teaching and other routine duties of the organization, assistance of a JRF is required for the smooth running of the project. The JRF would assist the PI in developing the code, parallelizing the code, and developing the simulator. It is also an opportunity for the JRF to improve his profile and hone his skills, apart from getting a job.

Consumable Cost Detail :

Year-1 Amt (in Rs.)	Year-2 Amt (in Rs.)	Year-3 Amt (in Rs.)	Total Amt (in Rs.)
15,000	5,000	5,000	***25,000***

Justification for Consumables :

1 . Cost of printer cartridges, stationery items, books, reference material etc.

Travel Cost Detail :

Travel	Year-1 Amt (in Rs.)	Year-2 Amt (in Rs.)	Year-3 Amt (in Rs.)	Total Amt (in Rs.)
Inland travel	*0*	*25,000*	*25,000*	***50,000***

Justification for Travel :

1 . Attending two conferences in India

Equipment Cost Detail :

Generic Name	make	Model	Quantity	Estimated Cost in INR	Estimated Cost in Foreign Currency	Foreign Exchange Rate	Spare time for other users (in %)
Tower Workstation with P5000 GPU	Netweb Technologies India Pvt Ltd	Intel Xeon E5-2695 processor and Nvidia GPU	1	***5,18,700***	0	0	25

Justification for Equipments :

1 . The nature of the proposed project (real-time performance) is such that it requires a computer with one and only one processor (to minimize data transfer times), but the processor should contain several cores (for parallel processing). Computers with quad-core or octa-core processors are already available in PI's organization, but they are not enough. Hence a workstation is essential. The workstation could also be useful to the PI to carry out any subsequent project.

Overhead Detail :

Year-1 Amt (in Rs.)	Year-2 Amt (in Rs.)	Year-3 Amt (in Rs.)	Total Amt (in Rs.)
50,000	*30,000*	*20,000*	***1,00,000***

Justification for Overhead :

1 . Purchasing cost, setting up the lab facility, lab maintenance etc.

RTGS Details :

Comments : null

Name of Account Holder :

Email ID :

Designation :

Account Number :

Bank Name :

Branch Name and Address :

IFSC Code :

Any other relevant matter : Not Available

Suitability of the proposed work in the major national initiatives of the Government :

SNo.	Program Name
1	Swasth Bharat
2	Startup India
3	Innovate India

Theme of Proposed Work :

SNo.	Theme Name
1	Health