FONDECYT NATIONAL RESEARCH FUNDING COMPETITION

2012 REGULAR COMPETITION

NATIONAL COMMISSION FOR SCIENTIFIC & TECHNOLOGICAL RESEARCH

OFFICIAL VERSION

PRINCIPAL INVESTIGATOR:

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FONDECYT STUDY GROUP
INGENIERIA 2
N°1120495

FONDECYT NATIONAL RESEARCH FUNDING COMPETITION
2012 REGULAR COMPETITION

GENERAL INFORMATION

PROPOSAL ID	: 1120495
PROPOSAL TITLE	: Improving the functionality and performance of meshing tools
FONDECYT COUNCIL	: Technology
PROPOSED LENGTH	: 3 Year(s)
PROPOSAL KEYWORDS	: Meshing tools Gpu-architectures Delaunay meshes
PRIMARY FIELD	: Computing Engineering
SECONDARY FIELD(S)	: Other areas of Engineering
APPLICATION SECTOR	: General Knowledge
APPLICATION REGION(S)	: Does not apply

YOUR PROPOSAL INVOLVES STUDY/STUDIES ON/WITH:

STUDY TYPE(S)	**REQUIRED CERTIFICACTION(S) ONE OR MORE OF THE FOLLOWING**	
Clinical studies in human beings (use of samples and/or biological material)	Fully explanatory and detailed Approval certificate from the Institution Ethics Committee, Permission from the institutional responsible officer, Informed Consent (subjects over 18 years of age), Informed Consent (subjects less than 18 years of age)	
With persons (interviews, surveys, focus groups, other)		
In/With animals, obtaining and/or using animal samples and/or biological material	Fully explanatory and detailed Approval certificate from the institution Bioethics Committee based on the "3Rs" principle, Animals Handling Protocol (techniques, supervision and other)	
In/with hazardous materials(pathogenic agents, recombinant DNA and/or radioisotopes, waste, other)	Approval certificate from the institution Biosafety Committee	
Other Certificates and Permissions	Approval document from the Council of National Monuments, Certificates from the SAG (Agricultural and Livestock Service), CONAF (National Forestry Corporation), Sernapesca (National Fishing Service), SNASPE (National System of State-protected Wilderness Areas), Access to archives and/or databases, etc.	
Does not apply	Not Applicable	X

FUNDING REQUEST SUMMARY (1000CLP $)

BUDGET ITEMS	Annual Amounts (1000 CLP$)			
	YEAR 1	**YEAR 2**	**YEAR 3**	**Total**
Staff	10.400	10.400	10.400	31.200
Travel	2.060	2.060	2.060	6.180
International Cooperation Travel	0	0	0	0
Operational Expenses	1.400	1.400	1.400	4.200
Equipment	1.200	0	0	1.200
Annual Total (1000CLP $)	**15.060**	**13.860**	**13.860**	**42.780**

SPONSORING INSTITUTIONS

UNIV.DE CHILE --> FAC.DE CS. FISICAS Y MATEMATICAS --> DEPTO.CS. DE LA COMPUTACION

ADDITIONAL FUNDING COMMITTED FROM OTHER INSTITUTIONS/SOURCES

INSTITUTION	Amount (1000 CLP$)
TOTAL	**0**

PROPOSAL PARTICIPANTS

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PROPOSAL ABSTRACT: Describe the main issues you plan to address, including goals, methodology and expected outcomes. A good summary facilitates an understanding of what you intend to achieve and the proposal review process. The abstract of funded proposals may be published on CONICYT website. The maximum length for this section is 1 page (Use Verdana, font size 10).

This project centers on the study and design of algorithms and data structures for two and half dimensional ($2\frac{1}{2}$D) mesh generation and three dimensional (3D) mixed element meshes that can be useful in several engineering applications. In particular, we are interested in two problems: $2\frac{1}{2}$D triangulations for face modeling and three growth simulation, and (2) 3D mixed element meshes appropriated for the finite volume method (CVM) useful, for example, for the simulation of semiconductor devices.

We already count with a tool for the generation of $2\frac{1}{2}$D triangulations and for 3D mixed element meshes but the implemented algorithms still have several drawbacks in modeling complex domains, in the moving boundary strategies, in generating elements of good quality, in fulfilling the density requirements with as few points as possible and in performance. In particular, (a) for face modeling we need to improve the quality of the mesh and the interpolation strategy to model large mouth movements, (b) for tree stem deformation, we need to improve the collision detection algorithms and to add smoothing algorithms, and (c) for the mixed element meshes useful for the CVM, we need to generate 3D Delaunay meshes where no Voronoi point is outside the domain and to model more complex domains than before.

We propose to improve, extend and adapt our previous tools in order to fit the requirements of the applications mentioned above. This work involves (a) the design of more general strategies to fit domain geometries (b) the design of more efficient and robust strategies to move boundaries (c) the design of more efficient strategies to refine, de-refine and improve elements. We plan to improve the performance of the algorithms by designing and implementing parallel solutions on the GPGPU (General-Purpose computation on Graphics Processing Unit) using CUDA, a non-graphics API for NVIDIA GPUs that support the development of parallel applications.

As result of this research, we expect to count with more efficient and robust tools for the generation of both surface triangulations and mixed element meshes and to leave them as open source code through the web. Moreover, we expect to design new parallel GPU-based algorithms for different aspects involved in the mesh generation process. We also want to explore the application of Delaunay tessellations for the modeling of atmospherical phenomena in cities and for analyzing the distribution of galaxies.

PROPOSAL DESCRIPTION, THEORETICAL BACKGROUND AND LITERATURE REVIEW: This section must include a general presentation of the problem and its relevance as research topic. Include novel aspects that you intend to address, approaches currently being used to solve it, theoretical background and review of the current literature on the topic. Please read item 1.10. of the document Bases Concurso Nacional de Proyectos FONDECYT Regular 2012. If appropriate, include additional information that you consider relevant and that would facilitate this proposal review. The maximum length of this section is 7 pages (Use Verdana, font size 10). Use additional sheets to list your cited references.

Modeling and simulating complex natural phenomena, scientific and engineering problems, and medical applications, among others, usually require of a proper spatial discretization of the domain (object) to be modeled. Depending on the requirements of the mathematical model used to simulate the behavior of the object, triangles, quadrilateral or both in two dimensions (2D), and tetrahedra, hexahedra or both in three dimensions (3D) are used as basic elements of the discretization [1]. In case only triangles (tetrahedra) are used, the discretization is called a 2D (3D) triangulation. In case only quadrilaterals are used, the mesh is called a quadrilateral mesh and in case only hexahedra are used, the mesh is called hexahedral mesh. If several element shapes are used, the mesh is called mixed-element mesh. The main steps involved in almost any mesh generation tool are:

- read the geometry and physical values of the object to be modeled (domain) specified in some input format
- generation of a first mesh that fits the object geometry
- generation of smaller elements through the partition of the original ones in the object regions where the application requires it. This process is known as refinement process and permits to increase the number of points and elements in some regions of the object.
- improvement of the element quality. This process is usually required when the mesh elements do not satisfy some quality criteria such as minimum angle or aspect ratio, among others. The algorithms available for this step try to minimize the number of points to be inserted while increasing the mesh quality.
- optimization of the current mesh by moving points so that the quality of the mesh is improved.
- derefinement of the current mesh in order to eliminate unnecessary elements or to coarse a mesh in certain regions of the domain.
- generation of the final mesh in an appropriate output format.

In our previous Fondecyt projects, we have been working on the development of different algorithms and data structures in order to generate meshes for specific applications. For example, in Fondecyt project Nr 1960735, we worked in the design and implementation of both a 2D triangulator [2] and a 3D mixed element mesh generator for the generation of meshes appropriate for the CVM [3]; in Fondecyt project Nr 1030672, we improved the algorithms of the 3D mixed element mesh generator [4, 5]. At the same time, we started by defining a preliminary software architecture for developing a family of 2D meshing tools [6].

This previous work has been done to model objects with fixed geometry (fixed boundaries). In Fondecyt Project Nr 1061227, we started designing and implementing algorithms and data structures to model problems where the geometry of the domain changes continuously (moving boundary problems). We focused our research on the generation of meshes for the simulation of a tree stem deformations [7, 8, 9, 10] and the simulation of the brain shift problem that occurs during surgery [11, 12, 13]. At the same time, we have extended our 2D software architecture to model a family of 3D meshing tools for fixed domain geometries [14, 15]. We have developed two general purpose prototype mesh generators following the proposed architecture: a surface mesh generator for fixed- and moving-boundaries [8, 9, 10], and the other one for the generation of 3D meshes [16] for fixed boundaries. These tools have been implemented using good software engineering practices so that the software architecture of the implemented tools can be easily adapted to new mesh requirements.
The surface mesh generator can be used for improving the quality of an already generated surface mesh or for simulating tree stem deformations. In case of improving the quality of a surface triangulation, an input mesh can be: (a) transformed into a Delaunay mesh, (b) refined so that all triangles have their area or edge-length less than a threshold value, (c) de-refined until all triangles have their area greater than a threshold value, and (d) transformed into a quadrilateral mesh. The implemented refinement algorithm is the Lepp-Delaunay [17] and the de-refinement algorithm is based on the edge-collapse operation [18]. The algorithm to transform any mesh into a Delaunay mesh and the de-refinement algorithm work very well and are very robust, but when the meshes have more that 100,000 triangles, these algorithms are quite slow. Then, during the last two years, we have started to explore and design new solutions for improving their performance by using a GPGPU architecture. As result, we have designed and implemented parallel GPU-based solutions for improving the quality of a mesh doing it Delaunay [19] and for managing geometry changes [20]. In particular, the transformation of any mesh into its Delaunay counterpart is done by an iterative algorithm that flips in parallel as many edges as possible. At each iteration, one thread is in charge of one edge of the triangulation. The Delaunay condition is locally checked and also if the edge must be flipped, this is locally done. A parallel exclusion mechanism was designed to avoid to flip neighbor edges. The algorithm finishes when all edges fulfil the Delaunay condition. The results are very promising and that is why we want to explore the possibility of parallelizing other parts of the surface mesh generator on GPGPU architectures. The algorithms that are more naturally parallelize on this kind of architectures are the ones that do not need to add new vertices.
In case of the simulation of tree stem deformations, the geometry of the mesh is deformed according to a growth hormone value associated to each mesh point. We have implemented two algorithms to deform the mesh: one of them move the mesh points until the first neighbor triangle collision is found and the other the whole required amount. Both are still not too robust and do not take care of collisions of triangles that are not neighbors. We think that strategies that move the points changing a little the point trajectory while they are moving can also be very appropriate for this kind of simulation. In order to propose a better algorithm, we will first study the work of Taubin [21] for smoothing surface triangulations and of Zaharescu et al. [22] for mesh deformation, and then design/adapt and implement a better sequential algorithm and propose a GPGPU-based algorithm.
We have also extended the surface mesh generator to model speech-driven facial animation [23, 24]. In this case, the input to the mesh generator is a real head model given by a surface triangulation. The feature points and their movements are specified through a simple publically available face model known as Candide-3 [25]. We assumed that these movement parameters have been generated by other application and represent the movements done by a real person while speaking. The

Candide-3 face model is defined by a small triangulation (approximately 100 triangles) where each point has associated a parameterization that indicates its movement (Action Unit). First, we adjust manually the real head model we want to deform with the Candide-3 face model and second, we apply a projection between both triangulations using the Euclidean distance. After this second step, each Candide-3 vertex has associated one head model point. The Candide-3 points are the control points for the head model. To move the rest of the head model points, each point is associated to the three control points of the triangle that contains this point. Each point is then expressed as a linear combination of the control points. The idea is that under the same translation or rotation of a set of control points, all related head mesh points must exhibit the same rotation and translation [23, 24]. Although this interpolation method gives good results in several speech-driven animations, we still observe several problems in the mesh deformation close to the lips when the mouth must be largely open. This is probably because our interpolation technique is too simple and works well only for small deformations. Is is also possible that the Candide-3 mesh is too coarse to allow us a good representation of large movements. We will explore the use of interpolation methods based on radial basis functions (see section Literature Review) and to work with a Candide-3 triangulation finer around the mouth.

These previous works also motivate us to improve our mixed element mesh generator [4] by exploring solutions to model more complex objects and to improve its performance. This mesh generator is based on the modified octree approach [26, 27] and generalizes it in several aspects: (1) the whole object no longer encapsulated in a single octree, but partitioned into a set of basic elements: cuboids, rectangular prisms and pyramids. (2) Elements are either bisected or refined by introducing appropriate edge points in order to get the density requirements. (3) Elements are done 1-irregular, i.e, only one Steiner point per edge is accepted, otherwise the element is refined. (4) Finally, a Delaunay tessellation that includes tetrahedra, prisms, pyramids and other basic elements [4] is template-based generated. This mesh generator still needs to be improved in the step of fitting the object geometry by including the recognition and representation of fractal configurations in order to be able to model more complex objects, and in reducing the number of points inserted when the elements are done 1-irregular. In order to be a proper mesh for the CVM, the mesh must be a Delaunay tessellation where the center of the circumsphere of each boundary/interface element must be inside the element itself or inside a neighboring element through internal faces [28, 29]). This requirement guarantees that the Voronoi diagram associated to the mesh satisfies some restrictions that are required for the CVM around each boundary/interface point. (Note that the Voronoi regions are used as control volumes.)

Novel aspects

We propose to improve the strategies already implemented in the surface mesh generator and in the 3D mixed element mesh generator by designing algorithms that (a) run efficiently on GPGPU architectures, and (b) improving the current available sequential implementations.

$2\frac{1}{2}$D surface mesh generation

We want to improve the surface mesh generator for the applications mentioned above. Each application requires special functionalities but at the same time all they need to improve the quality of the mesh by using refinement, improvement or de-refinement algorithms. Both tree stem deformation and speech-driven face modeling require moving boundary strategies and the ones that are already implemented are not robust enough or still cannot model appropriately the whole problem. We think that novel aspects in this proposal will appear by:

- designing and implementing new moving boundary strategies that accommodate the points while moving them.
- designing and implementing GPGPU-based moving boundary strategies
- designing and implementing a GPGPU-based derefinement algorithm
- exploring the possibility of a GPGPU-based refinement algorithm
- designing and implementing an interpolation method that works well for both small and large deformations in speech-driven animation
- Increasing the resolution of the Candide-model mesh in order to represent in a better way the real faces.
- improving the method to match the Candide-3 triangulation with the triangulation that represents the real face. Currently, this step is done manually with the help of a graphic interface.

For the moving boundary algorithms, we would like to explore the possibility of adapting the method proposed by [21] so that the mesh can iteratively evolve without changing the topology. At the same time we will also adapt and implement the method proposed by [22] which also moves points iteratively but the topology can change when triangle intersections are produced. We want to test both methods in the context of tree stem deformation and face modeling. For the implementation of the GPGPU-based algorithm that uses the edge-collapse operation, the smallest edges that must be removed will be first identified in parallel. Then, the set of triangles that would be affected by each edge-collapse will be marked so that the algorithm only removes in parallel edges whose set of triangles do not intersect any other set.

We will also explore which part of the Voronoi-point insertion [30] or the Lepp-based refinement and improvement algorithm [17] can be parallelized on a GPGPU architecture. Notice that these algorithms add new points and this problem has not been solved yet properly. All known strategies for refinement are pattern-based solutions that add points implicitly and only for rendering (see section Literature review).

Finally, the current mesh generator will be extended in such a way that future requirements can be easily added. The software must allow the user to select interactively both parallel and sequential implementations. It will also exist the possibility that through a meshing tool factory, a user can generate a specific tool with the features that his/her application requires .

3D mixed element meshes

In case of complex applications such as the semiconductor device simulation, due to the geometry of the devices, the representation of very thin layers is needed, and due to physical properties, edges parallel to the current flow are desirable. Empirically it has been found out that the CVM tolerates very well longest edges aligned to the flow and shortest edges perpendicular to them which are very useful to solve boundary parallel currents. Note that in this application, small angles do not produce convergence problems as in finite element methods, but it is recommended to avoid too big obtuse angles. In what follows we shall call *well-shaped elements* to the (a) co-spherical elements that can be used as elements to fit the object geometry, (b) can be refined into elements that belongs to the same set and (c) fulfill the basic requirement of the CVM at the boundary/interfaces. The *well-shaped final elements* include the previous *well-shaped elements* and other convex elements elements that can be used as internal elements in the final Delaunay tessellation. We want to complete the set of *well-shaped final elements* and to improve the mixed element mesh generator by designing and implementing:

- a better and more robust algorithm for generating the initial mesh compose of anisotropic co-spherical convex elements
- the generation of well-shaped anisotropic elements aligned to the boundary and physical flow
- a GPGPU based partition strategy in order to recognize well-shaped final elements that fits 1-irregular elements generated after refining the mesh
- a postprocess algorithm for improving the quality of tetrahedra lying at the boundary/interfaces so that they fulfill the CVM restrictions.

In order to generate the initial mesh, the algorithm must choose the element that better adapts to each part of the geometry. For example, cuboids will be used to represent very thin layers. The use of mixed elements strongly reduces the number of final mesh elements and edges, and simplifies the numerical evaluation of the CVM. *Well shaped tetrahedra* are not easy to generate at the boundary/interface because if the shape of a tetrahedron is not close to the regular tetrahedron, the center of its circumsphere (Voronoi point) is usually outside of it [31]. We also want to explore the use of mixed elements meshes in applications such that the modeling of cities for the simulation of atmospherical phenomena and in particular the air pollution at local scale. We believe that the use of elements such as cuboids, prisms and pyramids will allow us to model in a more natural way the shape of the buildings.

Literature Review

In this section, we review meshing strategies already published related to this proposal and in particular related to parallel GPU-based meshing algorithms.
Since the research in unstructured mesh generation techniques started about 30 years ago, there exists today many published approaches and available products [32]. In the context of this project, we are mainly interested in meshing algorithms for (a) deforming a geometry, (b) refining, de-refining and improving a given triangular surface mesh (c) parallelizing these algorithms on GPGPU architectures and (d) improving the quality of the generated meshes and the performance of a mixed-element mesh generator.
For the refinement and improvement of surface meshes, Delaunay [30, 33] and Lepp-based algorithms, among other approaches [34, 35], have been successfully used. The same occurs for the quality improvement and optimization of surface meshes [21, 36, 37, 38, 39, 40]. In the design of moving boundary algorithms, the approaches can be mainly classified in the ones that preserve the topology of the evolving mesh [41, 42] and the ones that not [43, 22]. In the case of tree stem deformation we want to test both approaches and select the one that allow us to get better simulation results.

In the last five years, several parallel GPU-based algorithms have been published related to meshing applications. Cao Thang [44, 45] has developed a GPU-based algorithm for the generation of Delaunay triangulations. The algorithm computes first the Voronoi diagram of a subset of the input points handled on a grid, then computes a quasi-Delaunay triangulation and finally repairs it and flips edges to obtain a Delaunay triangulation. The parallel processing unit is a triangle. Cervenansky et al.[46] proposed a GPU-based triangulation algorithm for image processing based on the edge-flip operation. They model the problem by taking an edge as parallel processing unit. The subset of edges that are flipped in parallel depends on a function cost and on the number of region of interest defined on the image: only one edge is flipped in each region of interest. The design and implementation of adaptive GPU-based refinement strategies are usually pattern-based and they are normally used for improving the quality of rendering [47, 48, 49, 50]. These strategies do not insert new points explicitly in the mesh. Mesh simplification has also been approached by taking advantage of the geometry shader stage of the rendering pipeline and using a novel data structure called a probabilistic octree. They have adopted a vertex clustered method that is used to simplify the mesh to be rendered [51]. As we have mentioned before, we have also designed and implemented two GPU-based algorithms using the programming environment CUDA [52], one for transforming any mesh in a Delaunay mesh [19, 20] and another for collision detection problems [20]. The performance improvement of the parallel GPU-based algorithm that transforms any mesh into its Delaunay counterpart is from 11 up to 80 times faster than the sequential implementation depending on the specific GPU (9800 GTX or GTX 580) that was used. It is also worth to mention that there are several works on meshing algorithms designed and implemented on other parallel architectures. Antonopoulos et al. [53] proposed a parallel algorithm that refines a mesh on a parallel multilevel architecture with distributed memory. Rivara et al. [54] proposed a global refinement for tetrahedral meshes based on the terminal edge refinement concept. Chernikov et al. [55] proposed a parallel algorithm for 2d constrained Delaunay generation. We will have these works (and more recent published ones) in mind in order to compare these as far as possible against the algorithms we will develop in this project.
The facial modeling for the simulation of a real person while speaking requires of an appropriate mesh and proper interpolation methods. The facial movements are usually specified through the movement of few feature points (control points) and the movement of the rest of the face points is then obtained through interpolation. Kshirsagar et al. [56] describe a strategy that calculates first the feature point regions: Neighbor feature points are the ones that share a common feature point region boundary. This information is used to compute the influence of each feature point on each mesh vertex. The advantage of this method is its simplicity and usually provides an adequate interpolation. However, because of its simplicity, sometimes it does not produce realistic animations. Jacobsson et al. [57] and Kojekine et al. [58] use an approach based on radial basis functions. Radial basis functions are defined as real-valued functions whose value depends only on the distance from the origin. These functions provide a very general and flexible way of interpolation because the deformation algorithm can generate different results just by changing the radial basis function. Berger et al. [59] match a very dense mesh with a very sparse one (with markers) of the person being modeled without manual interaction. The facial movements are obtained from the sparse mesh and the animation is done by using the dense mesh. In this proposal, we want to adapt and implement an interpolation method based on radial basis functions and explore which radial basis functions are more appropriate to solve the problems our current interpolation method presents. Another important aspect is how to improve and automate the algorithm to map a small and simple surface mesh to a larger mesh. In the literature, we can find several registration

techniques that can help us to aboard this problem. Registration techniques are methods that try to find an optimal geometric transformation between partially similar geometric data sets [60]. One very interesting work is the registration method created by Bucki [61], which is based on a registration energy function. This function is an elastic function that minimizes a given registration error (registration energy) between a source point set and a destination point set. The registration energy must be chosen so that it reflects the nature of the problem. In our case we have to consider not only the shortest Euclidean distance between the points of both meshes, but also that the face features such as eyes and mouth are matched together.
3D Mixed element meshes have been not so frequently used as tetrahedral meshes or hexahedral meshes. Our main approaches to generate mixed-element unstructured meshes for fixed domains are two: (1) An octree- and mixed element tree (MET)- based approach [62, 63, 4] and (2) a normal offsetting based approach [5]. Currently, there exists very good and robust free software in 3D for the generation of tetrahedral meshes such as Tetgen (http://tetgen.berlios.de/) and the one developed by the GRUMMP project (http://tetra.mech,ubc.ca/GRUMPP) but not for 3D mixed element meshes. Our goal is also to leave our software free.

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HYPOTHESES: State your working hypotheses or research questions that will guide your research. Make sure your hypotheses or research question(s) are grounded on the theoretical-conceptual background of your proposal. The maximum length for this section is page. (Use Verdana, font size 10).

Our working hypotheses are:

- Realistic speech driven face animation and tree stem deformation require a quality surface mesh at each animation or simulation step. The required quality can be achieved by refining the mesh where it is too coarse, de-refining the mesh when is too dense or applying optimization algorithms. In case of face animation, accurate interpolation strategies are required to compute the movement of newly inserted points.
- The performance of the algorithms for moving boundary, refining, derefining, improving and visualizing meshes can be highly accelerated by programming them directly on a GPGPU architecture.
- Mixed elements meshes can help to model in a more appropriate way complex geometries that have very thin layers and need elements with edges parallel to physical and geometry features. They can also been a good candidate to model cities.

GOALS: Specify your general and specific goals. The maximum length for this section is page. (Use Verdana, font size 10).

The main goal of this project is to build meshing tools with improved functionalities for managing speech-driven facial animation, tree stem deformations and applications where mixed element meshes are good alternative. The specific goals are:

- Improve the moving boundary strategies of the surface mesh generator for both tree stem deformations and facial animation. For facial animation, improve also the interpolation methods and the representation of the real face.
- Improve the performance of the algorithms involved in the surface mesh generator by designing and implementing parallel algorithms on a GPGPU architecture. Compare them as far as possible with sequential and parallel solutions implemented on clusters or multicore architectures.
- Improve the sequential algorithms involved in the steps to generate a final mixed element mesh in order to model more complex geometries and to generate a final optimal mesh. Explore its use in other applications such as the modeling of atmospherical phenomena and air pollution at local scale.
- Improve the performance of the algorithms involved in the mixed element mesh generator on a GPGPU architecture as far as possible.

METHODOLOGY: Describe and justify your choice of method(s) you will use to achieve the proposed goals. For example: Full description of experimental designs (quantitative or qualitative), sampling procedures choice, use of databases, archives, methods for the statistical analysis of results (if appropriate), etc. The maximum length for this section is 3 pages (Use Verdana, font size 10).

We have planned to execute this project in three years. The algorithms and data structures will be implemented in C++ because this is the language we have been using in the implementation of our previous meshing tools and we have got good results. We will use CUDA as the programming environment for GPU's. As design and programming methodology we are using an object oriented approach which has allowed us to build software easy to extend, adapt and reuse. We have put emphasis in building reusable and extensible components, because we want to make them available as open source code. The software development process will be iterative and incremental. In order to reach the goals specified above, we plan to do the following:

1. Update the literature review about meshing techniques and parallel meshing algorithms on GPGPU architectures
2. Review parallel meshing algorithms on other parallel architectures
3. Improve the current sequential implementations of the surface mesh generator and of the mixed element generator
4. Adapt and implement the moving boundary strategies mentioned in the proposal
5. Adapt and implement a registration method with few user interaction and a more flexible and general interpolation methods such as the one based on radial basis functions.
6. Design and implement realistic test cases for the evaluation of the facial animation algorithm
7. Analyze the implemented algorithms of the surface mesh generator and develop GPGPU-based solutions for some moving boundary strategies and de-refinement algorithms
8. Analyze the implemented algorithms of mixed element generator and develop GPGPU-based solutions
9. Design good test-cases for the evaluation of sequential and parallel implementations
10. Design and implement strategies to evaluate the correctness of the generated meshes
11. Design and implement a prototype factory of meshing tools
12. Select and adapt if necessary already implemented components of our previous mesh generators in order to count with a set of of reusable components that can be combined inside of our factory of meshing tools to build new meshing tools.
13. Evaluate the new generated meshing tools with respect to performance and time of a meshing tool construction.

WORK PLAN:

On the basis of your stated goals, indicate the stages and describe the activities **to be carried out each year**. **The maximum length for this section is 1 page.** (Arial or Verdana, font size 10). **If appropriate, use a Gantt chart.**

Goals	Year 1	Year 2	Year 3
Improve the moving boundary strategies of the surface mesh generator for the mentioned applications. For facial animation, improve also the interpolation methods and the representation of the real face.	Design an algorithm to match as automatic as possible a simple face model with the real face model. Adapt more sophisticated interpolation algorithms to model large mouth movements. Design, adapt moving boundary algorithms for tree stem deformation and face animation. Design and implement a factory of surface meshing tools	Implementation of a strategy to automatically match simple and complex face models. Test the implemented algorithms with complex real cases. Evaluate the factory of surface meshing tools	Complete the design and implementation of the expected functionality Evaluate the correctness and robustness of the implemented meshing algorithms. Evaluation and comparison with other a sequential approaches.
Improve the performance of the algorithms involved in the surface mesh generator by designing and implementing parallel algorithms on GPGPU architectures. Compare them as far as possible with sequential and other parallel solutions.	Design and implement the de-refinement algorithm based on the edge-collapse and one moving boundary algorithm on GPGPU architectures. Evaluate and compare them with sequential implementations.	Analyze other moving boundary, optimizing and refinement and propose parallel solutions on GPGPU architectures . Evaluate and compare them with the sequential implementations .	Complete the design and implementation the missing algorithms. Design of good test cases in order to evaluate the robustness of the implemented algorithms. Compare them as far as possible with parallel solution available on clusters or multicore architectures.
Improve the sequential algorithms involved in the steps to generate a final mixed element mesh in order to model more complex geometries and to generate a final optimal mesh. Explore its use in other applications such as the modeling of atmospheric phenomena and air pollution at local scale.	Revise the well-shaped set of co-spherical convex elements, improve the algorithm to generate the initial mesh, improve the algorithms to decrease the amount of inserted points while doing the mesh 1-irregular and to generate the final mesh. Improve the software architecture of the current implementation.	Design and implement a new algorithm for the generation of the initial mesh with element aligned to boundary/ interface faces. Explore the application of mixed element meshes for the modeling of cities and other applications	Test and evaluate the mixed element mesh generation with other approaches. Development of a prototype for the modeling of buildings.
Improve the performance of the algorithms involved in the mixed element mesh generator on a GPGPU architecture as far as possible	Study and design parallel algorithms on a GPGPU architecture for some steps of the mixed-element mesh generator.	Implement the designed solutions and compare them against the sequential implementations.	Evaluate the correctness and robustness of the developed prototypes with complex test-cases

We plan to submit our results to meshing, computer graphics or geometric modeling international conferences Final results will be published in international journals (ISI). We expect to publish at least three conferences papers and two journal papers.

RESEARCHERS ACTIVITIES:

Describe the tasks/activities to be carried out annually by each researcher.

NAME	Nancy Hitschfeld Kahler
TASKS/ACTIVITIES TO CARRY OUT	
Year 1: Update literature review, design of meshing algorithms and data structures for the applications mentioned in the proposal, study and re-design of algorithms whose performance can be improved by using a GPU, Supervision of students and elaboration of publications. Year 2: Design and evaluation of meshing algorithms. Design techniques to improve the performace of already implemented algorithms. Comparison with other approaches. Supervision of students and elaboration of publications. Explore the use of mixed element meshes in other applications. Year 3: Design and evaluation of the meshing tools. Evaluation of the generated meshing tools and comparison with other approaches. Supervision of students and elaboration of publications.	

TIME COMMITTMENT TO THE PROPOSAL:
Number of hours per week committed to the proposal by each researcher.

NAME	YEAR 1	YEAR 2	YEAR 3
Nancy Hitschfeld Kahler	12	12	12

OUTREACH TO SOCIETY ACTIVITIES: Specify the potential benefits to society of this proposal results. Describe at least one activity you plan to implement during this proposal execution period to make the general public aware of the goals, outcomes and broader impacts of your research project. Funding may be requested and justified in the proposal budget under travel and/or operational expenses item.
The information provided in this section will not be considered in the proposal evaluation process. However, if funded, a report on the outcomes of such activities must be included in the annual academic progress reports. The maximum length for this section is page. (Use Verdana, font size 10).

The meshing tools are very useful in applications such as the computational simulation of natural phenomena, computer games, computer aided design and medicine, among others. In the context of this project, we plan:

- give presentations to students via the platform offered by Explora
- build a web page where the software developed in this project can be uploaded for free.

PRIOR WORK ON THE TOPIC BY THIS PROPOSAL AUTHOR(S):: If appropriate, summarize the main results of previous work conducted on this proposal topic. The maximum length for this section is 1 page. (Use Verdana, font size 10).

As stated in the formulation of this project, this is a continuation of our previous Fondecyt projects, both in surface mesh generation and in mixed-element meshes.
The proposed research on facial modeling and animation can be seen as an extension of the work published in [23,24]. This work involves (a) mesh generation issues that are going to be aboard in this project, (b) the transformation of input movements taken from videos into CANDIDE-3 action units and the generation the head mesh to be animated done by the group of Dr. Lucas Terissi and Prof. Juan Carlos Gómez, both from the Universidad Nacional de Rosario, and (c) the extraction of movements from videos or from a sequence done by the PhD student Mauricio Cerda (PhD supervisor Dr. Bernard Girau), both from Inria, Nancy. The engineer student Renato Valenzuela (from DCC, Universidad de Chile) has developed a preliminary prototype by implementing a first approach to facial modeling and animation which includes user interaction [23] and now the student Vanessa Peña is doing her final work in order to improve the modeling of large facial movements.
We have also designed and implemented a new parallel GPGPU based algorithm for transforming any surface triangulation into a Delaunay triangulation[18,19] According to our test cases, the performance has been improved from 11 up to 80 times in comparison with a CPU-sequential implementation and scales very well in more powerful GPU's. The performance depends on the number of edge-flips and iterations required and this depends on how much reparation requires the input mesh. The PhD student Cristobal Navarro is working on meshing algorithms to be improved on GPGPU architectures.
For the modeling of tree stem deformations, there is a collaboration with Jaime San Martin (Chair of Mathematical Modeling center and Prof. of the Mathematics Department) and Fernando Padilla, Forestal Engineer (Mathematical Modeling Center), both of the University of Chile.
For the improvement of the mixed element-mesh generator, the student Roberto Sapiain is doing his final work re-designing the software architecture and improving some sequential algorithms. The students Gonzalo Urroz and Violeta Diaz are analyzing the components of surface mesh generator and designing factories of meshing tools for face modeling and tree stem deformation.

RESEARCHERS CURRICULA

PERSONAL BACKGROUND

Name	: Nancy Viola Hitschfeld Kahler
Taxpayer ID Number	: 8108326-6
Passport Number	:
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ACADEMIC BACKGROUND

Professional Title(s)

Professional Title Name	: B.Sc. in Computer Science
University	: UNIVERSIDAD DE CHILE (UCH)
Country	: CHILE
Year Awarded	: 1984

Academic Degrees

Degree Name	: MAGISTER EN CIENCIAS C/M COMPUTACION
University	: UNIVERSIDAD DE CHILE (UCH)
Country	: CHILE
Year Awarded	: 1987

Degree Name	: Doctor of Technical Sciences
University	: Federal Institute of technology (ETH) Zurich
Country	: SWITZERLAND
Year Awarded	: 1993

Line(s) of Research:

1. geometrical modeling

2. mesh generation
3. object orientation

Primary Field : Computing Engineering

Academic Appointments

Appointment	: profesora asociada
Institution	: Departamento de Ciencias de la Computación, Univ. de Chile
Hours per week	: 44 horas semanales.

Participation in FONDECYT-approved projects (Last 10 years)

Project number	: 1030672
Title	: MESH GENERATION ALGORITHMS FOR COMPLEX APPLICATIONS
Role	: Principal Investigator (PI)
Begin year	: 2003
End year	: 2006

Project number	: 1040713
Title	: LEPP ALGORITHMS FOR PARALLEL MESH REFINEMENT
Role	: Coinvestigator (Co-PI)
Begin year	: 2004
End year	: 2007

Project number	: 1061227
Title	: MIXED-ELEMENT MESH GENERATION FOR MOVING BOUNDARY APPLICATIONS.
Role	: Principal Investigator (PI)
Begin year	: 2006
End year	: 2009

Project number	: 1090246
Title	: PARTIAL DIFFERENTIAL EQUATIONS FOR 3D PHOTON DENOISING, OPTICAL FLOW AND ADJACENT ACTIVE SURFACE MODELS FOR HIGH THROUGHPUT IN VIVO SPINNING DISK MICROSCOPY
Role	: Coinvestigator (Co-PI)
Begin year	: 2009
End year	: 2012

Participation in other projects or research programs funded by national or foreign sources (Last 5 years).

Title	: Neurocirugia asistida por computador: modelamiento biomecanico de tejidos blandos
Funding Source	: ECOS/CONICYT
Role	: Coinvestigator (Co-PI)
Begin year	: 2006

End year	:	2008
Specification	:	Proyecto de colaboracion que apoya intercambio de investigadores
Title	:	PLOMO- Mutual Software Platform for the elaboration of Soft Tissues physical models
Funding Source	:	Stic-AmSud Regional Program (CNRS-Conicyt)
Role	:	Otro Chilean Coordinator
Begin year	:	2007
End year	:	2008
Specification	:	Collaboration project that support the organization of meetings by financing the travels and stays of the researchers.
Title	:	"Bavi: Bio-inspired audio/visual information integration".
Funding Source	:	SitcAmSud Regional Program (CNRS-Conicyt)
Role	:	Otro Chilean coordinator
Begin year	:	2009
End year	:	2010
Specification	:	Collaboration project that supports the organization of meetings by financing the travels and stays of the researchers.

Journal Publications since 2006

- María Cecilia Bastarrica, Nancy Hitschfeld-Kahler and Pedro O. Rossel. "Product Line Architecture for a Family of Meshing Tools" ICSR 2006, LNCS 4039, vol 4039, pp 403 - 406. 2006. FONDECYT Project Nº 1030672. Published. ISI

- María Cecilia Bastarrica, Nancy Hitschfeld-Kahler. "Designing a Product Family of Meshing Tools" Advances in Engineering Software, 37(1):1-10. 2006. Elsevier Ltd. FONDECYT Project Nº 1030672. Published. ISI

- Jocelyn Simmonds, María Cecilia Bastarrica, Nancy Hitschfeld-Kahler, Sebastián Rivas. "A Tool Based on DL for UML Model Consistency Checking" International Journal on Software Engineering and Knowledge Engineering. 18(6):713-735, 2008. FONDECYT Project Nº 1061227. Published. ISI

- G. F. Cabrera, S. Casassus, and N. Hitschfeld. "Bayesian Image Reconstruction Based on Voronoi Diagrams". The Astrophysical Journal, 672:1272-1285, 2008. Published. ISI

- Felipe Contreras, Nancy Hitschfeld-Kahler, Maria Cecilia Bastarrica, Carlos Lillo, Balancing Flexibility and Performance in 3D Meshing Tools. Advances in Engineering Software, 41:471-479,2010. FONDECYT Project No 1061227. Published. ISI

- Marek Bucki, Claudio Lobos, Yohan Payan, Nancy Hitschfeld. Jacobian Reparation of Finite Element Meshes after Registration. Engineering with Computers (2011). 27(3):285-297. Fondecyt Project 1061227. ISSN 0177-0667. Published. ISI

Book Chapters since 2006

- Lobos C., Payan Y. and Hitschfeld N., Editor: A. Daskalaki. Chapter IX: Techniques for the generation of 3D Finite Element Meshes of human organs. In "Informatics in Oral Medicine: Advanced Techniques in Clinical and Diagnostic Technologies". Hershey, PA: Medical Information Science Reference, 2010, pp: 126-158.

Publications in Proceedings of Scientific Meetings since 2006

- C. Lobos and Nancy Hitschfeld-Kahler "3D NOffset mixed-element mesh generator approach" Short communications proceedings of the 14th International Conference in Central Europe on

Computer Graphics, Visualization, and Computer Vision (WSCG 2006), in co-operation with Eurographics Country: Czech Republic City: Plzen Date: January 2006 Page(s) 47-52

- Nancy Hitschfeld-Kahler, Carlos Lillo, Ana Cáceres, María Cecilia Bastarrica, María Cecilia Rivara First International Workshop on Advanced Software Engineering, Expanding the Frontiers of Software Technology Sergio F. Ochoa, Gruia-Catalin Roman eds., "Building a 3D Meshing Framework Using Good Software Engineering Practices" Springer, ISBN 978-0-387-34828-5 Santiago, Chile, August 2006, Pages(s): 162 - 169

- María Cecilia Bastarrica, Nancy Hitschfeld-Kahler and Pedro O. Rossel First International Workshop on Advanced Software Engineering, Expanding the Frontiers of Software Technology Sergio F. Ochoa, Gruia-Catalin Roman eds., "A Meshing Tool Product Line Architecture" Springer, ISBN 978-0-387-34828-5 Santiago, Chile, August 2006, Page(s): 1 - 15

- Daniel Pizarro, Patrizzio Virgili, Luis E. Campusano, Nancy Hitschfeld-Kahler, Roger G. Clowes and Ilona Söchting Studies in Computational Intelligence, "Clustering of 3D Spatial Points using a Maximum Likelihood Estimator over Voronoi Tessellations: Study of the Galaxy Distribution in Redshift Space" Springer-verlag, Country: Canada City: Alberta Date: July 2006 Page(s) 112-121

- M. Cerda, N. Hitschfeld-Kahler, D. Mery. Robust Tree-ring detection. Advances Image Video and Technology, diciembre 2007 (PSIVT 2007). LCNS 4872. Page(s): 575-585.

- Claudio Lobos, Marek Bucki, Nancy Hitschfeld, and Yohan Payan. Mixed-element mesh for an intra-operative modeling of the brain tumor extraction. Proceedings of the 16th International Meshing Roundtable, octubre 2007, published by Springer. Pages(s):387-404.

- Maria Cecilia Bastarrica, Nancy Hitschfeld-Kahler, Pedro O. Rossel, Cesar Castro. Rapidely Generating Di fferent Meshing Tools", Abstracts of the 10th U.S. National Congress for Computational Mechanics, in the 7th Symposium of Trends in unstructured mesh generation. Columbus, Ohio. USA. 16-20-July 2009.

- Pedro Rossel, María Cecilia Bastarrica and Nancy Hitschfeld-Kahler. A Systematic Process for defining a Meshing Tool Software Product Line Domain Model, Proceedings of 12th Workshop on Requirements Engineering, WER-2009, Valparaiso, Chile, pp:103-114.

- Mauricio Cerda, Renato Valenzuela, Nancy Hitschfeld-Kahler, Lucas D. Terissi, Juan C. Gomez. Generic face animation. Proceedings of the XXIX International conference of the Chilean Computer Society. Publisher IEEE Computer Society. 2010, pp: 252-257

- Lucas Terissi, Mauricio Cerda, Juan C. Gomez, Nancy Hitschfeld-Kahler, Bernard Girau, Renato Valenzuela. Animation of generic 3d head models driven by speech. Accepted in the IEEE International Conference on Multimedia & Expo (ICME 2011).

- Cristobal Navarro, Nancy Hitschfeld, Eliana Scheihing, "A parallel GPU-based algorithm for Delaunay edge-flips", Abstracts from 27th European Workshop on Computational Geometry, Morschach, Switzerland, March 28-30, 2011. pp: 75-78

Thesis Direction since 2006

- Lillo Borquez, Carlos Enrique. Análisis, Diseño e Implementación de un Sistema Orientado a Objetos que Permita la Construcción, Mejoramiento, Refinamiento y Visualización de Mallas de Objetos en 3d Magíster en Ciencias, Mención Computación, 2006

- Virgili Peñaloza, Patrizzio Corrado. Herramienta de Visualización 3d del Potencial Gravitacional y la Distribución de Cúmulos de Galaxias Ingeniería Civil en Computación, 2006

- Conejeros Gutiérrez, Esteban Andrés. Diseño e Implementación de un Visualizador de Mallas 3d Ingenieria Civil en computación, 2006

- Rodrigo Basualto, José Miguel. Reingeniería y Optimización: Sistema de Mapeo Digital Magíster en Tecnología de Información, 2007

- Cerda Villablanca, Mauricio David.. Reconocimiento de Bordes en Imágenes, un Enfoque Aplicado Ingeniero Civil en Computación, 2007

- Silva Herrera, Nicolás Javier. Modelamiento Del Crecimiento de Árboles Usando Mallas de Superficie Ingeniero Civil en Computación, 2007
- Aguilar Vergara, Pablo Agustin, Reconocimiento de Bordes en Imagenes Aplicado a Anillos de Arboles, Ingeniero Civil en Computacion, 2008.
- Mora Campos, Hugo Ernesto, Desarrollo de Aplicacion para Gestion de Riesgo Operacional en Procesos, Ingeniero Civil en Computacion, 2008.
- Valenzuela Martinez, Jorge Gustavo, Extension y Mejoramiento de Herramienta de Generacion de Mallas Geometricas en Dos Dimensiones, Ingeniero Civil en Computacion, 2008.
- Melo Lagos, Cristina Sonia, Desarrollo de una Herramienta Que Genera Mallas de Superficie Compuestas de Cuadrilateros para Modelar el Crecimiento de Arboles, Ingeniero Civil en Computacion, 2008.
- Muñoz Vergara, Marcelo Alejandro, Diseño e Implementacion de un Visualizador de Equipos Gps en Mapas de 3 Dimensiones Utilizando Sistemas de Informacion Geografica, Ingeniero Civil en Computacion, 2008.
- Claudio Lobos Yanez. Improved techniques for the generation of 3D finite element meshes of human anatomical structures. PhD Thesis. Universite Joseph Fourier. (Co-guia) 2009.
- Vives Cofre, Jose Miguel . Diseño e Implementacion de Sistema de Validacion de Informacion de Organizaciones Bancarias. Ingeniero Civil en Computacion. 2010.
- Valenzuela Palominos, Renato Emilio Felipe. Creacion de una Herramienta para la Visualizacion de Animaciones de Rostros. Ingeniero Civil en Computacion. 2010.
- Cristobal Navarro. Aceleracion de algoritmos geometricos mediante GPGPU. Instituto de Informatica, Universidad Austral de Chile. Ingeniero civil en Informatica. 2010.
- Krauss Benavente, Felipe Antonio Reingenieria de un Software para Reconocimiento de Imagenes. Memoria para optar al t´tulo deIngeniero Civil en Computacion. 2010.
- Castillo Navarrete, Ernesto Jorge. Implementacion de una Aplicacion Grafica para el Procesamiento y Visualizacion de Datos Geofisicos de Potencial. Memoria para optar el título de Ingeniero Civil en Computacion. 2010.
- Mascaro Cumsille, Javiera Alejandra Visualizador y Evaluador de Mallas Geometricas Mixtas 3D. Memoria para optar al título de Ingeniero Civil en Computacion. 2011.

AVAILABLE RESOURCES: Identify the means and resources available at the sponsoring institution(s) to carry out this proposal, provided by FONDECYT and other funding sources. For examples: Internet access, equipment, journal subscriptions, available software and licenses, etc. The maximum length for this section is 1 page (Verdana, font size 10).

The Department of Computer Science, FCFM, University of Chile, provides facilities for online access to journals and conference proceedings, Internet access, photocopying and printing documents. The project is going to be developed on open-source software, then we do not need software licenses.

AMOUNTS AND JUSTIFICATION OF FUNDS REQUESTED FROM FONDECYT.

FUNDS FOR EACH PERFORMING UNIT.

Institution : UNIV.DE CHILE --> FAC.DE CS. FISICAS Y MATEMATICAS --> DEPTO.CS. DE LA COMPUTACION
Representative Name : PATRICIO VELASCO
E-mail : pvelasco@uchile.cl
Phone : 9782167

STAFF	YEAR 1	YEAR 2	YEAR 3	Sub-Total (1000CLP$)
Principal Investigator Name: Nancy Hitschfeld Kahler	5.000	5.000	5.000	15.000
Thesis Students	5.400	5.400	5.400	16.200
Technical & Support Staff	0	0	0	0
SUBTOTAL	10.400	10.400	10.400	31.200

PROPOSAL TRAVEL	YEAR 1	YEAR 2	YEAR 3	Sub-Total (1000CLP$)
Domestic Per Diem	200	200	200	600
International Per Diem	660	660	660	1.980
Domestic Fares	100	100	100	300
International Fares	1.100	1.100	1.100	3.300
SUBTOTAL	2.060	2.060	2.060	6.180

INTERNATIONAL COOPERATION TRAVEL	YEAR 1	YEAR 2	YEAR 3	Sub-Total (1000CLP$)
Domestic Per Diem	0	0	0	0
International Fares	0	0	0	0
SUBTOTAL	0	0	0	0

OPERATIONAL EXPENSES	YEAR 1	YEAR 2	YEAR 3	Sub-Total (1000CLP$)
Operational Expenses	1.400	1.400	1.400	4.200

EQUIPMENT	YEAR 1		YEAR 2		YEAR3		Total	
	Qty.	1000 CLP	Qty.	1000 CLP	Qty.	1000 CLP	Qty.	1000 CLP
Computador	1	1.200		0		0	1	1.200
SUBTOTAL	1	1.200	0	0	0	0	1	1.200

TOTAL (1000CLP$)	15.060	13.860	13.860	42.780

JUSTIFICATION OF REQUESTED AMOUNTS:
Justify the amounts requested for each of the items above. Unjustified requests will not be considered. Make sure the total amounts requested per item are consistent with those entered in table Funding requested, step 1 of your application. (Use Verdana, font size 10).

TECHNICAL & SUPPORT STAFF:
Describe, if applicable, the tasks of all technical & support staff for which honoraria are being requested in relation to the goals and proposed work plan. For example: lab technicians, programming assistants, etc. Do not include occasional staff, such as document translator.

THESES STUDENTS:
Specify if this proposal intends to fund theses students. If so, indicate the topics of the theses you intend to direct. Make sure the topics are directly related to the proposal goals.

During these three years, we are asking for funding at least six undergraduate student theses, two master theses and at least one doctoral student. Some of the topics of the student theses are:

- Design and implement algorithms to integrate audiovisual information, deformation and interpolation strategies for realistic facial animation while speaking (Vanessa Peña)
- Design(adapt) and implement a new moving boundary strategy for tree stem deformations (one undergraduate or master thesis)
- Design and implement a registration algorithm to map a coarse mesh with a dense mesh with few user interaction (one undergraduate or master thesis)
- Improve the architecture and algorithms of the mixed element mesh generator (Roberto Sapian, other undergraduate thesis and one master thesis)
- Parallelization of the mixed element mesh generator (two undergraduate or master students)
- Model, design and build a meshing meshing tool factory (Gonzalo Urroz y Violeta Diaz)
- Parallelization of meshing surface algorithms on gpgpu architectures and evaluation against different parallel architectures (phd thesis or master theses)

PROPOSAL TRAVEL:
Funding for domestic and foreign travel may be requested for activities directly related to the proposal development, dissemination of results and outreach to society. All trips require a clear justification. Indicate tentative destinations, number of days and amounts requested for each trip. Make sure the annual amounts correspond to those entered on the online application form.

FOREIGN TRAVEL:
Remember that only coach fares are acceptable. For further information, please read the **Application Instructions.**

Table 1: FOREIGN TRAVEL (AMOUNTS IN 1000 CLP$)

	Fares	**Per Diem**	**No. Days**	**Purpose/Justification**
Year 1	1100	660	7	Presentation of a paper in an International conference (Europe, USA or Canada)
Year 2	1100	660	7	Presentation of a paper in an International conference (Europe, USA or Canada)
Year 3	1100	660	7	Presentation of a paper in an International conference (Europe, USA or Canada)

DOMESTIC TRAVEL:
For field trips and domestic travel please include the transportation to use and a tentative list of scientific meetings you plan to attend.

Table 2: DOMESTIC TRAVEL (AMOUNTS IN 1000 CLP$)

	Fares	**Per Diem**	**No. Days**	**Purpose/Justification**
Year 1	100	200	5	Student presentation of a paper in a local conference (SCCC, Encuentro Chileno or other)
Year 2	100	200	5	Student presentation of a paper in a local conference (SCCC, Encuentro Chileno or other)
Year 3	100	200	5	Student presentation of a paper in a local conference (SCCC, Encuentro Chileno or other)

INTERNATIONAL COOPERATION FOREIGN TRAVEL:
Please justify your request for funding of international cooperation activities. Explain why the visit of a researcher residing abroad will benefit your proposal goals achievement. Remember that only coach fares are acceptable. Please read the **Application Instructions. Justification (for each year):**

Table 3: INTERNATIONAL COOPERATION FOREIGN TRAVEL ITEM

			Per Diem		**Air Fares**	
Name of collaborator (if known)	**No Days**	**1000 CLP$/day**	**Total (1000 CLP$)**	**Itinerary**	**Cost (1000 CLP$)**	
Year 1						
Year 2						
Year 3						
Year 4						
		TOTAL (1000 CLP$)		**TOTAL (1000 CLP$)**		

OPERATIONAL EXPENSES:
Indicate in the table below the estimated annual amount(s) for each the subitems required for successful execution of the proposal. Add as many rows as needed. Justify your request in the space provided.

Table 4: OPERATIONAL EXPENSES (AMOUNTS IN 1000 CLP$)

Subitem	**Year 1**	**Year 2**	**Year 3**
Office Supplies	100	100	100
Computing-related items	200	200	200
Reagents and other laboratory non-durable materials			
Field trip related expenses (vehicle rental, shipping charges, gasoline, lubricants, highway tolls)			
Books purchases, scientific journals and subscription fees	250	250	250
Scientific meetings registration fees	550	550	550
Payments for services			
Hiring of occasional auxiliary personnel	300	300	300
Journal publishing costs			
Software and licenses			
Survey(s) Cost			
Focus Group(s) Cost			
Other: Specify			
TOTAL (1000 CLP$)	1400	1400	1400

EQUIPMENT:
Each piece of equipment requested must be clearly justified considering the proposal goals and Methodology. A formal quotation for the equipment requested is not required, thus you must provide a full description and technical specifications for each of the items funding is requested for. Please include the full name of the distributor/manufacturer you have consulted. The amounts requested must include transportation, insurance and applicable import taxes costs. Non-durable, expendable items, must be included under Operational Expenses.

We need a computer that can be used as a server and, at the same time, supports the development of GPU-based algorithms. For handling meshes with more than 1 million triangles or mixed-elements, we need a powerful GPU. The implementation of the meshing tool factory and the evaluation of the generated meshing tools will be also done in this computer.

ANNEXES

Certificado de Patrocinio Institucional

El Sistema de Postulación en línea del Concurso FONDECYT Regular 2012 certifica el patrocinio del (de la) institución "UNIVERSIDAD DE CHILE (UCH)" en el proyecto "Improving the functionality and performance of meshing tools", autorizado por su Representante Institucional, Sr.(a) PATRICIO VELASCO.

Nombre Concurso:	Concurso FONDECYT Regular 2012
Título Proyecto:	Improving the functionality and performance of meshing tools
Número de Certificado:	56681
Fecha de Emisión:	04-07-2011 02:20:08 PM
Código de Transacción:	258747MRYXTG7TPVRY14N6AE97
Número de Folio :	1120495
Nombre :	Patricio Velasco
E-Mail:	pvelasco@uchile.cl

FONDO NACIONAL DE DESARROLLO CIENTIFICO Y TECNOLOGICO

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Certificado de Declaración ante CONICYT

DECLARACIÓN ANTE LA COMISIÓN NACIONAL DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA (CONICYT). El(La) Investigador(a) Responsable don(doña) Nancy Hitschfeld Kahler, postulante al Concurso FONDECYT Regular 2012, manifiesta tener pleno conocimiento de las bases e instrucciones que rigen su postulación. En consecuencia, certifica que toda la información contenida en ésta es verídica/fidedigna y cumple con los requisitos de presentación señalados en las bases e instrucciones del presente concurso. Asimismo, toma conocimiento que dicha información estará sujeta a verificación y se compromete a proveer toda la documentación de respaldo que sea requerida por los Consejos Superiores de FONDECYT, así como los antecedentes e información que se juzguen necesarios durante el proceso de postulación del proyecto, en la forma y plazos requeridos. La omisión o declaración falsa de cualquier dato de la postulación, así como el incumplimiento a las condiciones anteriormente descritas, serán causales para declarar la postulación fuera de bases..

Nombre Concurso:	Concurso FONDECYT Regular 2012
Título Proyecto:	Improving the functionality and performance of meshing tools
Número de Certificado:	56680
Fecha de Emisión:	28-06-2011 09:22:28 PM
Código de Transacción:	2587469E5I638F2C1NCDRBPKDI
Número de Folio :	1120495
Nombre :	Nancy Hitschfeld Kahler
E-Mail:	nancy@dcc.uchile.cl

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CONICYT
COMISIÓN NACIONAL DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA

GOBIERNO DE CHILE

Certificado Recepción de Postulación

CONICYT certifica que el siguiente proyecto ha completado todos los antecedentes y ha sido recepcionado electrónicamente por FONDECYT.

Nombre Concurso:	Concurso FONDECYT Regular 2012
Título Proyecto:	Improving the functionality and performance of meshing tools
Número de Certificado:	57625
Fecha de Emisión:	04-07-2011 02:20:08 PM
Código de Transacción:	259692KIDTQAVPAYS28FBTMUS3
Número de Folio :	1120495
Nombre :	Nancy Hitschfeld Kahler
E-Mail:	nancy@dcc.uchile.cl