Regional Program STIC-AmSud
2023 Project Proposal (Research – Innovation)

Basic Form

- This form, and the associated CVs, must be filled in English. Before filling the form, please read carefully the bases published in the STIC-AmSud site (http://sticmathamsud.org/).

A. General Information

A1	Project title
	Context-Guided Future Liver Remnant Volume Estimation using Artificial Intelligence Models

A2	Acronym
	CGFLRVE

A3	Research domain
	Artificial Intelligence for Medicine

A4	Project goals
	O1. Evaluate state-of-the-art liver segmentation models. **O2.**Design and evaluate models for fine-grained liver segmentation models. **O3.**Estimate future liver remnant volume using the proposed fine-grained liver segmentation model. **O4.** Integrate contextual information by prompts for fine-grained liver

	segmentation. **O5.** Evaluate and adjust the proposed models.

A5	**Abstract**
	Automatic Liver-Segmentation is an essential task in the medical context. Current AI-based models are focused on liver and tumor segmentation, that is not enough for surgical planning, especially for liver metastases. An automatic liver and tumor segmentation method can greatly relieve physicians of the heavy workload of examining CT images. However, for surgery, a more challenging task is required. In this context, it is critical to estimate accurately the remnant liver volume after resection; for instance, in patients with liver metastases. Estimating the future liver remnant is a challenging task because the type of surgery to be performed depends on each patient's clinical setting, the center's experience, number and location of liver lesions, among others. This means that future liver remnant segmentation depends on the patient's clinical context. Therefore, the goal of this project is to design, implement and evaluate fine-grained liver segmentation guided by the context that allows us to precisely estimate remnant liver volume. Our work is guided by five objectives: (1) evaluate SOTA liver segmentation models, including the recent published architecture HybridGNet; (2) design and evaluate models for fine-grained liver segmentation models taking into account models like SAM and HybridGNet; (3) estimate remnant liver volume using the fine-grained liver segmentation model; (4) Integrate contextual information by prompts for liver segmentation. Finally, we present results on public and private datasets. For the private case, we collaborate with a local health center, which provides us access to data. To accomplish the proposed objectives, we have formed a multidisciplinary team, including physicians with specialization in radiology and experts on computer vision applied to medical images.

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A7	Other participating institutions	
	In South America Pamela Guevara <Universidad de Concepción>	**In France**

A8	List of expected participants (name and affiliation and status : junior, senior)
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A9	International Project Coordinator (to be chosen among the national coordinators mentioned in A6)
	Jose M. Saavedra Rondo (UANDES)

A10	Percentage of female participation in the project*

	5/8	62.5% (with respect to the senior reserachers)

**please determine the participation of women in the project considering all the teams in each country*

B. Project Details

B1. Project guidelines

Artificial intelligence and, particularly, machine learning, have shown significant impact in diverse fields. Among the wide diversity of fields with impact from AI, medicine stands as one in which there is tremendous potential along with equally critical challenges. This can be observed by the increasing number of publications in this field. For instance, we have seen many publications on image-based diagnosis using AI. This covers areas like radiographs, histology, and optic fundi, among others.

Radiology is the field of medicine in which there are the greatest number of clinical solutions that use AI. These solutions focus on problems of detecting findings, classifying lesions, organ or lesion segmentation, image processing, among others. Segmentation problems are very common in medical imaging, with hepatic segmentation being one of the most explored due to its applications in volumetry. Liver segmentation for volumetry is indicated in patients undergoing major liver surgery, defined as the resection of four or more liver segments. Most hepatectomies are performed in patients with liver neoplasms, such as hepatocarcinoma, cholangiocarcinoma and liver metastases. The objective of the liver volumetry is to estimate the total liver volume and the future liver remnant, the amount of liver parenchyma that would be left post-resection. Future liver remnant volume is directly correlated with post-hepatectomy liver function, and its precise measurement is crucial to prevent patients from developing post-hepatectomy liver failure[1-2].

Current models are focused on liver and tumor segmentation that is an important task but not enough for surgical planning. An automatic liver and tumor segmentation method can greatly relieve physicians of the heavy workload of examining CT images [21]. However, for surgery, a more challenging task is required. Indeed, for surgery planning is critical to accurately estimate the remnant liver volume after resection; for instance in patients with liver metastases.

Estimating the future liver remnant is a challenging task because the type of surgery to be performed depends on each patient's clinical setting, the center's experience, number and location of liver lesions, among others. This means that future liver remnant segmentation depends on the patient's clinical context.

Therefore, the goal of this project is to design, implement and evaluate fine-grained liver segmentation guided by context that allows us to precisely estimate remnant liver volume. Our project is guided by the following specific objectives:

O1. Evaluate SOTA liver segmentation models.

O2. Design and evaluate models for fine-grained liver segmentation models.

O3. Estimate remnant liver volume using the fine-grained liver segmentation model.

O4. Integrate contextual information by prompts for liver segmentation.

O5. Evaluation and adjusting the proposed models.

B2. Project description

Goals, motivation, methodology and contribution of each participating institution

Motivation:

Medical images play a central role in the assessment of patients undergoing major liver surgery, allowing for the evaluation of relevant anatomical factors, complications, and response to treatment. One of the relevant prognostic factors is the ***future remnant liver volume***, which must be estimated as accurately as possible, because it directly correlates with the development of post-hepatectomy liver failure [1-2].

This means that in patients who require partial liver resection, it is necessary to know how much liver parenchyma will remain after the procedure. If this volume is less than what the patient needs, liver failure can occur, which has high mortality.

The percentage of remaining liver volume is not the same for all patients. In a patient with a healthy liver, 20% may be enough. However, if the liver has a diffuse disease such as fatty liver or cirrhosis, the minimum percentage may reach 40%[2].

Currently, the gold standard for non-invasive volumetric evaluation is liver segmentation performed on computed tomography or magnetic resonance imaging, which is a technique that can take between 20 and 40 minutes per patient and requires a highly trained operator [3].

Most of the published studies evaluate the full liver segmentation. However, in patients that are candidates to major liver resection, the objective is to know the complete liver volume and the volume of the *future remnant liver*, in order to estimate whether it is compatible with life or not. There are several challenges in this partial liver segmentation. First of all, it must be known what type of surgery will be performed on the patient, which depends on the number and location of the lesions, the patient's status, vascular anatomical factors, the surgeon’s experience, among others.

This process is currently done manually or with the assistance of some semi-automatic or automatic segmentation tools. However, most semi-automatic or automatic tools focus on the segmentation of the complete liver, and do not consider these factors of the clinical context [4].

Image Segmentation

Image segmentation is one of the most popular tasks in computer vision. It can be regarded as an extension of the classification task, where the goal is to precisely classify any pixel of the input image into a set of classes. Formally, a segmentation task aims to split an input image into non-overlapping regions, each of which is relevant for the underlying context.

Segmentation has been studied for many years. However, like many other vision tasks, deep learning has allowed this task to achieve outperforming results and, consequently, be applied for industry [5, 6, 7, 8]. One of the applications where segmentation brings significant impact is in radiology [9]. In this area, automatic segmentation allows the physician to split up an image into segments that are essential for diagnosis and prognosis.

Models for Image Segmentation

After the bloom of deep-learning. We have seen enormous advances in image segmentation and its application in medicine. In this vein, one of the most popular models is UNET [5], an encoder-decoder convolutional architecture for pixel-wise classification. The general idea is to encode an input image in different scales using a convolutional neural network like ResNet [10] or ViT [14]. The representations in deeper layers are combined with representation from less deeper layers through a decoder block. The goal of this combination is to leverage high-semantics of deep layers with high-resolution information from shallow layers. At the end, we have a probability vector per pixel, indicating how likely this pixel corresponds to any of the relevant classes [11]. There is a variant of UNet called UNet++ [12] that incorporates convolutional blocks into the skip connections to reduce the semantic gap between encoder and decoder.

UNet has also been extended to 3D images [13], to deal with volumetric segmentation. This model is very similar to 2D UNet but improves the structure by applying 3D convolutions instead of 2D. A self configuring version of the UNet architecture entitled nnUNet [27] has also been proposed, which makes it really simple to train segmentation models with high accuracy. More recently, UNet has been equipped with transformer blocks [14, 20] due to the success of attentional models in NLP and vision tasks. Furthermore, Meta also released a general tool for segmentation (SAM) trained with nearly 1B of masks and 11MM of different images. SAM uses Visual Transformer (ViT) to encode an input image [14] and a mask-decoder to generate the segmentation masks. It would be beneficial to evaluate the capacity of SAM in the medical context.

Recently, Gaggion et al. (one of the collaborators in this project) proposed the HybridGNet [26] architecture specifically designed to improve anatomical plausibility in medical image segmentation. This approach combines the power of convolutional neural networks for image representation learning with graph neural networks to integrate topological constraints. First, the architecture uses a convolutional neural network to learn local features and a global low dimensional embedding. This component acts as the encoder of the model. The global low dimensional embedding is then reshaped as a graph structure, and processed using graph convolutions to decode plausible anatomical structures. This second component is the decoder of the model. Both the encoder and the decoder are combined following a UNet-like architecture. Our study is based on this recent work, but we will extend HybridGNet to incorporate attention mechanisms and evaluate it in the context of liver segmentation.

Generative models can also be used for segmentation, particularly, using conditional-generative models. In this case, the inference is conditioned by an input image. Examples of these models are Pix2Pix [15] and CycleGAN [16] that translate an input image into another image for diverse tasks. Recently, Damir et al. [17] proposed a transformer-based generative model for liver segmentation. The idea is similar to Pix2Pix and CycleGAN but including a transformer backbone in the encoder. The authors evaluate a discriminative transformer vs a generative model, achieving similar results in both cases, around 94% in the LITS dataset (Liver Tumor Segmentation Challenge)

So far we have seen a vast number of publications on liver segmentation based on deep learning. As we have seen, initial models were based on UNet [18, 19] and more recently transformers-based models [14] are representing the state of tre art. However, all of them focus on segmenting the entire organ, which is not enough to take critical decisions, especially where resection is required. Figure 1 shows an example of volume estimations using full liver segmentation.

Indications for liver surgery, segmental anatomy of the liver and its implications in volumetry:

Currently, some patients with liver metastases or those who are candidates for living donor liver transplantation, require a precise imaging evaluation. This evaluation aims at estimating whether the remaining hepatic volume after surgery will be enough to meet their physiological needs and thus avoid post-surgical liver failure.

The goal of major liver surgery in patients with liver metastases (Figure 2) is to completely remove the neoplastic disease from their body, which is referred to as an R0 status.

Therefore, only patients who have localized liver metastases and no neoplastic disease elsewhere in the body are candidates for this procedure. Over the last few years, there has been an increase in the indications for this procedure, including different types of primary tumors [22].

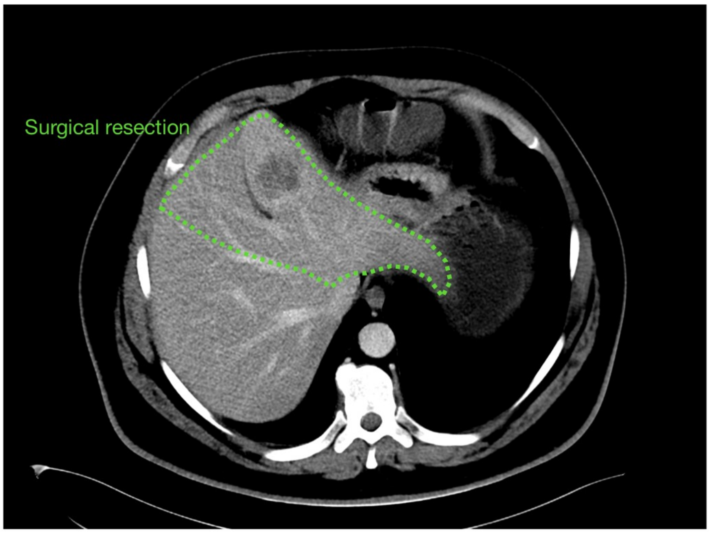

Figure 2: Shows a hepatic metastasis from colon cancer in the lateral segment of the left hepatic lobe. The green dashed lines represent the area of potential hepatic resection during surgery.

The liver has a vascular anatomy different from other organs. Between 70 to 80% of the blood flow comes from the portal vein, which receives blood from the intestinal territory. The remaining 20 to 30% is irrigated by the hepatic artery. Hepatic venous drainage is performed by the suprahepatic veins, which converge into the inferior vena cava. This peculiarity of its vascularization, associated with a biliary drainage system that reaches the small bowel, determines an anatomical configuration of the liver based on segments. Each segment has its own arterial and venous irrigation, biliary and venous drainage. Standard liver resections respect these segments, as they maintain the integrity and better control of vascularization during surgery and reduce complications in the remaining liver parenchyma [23]. Figure 3 shows the liver segmental anatomy with vascular landmarks.

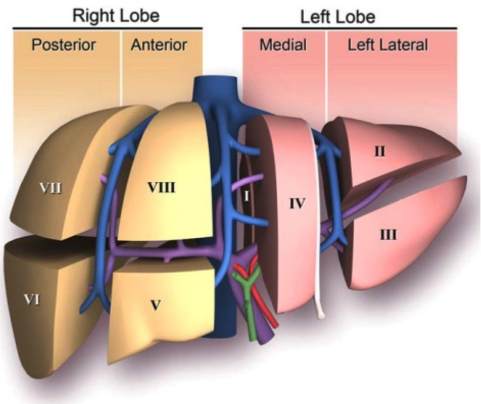

Figure 3. Liver segmental anatomy with vascular landmarks [23].

The gold standard for non-invasive liver evaluation is performed with computed tomography or magnetic resonance imaging with intravenous contrast. These imaging modalities allow for the detection of hepatic lesions, definition of vascular structures, potential anatomical variants detection and segmentation for volume estimation. Figure 4 shows results of a manual liver segmentation of the 8 segments and vascular remarks in a computed tomography.

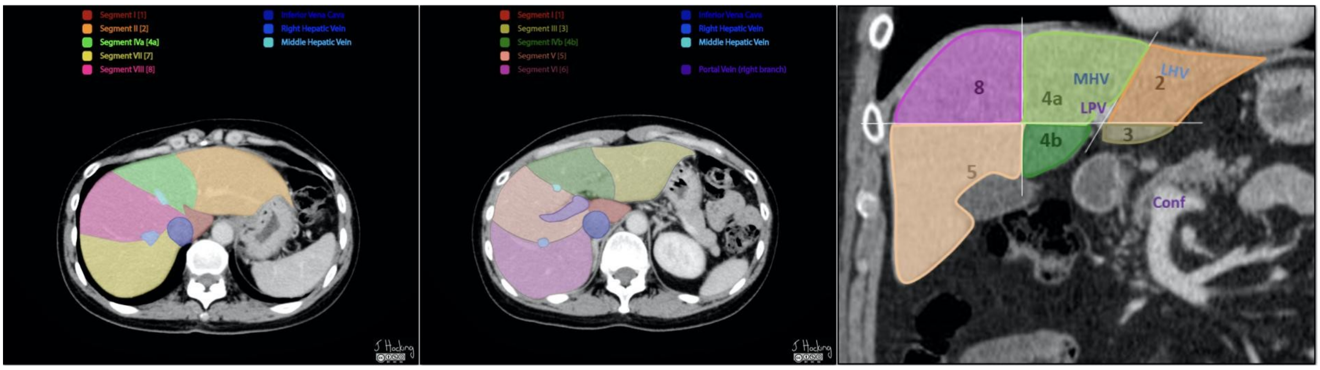

Figure 4. Manual liver segmentation of the 8 segments and vascular remarks in a computed tomography. (Case courtesy of Melisa Sia, ref=https://radiopaedia.org)

Liver volumetry:

Estimation of liver volume is a challenging task and should tackled via a multidisciplinary approach. Trained operators in medical imaging are required, as well as direct communication with the surgical team to understand the type of surgery that the patient will undergo and to communicate efficiently imaging findings related to anatomical variants that may hinder the surgical procedure.

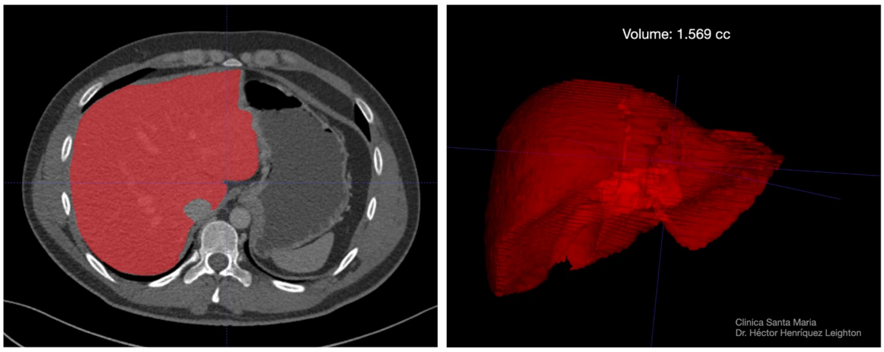

Figure 5: Entire Liver Volume Estimation

The first step is to perform a volumetry of the entire organ (Figure 5), which is a time consuming task, but does not offer a high level of difficulty from the segmentation point of view. Subsequently, a segmentation of the hepatic parenchyma that will remain intact after surgery should be performed (future remnant liver). This is a very challenging step, because it requires a high understanding of the anatomy, vascular landmarks, recognition of liver lesions and the surgical techniques, including post-treatment changes [24]. Figure 6 shows a segmentation of the lateral segment indicating the future remnant liver.

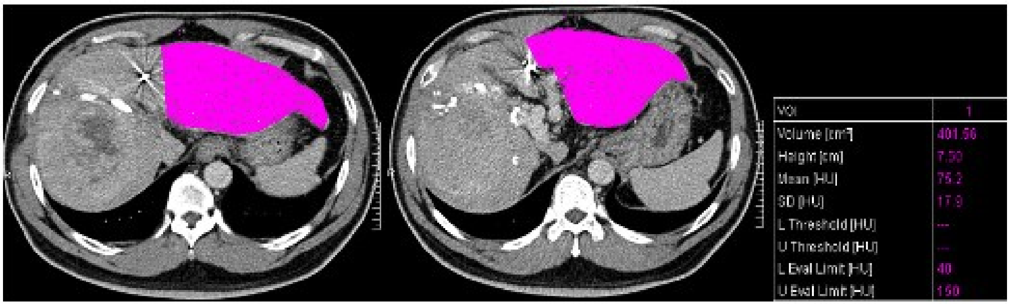

Figure 6. Liver with a metastatic lesion in the right lobe associated with post-treatment changes from a selective hepatic embolization that cause artifacts in the image. Segmentation of the lateral segment indicates the future remnant liver [24].

Contextual Information:

The segmentation of the future remnant liver requires a significant amount of contextual information, which differs between patients.

The most important information includes:

- **Type of surgery**: segmentectomy, right hepatectomy, left hepatectomy, right or left extended hepatectomy, right or left hepatectomy plus metastasectomy. Figure 7 illustrates the main types of liver surgeries.
- **Anatomical landmarks**
    - Accurate recognition of vascular structures.
    - There are anatomical variants of vessels and biliary tract.

- **Usual Variations**
  - Different sizes, shapes and intensity of the liver.
  - Neighboring structures that have similar intensity of the liver parenchyma.

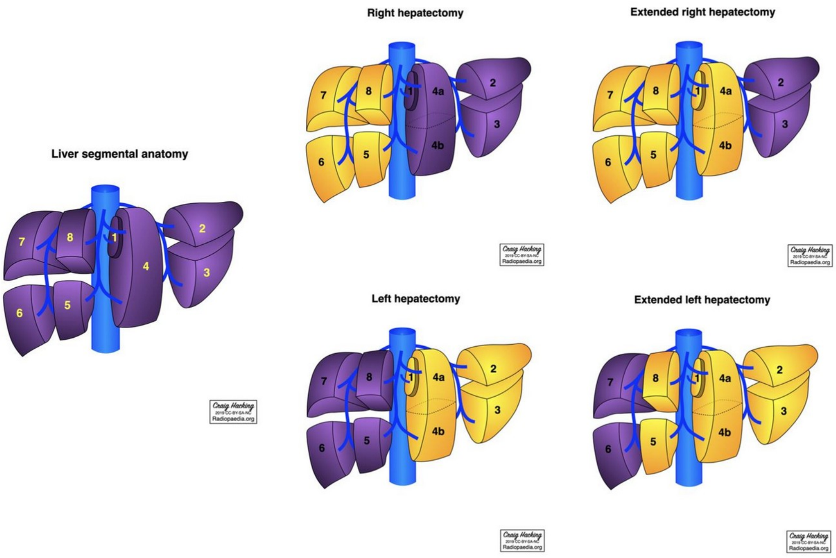

Figure 7: Main types of liver surgeries (Radiopaedia.org, rID: 68340).

Therefore, adding extra information to allow a model to accurately segment the liver of a patient could improve volume estimation. Figure 8 shows an example of future remnant liver estimation with vascular structures as resection landmarks.

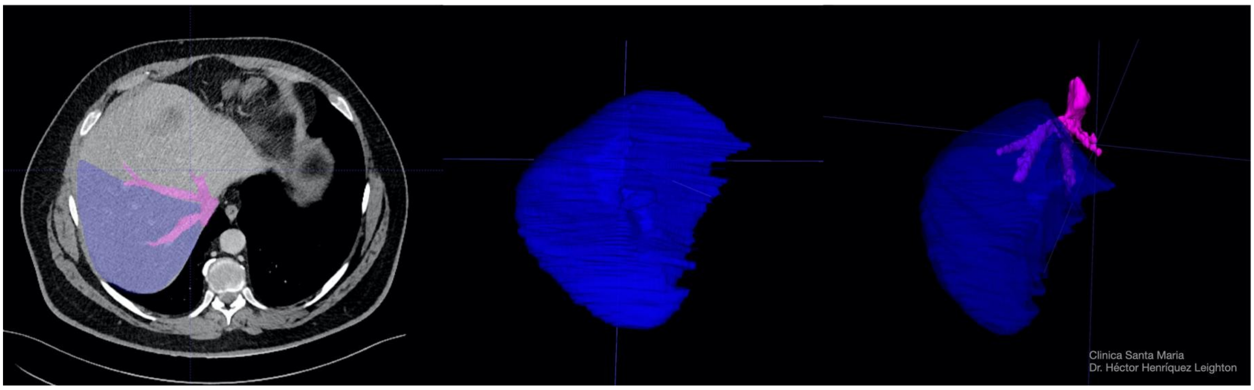

Figure 8. Example of future remnant liver estimation with vascular structures as resection landmarks.

Objective

To design, implement and evaluate fine-grained liver segmentation guided by context that allows us to accurately estimate future liver remnant volume. An illustration of our proposal is depicted in Figure 9.

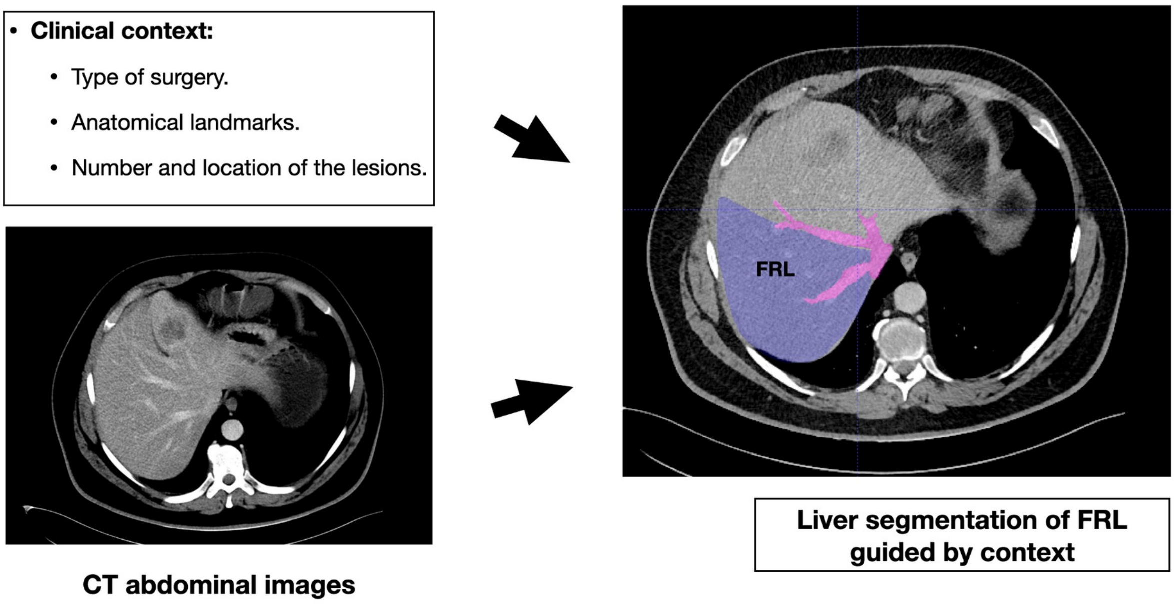

Figure 9: Illustration of the proposal.

Methodology

Our methodology follows four specific goals:

O1.*Evaluate SOTA liver segmentation models*. We will evaluate UNet-based and transformer-based models, including HybridGNet and SAM. Particularly, we are interested in adapting HybridGNet for liver segmentation. HybridGNet combines convolutional neural networks to produce visual representations for CT and graph neural networks to add topological constraints.

O2. *Design and evaluate models for fine-grained liver segmentation* (8 liver segments). Our design will be based on SAM and HybridGNet. This stage will also evaluate the impact of segmenting vascular elements for fine-grained liver segmentation.

In addition, our study includes evaluating HybridGNet with attention mechanisms replacing the GNN component by a ViT model, for whole liver segmentation and the fine-grained task. Given that attention, like Transformers, allows a model to learn representations based on the others, it could play the role of the GNN in the HybridGNet.

O3.*Estimate remnant liver volume using the fine-grained liver segmentation model*. For this task we will use the segments inferred in different images of the underlying CT.

O4. Integrate contextual information by prompts for liver segmentation. We will incorporate the following information as prompts:

- Type of surgery.
- Anatomical landmarks.
- Liver lesions.

O5. *Evaluation and adjusting the proposed models*. We will evaluate our proposal in public and private datasets. To this end, our team includes radiologists specialized in liver segmentation.

Datasets

Our study will leverage datasets from the public domain as well as local cases obtained from a local health institution.

- **Public Liver Datasets**
    - The Liver Tumor Segmentation (LiTS)

      LiTS dataset contains 200 computed tomography images in DICOM format. This dataset is split up into 131 images for training and 69 for testing.

- **Our own Liver Dataset**
    - **KiTS19 dataset**: Contains CT scans of 18 patients from KiTS19 Challenge [25], with full liver segmentations. Images and masks are in nrrd format.

    - **Clínica Santa María**: CT scans of 7 patients with full liver segmentations from Clinica Santa María. Study approved by Ethics Committee of Clinica Santa María (march 2020). Figure 10 shows an example of images included in this dataset.

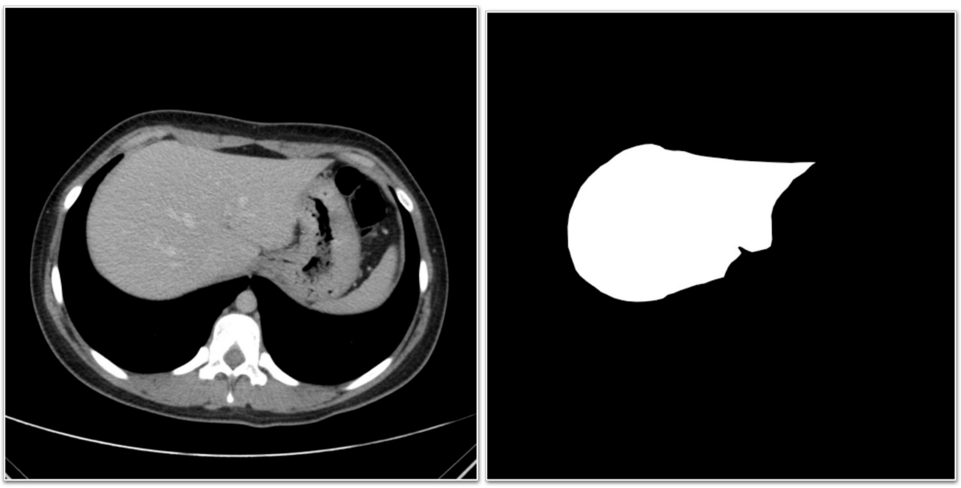

Figure 10. Example of CT images and binary mask from Clinica Santa Maria dataset.

Metrics

We will use the following segmentation metrics in 2D and 3D scenarios:

- DICE Coefficient
- Intersection over Union Score (IoU)
- Average Surface Distance
- Relative Volume Difference

Project scope

This is an interdisciplinary project combining artificial intelligence models with a great impact in the medical context. We will model an AI-based solution for automatically determining the future liver remnant volume through CTs. Our project combines the expertise of specialized radiologists with experts in artificial intelligence, particularly in the field of computer vision.

Expected results

- A model for fine-grained liver segmentation.
- A fine-grained liver segmentation improved by context information (prompts).
- A new dataset for fine-grained livers segmentation.
- A fruitful collaboration between the involved teams.
- A new baseline that potentially can be applied to other medical segmentation problems.
- Publications in high-level journals or conferences.
- An interdisciplinary collaboration between academia and medicine.

Dissemination actions of the project outcomes (and how STIC AmSud will be mentioned)

- Workshops
    - We will organize workshops to disseminate the results, with the corresponding acknowledgement to STIC AmSud.
- Publications
    - We plan to submit two papers (at least) to top tier journals in the context of AI and medicine.
- Conferences
    - We plan to participate in the following conferences:
        - MICCAI 2024, 2025
        - IPMI 2025
        - CVPR, ICCV 2024, 2025
        - RSNA annual meeting

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B3. Schedule, with main execution stages

T0. Initial administrative tasks. This will be conducted remotely with the whole team.

T1. Evaluation of SOTA liver segmentation mode. In this stage we elaborate a survey on deep-learning models for liver segmentation. We have undergraduate and graduate students who will support the experimentation process.

W1 Workshop 1 - Paris, France.

T2. Evaluation of SOTA fine-grained liver segmentation model. In this stage we elaborate a benchmark of deep-learning models for liver segmentation based on the liver's segments.

T3. Estimate future remnant liver volume based on the fine-grained segmentation.

W2:Workshop 2 - Buenos Aires, Argentina.

T4. Integrating prompt for liver segmentation. In this stage, we define the prompting mechanism to allow clinicians to estimate live volume based on the liver's segments. During this stage, our partners from Argentina will be visiting the team of UANDES.

W3: Workshop 3 - Rouen, France.

T5. Evaluation and adjusting the model. We evaluate our proposal and adjust the model.

W4 Workshop 4 - Santiago, Chile.

	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24
T0	■											
T1		■	■									
T2			■	■	■	■						
T3					■	■	■	■				
T4							■	■	■	■		
T5										■	■	■
W			W1 (FR)			W2 (AR)			W3 (FR)			W4 (CH)

B4. Contributions

Present contributions so as to highlight the role of each partner and the integration among partners.

- A survey of modern methods for liver segmentation. All the teams are involved in this item. The models will be defined by the AI team (France, Argentina and Chile), and the evaluation methodology will be validated by the Physician team.
- A new HybridGNet model using ViT. The model's authors are part of this project (from Argentina). Thus, the Chilean team will work directly with them to improve the model.
- A new model for fine-grained liver segmentation based on HybridGNet. Like in the first item, all the teams are involved here. However, we will especially leverage the experience of Maria Vakalopoulou and Enzo Ferrante in AI-based segmentation models in medicine.
- A survey of modern methods for fine-grained liver segmentation. All teams are involved here. However, we highlight the experience of Violeta Chang in the evaluation of AI models in the biomedical field.
- A model for context-based liver segmentation and volume estimation. Here, Hector Henríquez will support us with the medical methodology to define context information. Then, teams led by Caroline Petitjean and Jose M. Saavedra will determine and evaluate the models.
- Our students will be able to visit our different labs in France, Argentina and Chile.

B5. Regional Aspects

The project team comprises researchers from France, Argentine, and Chile, all involved in studying pattern recognition, data science, machine learning, and deep learning considering real problems. However, we are forming a well-complementing team with respect to the adopted strategies and applications. For instance, we have the motivation of physicians that provide knowledge on medical issues. In addition, they will push the proposed solution to be used in real context. On the other hand our team comprises different computer vision specialists like Caroline Petitjean, Maria Vakalopoulou and Enzo Ferrante in the area of medical image processing; Violeta Chang specialized in bioinformatics; and Jose M. Saavedra specialized in self-supervised models.

B6. Additional information

List all the complementary fundings expected or already obtained.

Experience of the coordinators in similar projects.

Jose M. Saavedra Rondo:

a) FAI-UAndes, "Desarrollo de modelos de deep learning multimodales para la predicción de mutaciones genéticas clínicamente relevantes en pacientes con cáncer de pulmón a través del análisis de características radiómicas obtenidas desde imágenes de tomografía por emisión de positrones – tomografía computarizada (PET-CT)" [Director].
b) 2019-2020 STIC-AMSUD 19-STIC-04 Optimized Deep Learning based Representations for Computer Vision Problems. [National Coordinator, Chile] (~USD 7,000)
c) 2018-2021 CORFO (18IEAT-93724) Inteligencia Artificial y Visión por Computadora para potenciar el mercado de la moda a nivel mundial. [Director] (~USD 180,000)
d) 2015-2018 FONDECYT INICIACION No 11150945: One Shot Image / Sketch Detection on Video and Image Large Datasets. [Principal Researcher] (~USD 100,000)

Violeta Chang Camacho

a) STIC-AMSUD (22STIC-04): Domain adaptation for cell segmentation and classification using weakly supervised machine learning. International coordinator, principal researcher. 2022–2023
b) FONDECYT (11190851): Deep learning models for breast digital pathology. Principal researcher. 2020--2023.
c) PAI (77180012): Fortalecimiento del área de aprendizaje de máquinas en pre y posgrado e investigación del Departamento de Ingeniería Informática. Principal researcher. 2019--2022.
d) FONDECYT (3160559): Generation of biomedical gold-standards using supervised learning based on multiple experts. Principal researcher. 2015--2019.

Héctor Henríquez:

a) Private research funds from Clinica Santa Maria (March 2020): "Automatic calculation of liver volumetry using Deep Learning Model". Principal researcher.

Enzo Ferrante:

a) "Unsupervised bias discovery: anticipating fairness issues in machine learning models for medical imaging without ground-truth annotations". Google Award for Inclusion Research". PI: Enzo Ferrante (2022-2023)
b) "Nuevos métodos de registración de imágenes médicas realistas y adaptables basados en redes neuronales convolucionales" PICT ANCPYT (PICT-PRH-2019-00009) PI: Enzo Ferrante. (2022-2024)
c) "Deep learning Meets biodiversity: unveiling the Microbiome of a Mega-river", National Geographics Society - AI for Earth Innovation Grant, Role: Collaborator. (2021-2022)
d) "Learning novel deep multi-scale representations of heart anatomy for cardiomics through graph neural networks", Royal Society (UK) International Exchanges 2020 (IES/R2/202165). PIs: Enzo Ferrante, Alejandro Frangi. (2020 - 2022)
e) "Registración de imágenes biomédicas por medio de redes neuronales convolucionales", CAI+D UNL 50220140100084LI. (2019 - 2021).PI: Enzo Ferrante
f) "Aprendizaje profundo multi-resolución en dominios irregulares", PICT ANCPYT Tipo B 2018-03907 (2019 - 2021). PI: Enzo Ferrante
g) "Image registration under the big data paradigm: boosting risk understanding through imaging technologies", AXA Research Fund Grant. PIs: Enzo Ferrante, Diego Milone

Caroline Petitjean:

a) STIC-AMSUD (22STIC-04): Domain adaptation for cell segmentation and classification using weakly supervised machine learning. French coordinator, 2022–2023
b) Project ANR (French research agency) MediSEG, 4 years: 2021-25, 402k euros on deep learning techniques and explainability for medical image segmentation, Principal investigator

Maria Vakalopoulou:

a) Project ANR (French research agency) Hagnodice, 4 years: 2021-2025, 200k euros on Holistic explainable artificial intelligence schemes for lung cancer prognosis. Principal Investigator
b) Project ARC Foundation for cancer researct (French research agency) 4 years (2018-2022), 200k euros Artificial intelligence-driven integration of Radiomics, Pathomics & Genomics to predict outcome of immunotherapy. Participant.

Present main activities and their relationship with the project's main goal.

Héctor Henríquez: Body Imaging Radiologist with 11 years of experience in abdominal and oncological imaging. Role in supervision of image annotations and clinical applicability of the results.

Jose M. Saavedra Rondo: PhD in computer vision and academic of Universidad de los Andes working in image processing and machine learning for almost 20 years. Currently he is working on selfsupervised and attention mechanisms for visual recognition tasks. His main role in this project is in the design of new models for image segmentation.

Violeta Chang Camacho: professor and researcher at Universidad de Santiago de Chile (Chile) and part of the MALIS-Lab (Machine Learning for Image & Signal Processing Lab). Her research interests are related with application of artificial intelligence with social impact, such as morphological human sperm analysis, breast/gastric/prostate cancer digital pathology and detection of underwater debris. She has students and papers already published with Prof. Caroline Petitjean (France) and José Saavedra (Chile).

Enzo Ferrante: CONICET faculty researcher in Argentina, leading a research group on machine learning methods for biological and medical image analysis at the Research institute for signals, systems and computational intelligence (CONICET / Universidad Nacional del Litoral) in Santa Fe, Argentina He is also a professor at Universidad Torcuato Di Tella and Universidad de San Andrés, in Buenos Aires, Argentina. He obtained his PhD in Computer Sciences in 2016 from Université Paris-Saclay, worked as a postdoctoral researcher at Imperial College London in the UK, and returned to Argentina in 2017. His role in this project is in the design and evaluation of new models for image segmentation.

Caroline Petitjean: professor and researcher at LITIS lab in the University of Rouen. Her main research deals with medical image analysis with machine learning. In this topic, she will be supervising students in image segmentations for medical applications.

Maria Vakalopoulou: Assistant Professor at CentraleSupélec, University of Paris-Saclay with a vast experience in medical image processing. Her role in this project is in the design and evaluation of new models for image segmentation.

Perspectives of continuing collaboration after project financing is over.

Yes, we will continue the cooperation among the formed teams through joint research, co-supervising students and proposing new models in the context of medical issues. Moreover, we expect to submit joint proposals for other sources of funding.

B7. Public and private support obtained related to the project:

Participation in a previous STIC AmSud, MATH AmSud or CLIMAT AmSud project?
NO

Other public support in the past (ECOS, COFECUB, CNRS, European Union, etc.):

Other private support in the past:

FAI Temático “Desarrollo de modelos de deep learning multimodales para la predicción de mutaciones genéticas clínicamente relevantes en pacientes con cáncer de pulmón a través del análisis de características radiómicas obtenidas desde imágenes de tomografía por emisión de positrones – tomografía computada (PET-CT)”

Prospects for public or private support in the future:

- ANID Fondecyt Regular Transdisciplinario
- Fondef-I+D in the context of self-supervised medical image segmentation.

C. Project Budget

Project title:

Participating institutions:

The STIC-AmSud program **funds travel expenses** (air tickets and *per diem*) to researchers in research missions and workshops.

C1. First year (2024)

Planned missions – Year 1

Researcher	Status (student, junior, senior)	Institution	Origin	Destination	Planned date	Duration (max. 30 days)	Estimated cost of the trip (€)	Estimate of total *per diem* (€)	Trip and Mission funding institution[1]	Mission objectives
Héctor Henríquez	Senior	STAMARIA	Santiago	Paris	JUN	8	1500	1000	ANID	discuss about advances in liver segmentation
Jose M. Saavedra	Senior	UANDES	Santiago	Paris	JUN	8	1500	400	ANID	present results in liver segmentation
Violeta Chang	Senior	USACH	Santiago	Paris	JUN	8	1500	1000	ANID	discuss about advances in liver segmentation

[1] **Each institution will pay for the trip and per diem of its own researchers.**

Enzo Ferrante	Senior	CONICET	Buenos Aires	Paris	JUN	8	1500	1000	MINCYT	present HybridGNet
Nicolás Gaggión	Junior	CONICET	Buenos Aires	Santiago	SEP	7	300	700	MINCYT	work on the adaptation of HybridGNet
Enzo Ferrante	Senior	CONICET	Buenos Aires	Santiago	SEP	7	300	700	MINCYT	discuss improvements and how to adapt HybridGnet to liver tasks
María Vakalopoulou	Senior	CENTRALESUPELEC	Paris	Bnos Aires	NOV	7	1500	700	MEAE	work on fine-grained liver segmentation
Nouman Hasany	PhStudent	UROUEN	Paris	Bnos Aires	NOV	7	1500	700	MEAE	work on fine-grained liver segmentation
Fania Pacheco	Senior	UROUEN	Paris	Bnos Aires	NOV	7	1500	700	MEAE	work on fine-grained liver segmentation
Héctor Henríquez	Senior	STAMARIA	Santiago	Bnos Aires	NOV	7	300	700	ANID	work on fine-grained liver segmentation
Violeta Chang	Senior	USACH	Santiago	Bnos Aires	NOV	7	300	700	ANID	present initial results on fine-grained liver segmentation

CONSOLIDATED BUDGET: Year 1

Funding requested to the STIC-AmSud Program

Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem)*	**TOTAL**
MEAE France	4500	2100	**6600**
CNRS France			
INRIA France			
Institut Mines-Télecom France			
MINCYT Argentina	2100	2400	**6 000 euro6 000 euro**
UMSA Bolivia			
CAPES Brazil			
ANID Chile	5100	3800	**8900**
CMM Chile			
MINCIENCIAS Colombia			
CONACYT Paraguay			
CONCYTEC Peru			
ANII Uruguay			
SENESCYT Ecuador			
MPPEUCT Venezuela[2]			
Total requested funding to STIC-AmSud			
Other funding[3]			
TOTAL	**11700**	**8300**	**20000**

[2] *Subject to confirmation*

[3] Specify in additional page.

Do you have additional funding sources for this project[4]? (if so please specify the amount and source (s)).

[4] Reserved for CNRS researchers

C2. Second year (2025)

Second year funding depends on approval of intermediate progress report.

Planned missions – Year 2

Researcher	Status (student, junior, senior)	Institution	Origin	Destination	Planned date	Duration (max. 30 days)	Estimate cost of t trip (€)
Héctor Henríquez	Senior	STAMARIA	Santiago	Paris	JUN	8	1500
Jose M. Saavedra	Senior	UANDES	Santiago	Paris	JUN	8	1500
Violeta Chang	Senior	USACH	Santiago	Paris	JUN	8	1500
Nicolás Gaggión	Junior	CONICET	Buenos Aires	Paris	JUN	8	1500
Enzo Ferrante	Senior	CONICET	Buenos Aires	Santiago	NOV	8	300
Nicolás Gaggión	Junior	CONICET	Buenos Aires	Santiago	NOV	8	300
Maria Vakalopoulou	Senior	CENTRALESUPELEC	Paris	Santiago	NOV	8	1500
Nouman Hasany	PhStudent	UROUEN	Paris	Santiago	NOV	8	1500
Fania Pacheco	Senior	UROUEN	Paris	Santiago	NOV	8	1500

[5] **Each institution will pay for the trip and per diem of its own researchers.**

<u>CONSOLIDATED BUDGET:</u> Year 2
Funding requested to the STIC-AmSud Program
Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem)*	**TOTAL**
MEAE France	4500	2400	**6900**
CNRS France			
INRIA France			
Institut Mines-Télecom France			
MINCYT Argentina	2100	2600	**4700**
UMSA Bolivia			
CAPES Brazil			
ANID Chile	4500	3000	**7500**
CMM Chile			
MINCIENCIAS Colombia			
CONACYT Paraguay			
CONCYTEC Peru			
ANII Uruguay			
SENESCYT Ecuador			
MPPEUCT Venezuela[6]			
Total requested funding to STIC-AmSud			
<u>Other funding</u>[7]			
TOTAL	**11100**	**8000**	**19100**

Do you have additional funding sources for this project[8]? (if so please specify the amount and source (s)).

[6] *Subject to confirmation*
[7] Specify in additional page.
[8] Reserved for CNRS researchers

C3. BUDGET TOTALS

	Year 1	Year 2	Total
Funding requested to MEAE (France)	6600	6900	**13500**
Funding requested to INRIA (France)			
Funding requested to CNRS (France)			
Funding requested to Institut Mines-Telecom (France)			
Funding requested to MINCYT (Argentina)	4500	4700	**9200**
Funding requested to UMSA (Bolivia)			
Funding requested to CAPES (Brazil)			
Funding requested to ANID (Chile)	8900	7500	**16400**
Funding requested to CMM (Chile)			
Funding requested to MINCIENCIAS (Colombia)			
Funding requested to CONACYT (Paraguay)			
Funding requested to CONCYTEC (Peru)			
Funding requested to ANII (Uruguay)			
Funding requested to SENESCYT (Ecuador)			
Funding requested to MPPEUCT (Venezuela)[9]			
Matching funds from the partners			
Other sources			
TOTAL	**20000**	**19100**	**39100**

[9] *Subject to confirmation*

D. Institutions and CVs of coordinators

Description of each participating institution, and curriculum vitae of project coordinators (maximum 2 pages per participant).

South-American Partner A: Universidad de Los Andes.

Universidad de los Andes was founded in 1989 at Santiago de Chile, by a group of academics, professionals and outstanding businessmen who proposed to found a higher education establishment whose specific purpose was to elaborate an organic and universal synthesis of the human culture, that integrates the dispersion of the specialties in the radical unity of the truth, enlightened and invigorated by the Catholic faith. The University campus is a geographic space specially designed to support the academic model of this House of Studies. The architectural design seeks to be the material concretion of our mission and vision, reflecting the concept of a complex university, centered on the person and at the service of the country. The definition of a single campus arises from the need to materially ensure the integration of diverse knowledge and interdisciplinary dialogue. The cultured coexistence promoted by the University among our scholars and students, expressed through the integral training offered, requires a common space to facilitate personal contact and openness to other disciplines. Also, the territorial unit effectivelyCONICYT favors the “open-door” policy of authorities and the participation of the University community in general activities keeping the union bond alive.

The institution provides the following resources:

- Two Servers for training deep-learning models (First server with 2GPUs x 12GB, used for undergraduate students, second server with 2GPUs x 24GB, used for postgraduate students)
- Server room: an appropriate space to keep servers containing racks and adequate ventilation.
- Meeting Rooms with connectivity and multimedia resources.
- Fast internet connection
- Postgraduate office rooms with connectivity and multimedia resources.
- Digital library with access to the most important journals.
- Overleaf accounts for writing papers collaboratively.
- Conference auditoriums

Coordinator: Jose M. Saavedra

South-American Partner B: University of Santiago

The Universidad de Santiago de Chile has a vast academic trajectory of 172 years and is projected as a campus of excellence, emphasizing research and a global outlook. According to the prestigious QS world ranking, it is ranked among the three best universities in Chile. This demonstrates the institutional academic commitment to quality and excellence expressed not only in the training of professionals who contribute to the country with the seal of social responsibility but also in frontier research. USACH currently has 379 research laboratories and 335,000 mts2 in a single university campus, which houses eight faculties (Engineering, Economics and Administration, Technology, Chemistry and Biology, Medical Sciences, Sciences, Humanities, Law). The Department of Computer Engineering (DIINF) is part of the Faculty of Engineering, with more than 40 years of experience. DIINF has 20 full-time professors, 74 part-time professors, and a staff of 19 administrative personnel. DIINF stands out for its interdisciplinary and applied research; it is considered a pole of excellence within the University. In this sense, DIINF academics together have more than 100 publications indexed in Web of Science during the last five years. Most of them focused on applying machine learning to various areas such as medicine, bioinformatics, education, society, and astronomy. In addition, more than half of the academics have R&D&I projects involving the use of machine learning applied to industry and services (CORFO, FONDECYT, FONDEF, among others). DIINF provides educational services to more than 900 undergraduate students and approximately 50 graduate students (33 masters and 16 doctorates). In addition, for the development of research, education, and service activities, DIINF has specialized hardware, such as rack and tower servers, server clusters, dedicated infrastructure, and communications.

Coordinator: Violeta Chang

South-American Partner C: Clinica Santa María

Clínica Santa María is a private Clinic in Santiago de Chile, founded in 1937 and focused on high complexity medicine with a strong emphasis on oncological diseases and organ transplantation. Our Radiology Department is one of the largest in the country with 85 radiologists from all subspecialties and state of the art equipment covering all existing diagnostic modalities.

We are part of the Radiology Postgraduate Program at Universidad de los Andes, helping to train multiple specialists for the last 12 years.

There is a high participation in technological development and research. We have collaborated directly in the development of radiology equipment with the industry (Siemens Healthineers) and we have been part of the network of Clinical Trials for cancer patients in collaboration with multiple pharmaceutical companies.

Coordinator: Héctor Henríquez

South-American Partner D: CONICET

The Research Institute for Signals, Systems and Computational Intelligence (sinc(i)) is part of the Argentinian National Scientific and Technical Research Council (CONICET) and National University of Litoral (UNL). The UNL is one of the oldest and most prestigious Argentinian universities, with more than 35.000 students. CONICET is the main fundamental research organization in the country, and the 2nd most important in Latin America (according to Scimago Institutions Ranking). As part of the National Ministry of Science, Technology and Innovation, it is related to outstanding international organizations and participates in several international scientific networks and platforms. In the last decade, CONICET has grown exponentially, reaching over 10.000 scientists, a similar number of PhD students and almost two hundred research centers distributed across the whole country.

The sinc(i) lab is composed by 19 permanent researchers and 14 graduate students (master and PhD). Research at sinc(i) aims to develop new algorithms for machine learning, data mining, signal processing and complex systems, providing innovative technologies for advancing healthcare, bioinformatics, precision agriculture, autonomous systems and human-computer interfaces. Researchers and PhD students at sinc(i) are also professors and teaching assistants, respectively, at UNL. They are in charge of several graduate and undergraduate courses such as Artificial Intelligence, Digital Signal Processing, Digital

Image Processing, Advanced methods for image analysis and representation, and Bayesian Estimation Methods, among others. This combination of high-quality research and excellence in education makes sinc(i) one the most outstanding computer science research institutes in Argentina and a reference in the region.

Coordinator: Enzo Ferrante

French Partner (FR): Laboratoire LITIS, UFR des Sciences, Université de Rouen (FRANCE)

The LITIS (Computer Science, information processing and systems) laboratory is a research unit in Communication and Information Sciences and Technologies of the Normandy Region. The laboratory gathers the researchers from the three leading Higher Education institutions of the region: Rouen University, Le Havre University, and the National Institute of Applied Sciences (INSA) of Rouen. The laboratory has 160 members, half of which are Ph.D. students. The LITIS is composed of seven teams whose research topics cover a broad spectrum of Communication and Information Sciences and Technologies, from fundamental research to applications, with some links with life sciences and Humanities. The involved researchers belong to two research teams: "Apprentissage" and "QuantIF". The "Apprentissage" research team comprises 18 faculty members (7 full professors, two associate professors, and eight assistant professors) from the University and INSA of Rouen and around 20 Ph.D. students. The team focuses its research on fundamental and applied machine learning and pattern recognition methods for interpreting various data (signal, image, text) that may be diverse from nature, dimensionality, stationarity, or coming from heterogeneous contexts. The "QuantIF" research team comprises five professors, three associate professors, 5 Ph.D. students, and eight associate members (physicians or computer engineers). Thus, it is a mixed research team: medicine and image processing. The research activity is dedicated to the quantification and the characterization of normal/pathological tissues in humans and small animals using in vivo multimodality imaging (MRI, PET/CT, SPECT, CT) and the leading scientific research topics in the image processing field concern image segmentation, data fusion, and image classification.
Coordinator: Caroline Petitjean

French Partner (FR): Laboratory in Mathematics and Computer Science, Université Paris-Saclay / CentraleSupelec, Paris, France

CentraleSupélec, is a French Grande Ecole d'Ingénieurs, and the coordinating institution of the Graduate School of Engineering and System Sciences, at the University of Paris-Saclay, a new university created from the cluster of several top historical academic institutions in the South of Paris region. This new university is ranked first in France in terms of academic records.

The MICS laboratory is the research laboratory in Mathematics and Computer Science at CentraleSupélec. Research at MICS focuses on the analysis of complex systems and data, whether they come from the industry, biosciences, socioeconomics, information technology or networks. The lab's specificity is that it combines formal and numerical research both in applied mathematics and computer science for this purpose. It includes 90 people, 4 research teams and a transverse axis in artificial intelligence. With 25 people, the Biomathematics team research interests are: mathematical modeling, statistics, artificial intelligence in life science, notably medical applications, and more specifically oncology.

Coordinator: Maria Vakalopoulou