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SECTION 4 – RESEARCH

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4.1. RESEARCH THEMES & SUMMARY

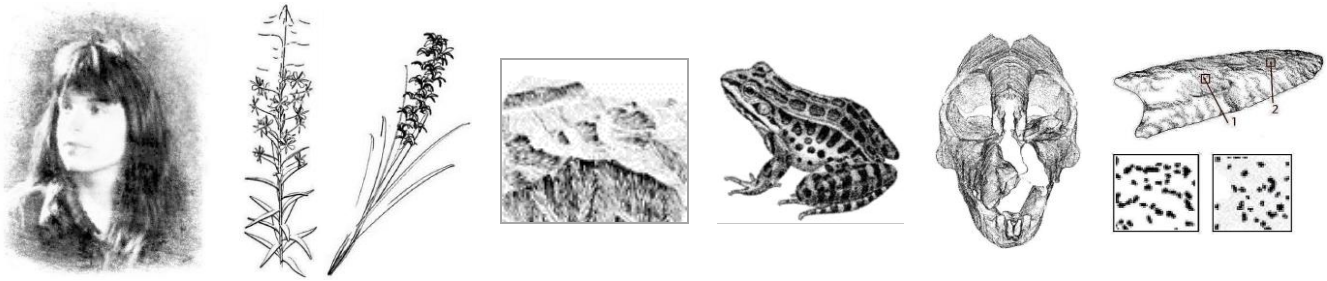
My research program has five interrelated Research Themes (RT), established progressively over the years:

- **(RT-1) Non-Photorealistic Rendering** (NPR)
- **(RT-2) Sketch-based Interfaces & Modeling** (SBIM),
- **(RT-3) Visualization & Visual Analytics** (Vis&VA),
- **(RT-4) Modeling & Simulation** (M&S), and
- **(RT-5) Human-Data & Computer Interaction** (HDCI).

Research projects from my group have their foundations (i.e., algorithms, techniques, methods) on these five Research Themes; however, each research project has one primary, more dominant RT. Each Research Theme and selected projects are described in more details below.

4.1.1. RT-1: Non-Photorealistic Rendering

Traditionally, imagery generated by illustrators (artistic, technical, scientific) has been used to provide information for different visual communication goals that may not readily be seen or perceived in real life or photographs. Generating such imagery involves stylization techniques, using various media and rendering techniques (e.g., pen-and-ink, pencil, stippling, painterly), driven by human perception and visual communication goals. The computer graphics field of non-photorealistic rendering (NPR) aims at applying a similar goal to computer-generated images (Costa Sousa '03a). The field of NPR introduced a new paradigm that leverages the traditional illustrator's fundamental and applied rendering skills in different domains of art, science, and engineering. NPR complements the field of photorealistic rendering, thus enhancing the expressive power of computer graphics.



(a) (b) (c) (d) (e) (f)

Figure 4.1. *Selected* NPR (RT-1) *results from my work and group (HQP and collaborators)* **(a)** Costa Sousa & Buchanan '99b; **(b)** Costa Sousa & Prusinkiewicz '03; **(c)** Buchin *et al.* '04; **(d)** Kim *et al.* '09; **(e)** Costa Sousa *et al.* '03; **(f)** Maciejewski *et al.* '08.

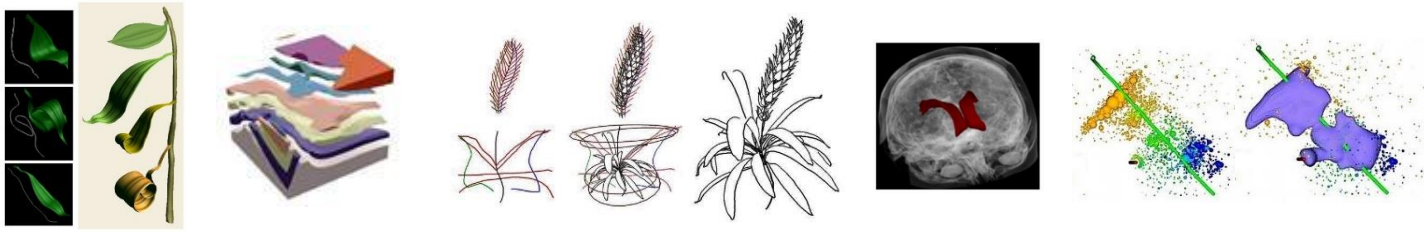
NPR was the main theme of my PhD research (Subs 1.4), where I investigated **computational models simulating natural media**. More specifically, the (microscopic) physics of graphite pencil interacting with kneaded erasers and drawing papers, in collaboration with researchers from chemical and materials engineering (Costa Sousa & Buchanan ['99b, '00]). These graphite pencil models were then used for automatic rendering of 3D models (Costa Sousa & Buchanan '99a). After my PhD, I worked on industrial R&D of NPR for 3D animation systems for production (Subs 1.5). In 2001, at the U. of Calgary, I established my research program and group focusing initially on RT-1 (NPR), collaborating with scientific and medical illustrators to formulate and design NPR algorithms approximating specific media and rendering styles (Costa Sousa '05(a-e), Sec. 6). Fig. 4.1 shows selected research results in NPR from my work and group (HQP and collaborators). In NPR, I have authored/co-authored a total of 36 peer-reviewed publications (i.e., 10 in journals, 26 in conferences), and supervised/co-supervised six theses (i.e., 1 PhD and 5 MSc, all completed, Subs. 3.4). I also organized one of the first NPR courses at SIGGRAPH (Costa Sousa '03, Sec. 6).

My HQP, collaborators (from industry and academia) and I have been working on several research topics and problems in NPR, including:

(1) **Silhouette extraction** (Brosz *et al.* '04, Buchanan & Sousa '00, Foster *et al.* ['04, '07]);
(2) **Automatic capture and reuse of artistic styles** in 3D objects and images (Brunn '06 [MSc, Subs. 3.4], Brunn *et al.* '07, Kim *et al.* '09, Luo *et al.* '06);
(3) **NPR for modeling representations** (beyond meshes), including implicit surfaces (Foster *et al.* '05, Jepp '07 [PhD, Subs. 3.4], Jepp *et al.* ['06, '08, '09], Proença '07 [MSc, Subs. 3.4], Proença *et al.* '08, Vital Brazil *et al.* ['10a, '11]) and vector graphics (Isenberg *et al.* '05);
(4) **Pen-and-ink hatching** inspired by traditional scientific illustrations (Medeiros '08 [MSc, Subs. 3.4], Medeiros *et al.* '09, Paiva *et al.* '09);
(5) NPR algorithms encoding **artistic composition principles** (Costa Sousa & Gooch '03, Gooch & Costa Sousa '03, Rivotti '07 [MSc, Subs. 3.4], Rivotti *et al.* '07), including alternate camera projections (Brosz *et al.* '07b);
(6) **Suggestive and precise pen-and-ink rendering of 3D models** (Costa Sousa & Prusinkiewicz '03) and (Buchin *et al.* '04, Costa Sousa *et al.* ['03, '04, '05c]), respectively, inspired by traditional scientific illustration techniques for depicting shape features. In particular, the work of Buchin *et al.* (2004) is my first NPR paper published in an inter-disciplinary venue (i.e., Cartography & Geomatics), reporting our research on NPR inspired by traditional ink-based rendering techniques long used by cartographers; and
(7) **Comparative analysis between hand-drawn and computer-generated stippling** rendering technique, in collaboration with scientific and medical illustrators (Isenberg *et al.* '06, Maciejewski *et al.* ['07, '08]).

4.1.2. RT-2: Sketch-based Interfaces & Modeling

Traditionally, imagery generated by illustrators (artistic, technical, scientific) involves the use of sketches to establish the overall architecture of the subject being depicted (i.e., its geometry, topology, proportions, posture), driven by human visual perception and communication goals. Domain experts from various disciplines (e.g., architecture, science and engineering) traditionally also make sketches and annotations while conceptualizing ideas and interpreting data. The computer graphics field of sketch-based interfaces and modeling (SBIM) aims at applying a similar goal to computer-generated models (Olsen *et al.* '09).



(a) (b) (c) (d) (e)

Figure 4.2. *Selected* SBIM (RT-2) *results from my group (HQP and collaborators)* **(a)** Cherlin *et al.* '05; **(b)** Amorim R *et al.* '14; **(c)** Anastacio *et al.* '06; **(d)** Chen *et al.* '06; **(e)** Amorim R *et al.* '12b.

SBIM techniques use sketches extracted directly from user input to create 2D and 3D digital models, augment existing models (i.e., by adding geometric detail), and use the input sketches for user interface operations and model manipulation. SBIM technology preserves the legacy of sketching found in different disciplines, building on expert users' practices, and at the same time provide completely new 3D digital modelling capabilities, as well as the underlying power of computation that is obviously lacking when using traditional media (i.e., paper and pencil). As in NPR (RT-1), SBIM enhances the expressive power of computer graphics. In fact, both NPR and SBIM are jointly known by the computer graphics research community as "Expressive Graphics". The research theme of SBIM was established in my program in 2004. Fig. 4.2 shows selected research results in SBIM from my group (HQP and collaborators). In SBIM, I have authored/co-authored a total of 27 peer-reviewed publications (i.e., 5 in journals, 22 in conferences), and supervised/co-supervised five theses (i.e., 2 PhD and 3 MSc, all completed, Subs. 3.4).

My HQP, collaborators and I have been working on several research topics and problems in SBIM, including:

(1) **Sketch-based 3D geological modeling** (Costa Sousa *et al.* '14) enabling users to perform two tasks:
- **(a)** interactively model geological structures inspired by traditional geological map view sketches and conventional symbols and annotations (Amorim R '17 [PhD, Subs. 3.4], Amorim R *et al.* '14) and cross-sectional view sketches (Jackson *et al.* '15, Rood *et al.* '16 (Sec. 6), Zhang *et al.* '17a); and
- **(b)** interactively adjust the geometry and extract features of interest by sketching directly over geoscience data including seismic volumes (Amorim R '17 [PhD, Subs. 3.4], Amorim R *et al.* '12(a, c)), micro-seismic point-clouds (Amorim R *et al.* '12b), and outcrop analogues (Sultanum *et al.* '13).

This research is in collaboration with researchers and professionals (from both industry and academia) in geoscience and petroleum engineering;

(2) **Hybrid sketch-based and procedural modeling of plants**, enabling users to interactively model plant structures inspired by traditional concept botanical sketches (Anastacio '07 [MSc, Subs. 3.4], Anastacio *et al.* ['06, '08, '09], Streit *et al.* ['05, '06]). In this project, construction lines from the input sketches are employed as a way to define and manipulate global-to-local characteristics of L-system models. This work was in collaboration with botanical illustrators and researchers in the disciplines biology and botany.

(3) **SBIM manipulation of 3D medical data** to rapidly extract features of interest from volumetric data (Chen '07 [MSc, Subs. 3.4], Chen *et al.* '06). This work was in collaboration with medical researchers and clinicians, also resulting in a patent US20090322748;

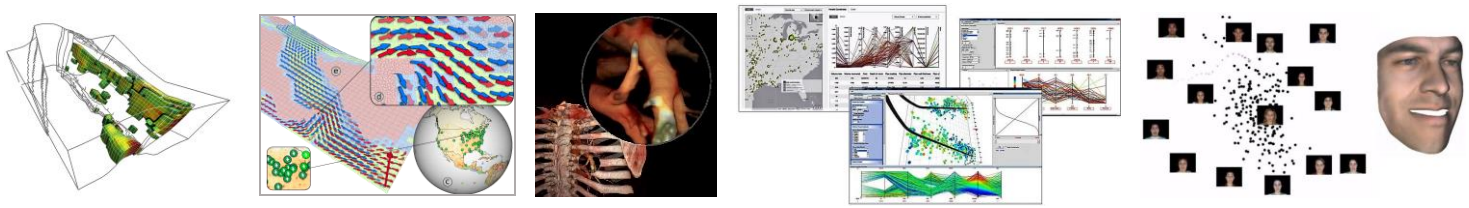
(4) **Fundamental SBIM research** for different geometric and topological representations, including adaptive meshes (Olsen *et al.* '05, Paiva *et al.* '11), parametric surfaces (Cherlin '06 [MSc, Subs. 3.4], Cherlin *et al.* '05), and implicit surfaces (Costa Sousa '07, Vital Brazil '11 [PhD, Subs. 3.4], Vital Brazil *et al.* ['10b, '14, '15], Schmidt *et al.* '05(a, b));

(5) **Gesture recognition** for sketch-based interfaces (Olsen *et al.* '07); and

(6) **Sketch-based warping** of multi-channel images for image-based editing and visual effects (Pereira *et al.* '11).

4.1.3. RT-3: Visualization & Visual Analytics

Scientific datasets are exponentially increasing in volume and complexity, representing diverse information, high dimensionality and varying levels of uncertainty. Creating software applications allowing users to gain insightful and actionable information from such vast amounts of data is a challenging problem. Visualization and Visual Analytics (Vis&VA) technologies play a critical role in such applications. The fundamental goal of Vis&VA is to present, transform and convert data into an efficient and effective visual representation that humans can rapidly and easily understand, analyze, and comprehend. As a result, data is transformed into information and then into knowledge.



(a) (b) (c) (d) (e)

Figure 4.3. *Selected* Vis&VA (RT-3) *results from my group (HQP and collaborators)*
(a) de Carvalho *et al.* '16; **(b)** Rocha *et al.* '17; **(c)** Taerum *et al.* '06; **(d)** Mostafa *et al.* '13a; Cevolani *et al.* '13; Sahaf *et al.* '17a; **(e)** Amorim E *et al.* '15.

Vis&VA was the main theme of my MSc research (Subs 1.4), where I investigated and developed **3D scientific visualization systems of reservoir flow simulation post-processing** (Costa Sousa & Miranda-Filho '94b), in collaboration with researchers and professionals from geoscience and petroleum engineering from both industry and academia. In 1994, right after concluding my MSc, I continued to work on industrial research and development of visualization technologies for the oil & gas industry (Subs. 1.5). The research theme of Vis&VA was established in my program at the U. of Calgary in 2005, focusing on inter-disciplinary projects in medicine, and from 2009 in the applied domain of

geoscience & petroleum engineering (Costa Sousa *et al.* '14). Fig. 4.3 shows selected research results in Vis&VA from my group (HQP and collaborators). In Vis&VA, I have authored/co-authored a total of 39 peer-reviewed publications (i.e., 6 in journals, 33 in conferences), and six theses under my supervision/co-supervision – i.e., 1 PhD and 3 MSc, all completed; and 2 PhD in progress, to be concluded in 2017/2018 (Subs. 3.4).

4.1.3.1. Illustrative Visualization

In Visualization, we focus on the area of illustrative visualization (IVis), aiming at developing methods to enhance the depiction of scientific data based on principles founded in traditional scientific illustration. The scientific illustration community has century-long experience in adapting their techniques to human perceptual needs in order to generate an effective depiction which conveys the desired message. Thus, their methods can provide us with important insights into visualization problems (Ebert & Costa Sousa '05, Sec. 6). The fields of IVis and NPR (RT-1) are closely related. Fundamentally, NPR is concerned with "how to render", whereas IVis is concerned with "what to render" (Costa Sousa *et al.* '08, Sec. 6). IVis introduced a new paradigm that leverages the traditional scientific illustrator's fundamental and applied rendering skills in different domains of science. IVis complements the repertoire of conventional scientific visualization techniques, thus enhancing the overall expressive power of computer graphics and visualization.

My HQP, collaborators and I have been working on several research topics and problems in IVis. We collaborate closely with scientific illustrators to formulate and develop algorithms approximating traditional techniques long used by them. Our projects include:

(1) **Cutaway and Exploded view diagrams** of 3D reservoir simulation grids (de Carvalho *et al.* '16, Martins Filho '13 [MSc, Subs. 3.4], Martins Filho *et al.* ['12, '15]);
(2) **Illustrative layering on surfaces using decals** for multi-variate data visualization (Rocha ('18) [PhD, Subs. 3.4]). This research is also applied to geoscience & petroleum eng. (Rocha *et al.* '17a) and oceanography (Rocha *et al.* '17b);
(3) **Contextual close-up views** of clinical volumetric data (Taerum '07 [MSc, Subs. 3.4], Taerum *et al.* '06). This research resulted in a patent US7893940 B2 and technology transfer to a multi-platform, cloud-based visualization system. This system is in use by researchers and medical professionals in industry and academia worldwide (ResolutionMD® & PureWeb®. *Calgary Scientific (CSI) Inc.*)
(4) **Visibility compositing and masking** for 3D models and medical data (Bruckner *et al.* '10); and
(5) **Focus + Context techniques** for medical training (Costa Sousa *et al.* ['05b, '06], Ebert *et al.* '05).

4.1.3.2. Interactive Visual Analytics

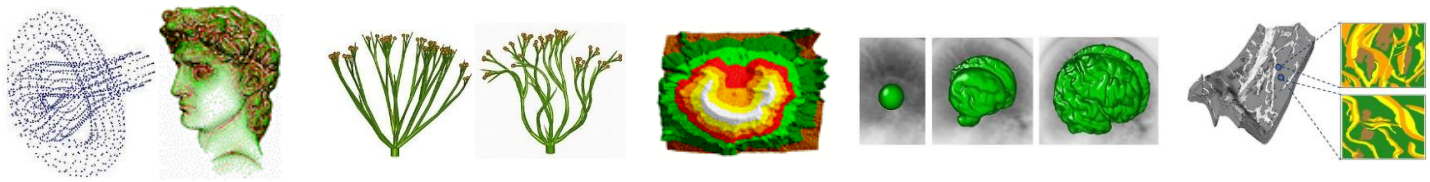
In Visual Analytics, we focus on interactive visual representations and analytical reasoning models of high-dimensional data and large parameter spaces – i.e., to extract, cluster, and compute correlations between data samples, and discover meaningful information in the data. Our projects include:

(1) Mathematical models and algorithms for **multi-dimensional data projection** (Amorim E '16 [PhD, Subs. 3.4], Amorim E *et al.* ['12a, '14, '15]);

(2) Case-studies involving three categories of data originating from:
(a) **Numerical simulations**, including:
1. Well-test visual steering (Hamdi *et al.* '15c);
2. Reservoir simulation post-processing analysis (Amorim E *et al.* '12b, Somanath *et al.* ['12, '14]);
3. History matching and reservoir optimization (Hajizadeh *et al.* '12, Hamdi *et al.* '15c);
4. Multi-parameter sensitivity analysis (Karami Moghadam *et al.* ['12, '16(a, b)]);
5. Geostatistical modeling for flow simulation studies (Sahaf *et al.* ['16, '17b]); and
6. Reservoir connectivity analysis (Cabral R Mota *et al.* '16c);
(b) **Observed & processed data**, including micro-seismic event monitoring (Mostafa *et al.* ['12, '13a]); and
(c) **Data repositories,** including petrology (Cevolani *et al.* '13), oil & gas operations (Sahaf *et al.* '17a), and facial feature expressions (Amorim E *et al.* '15).

4.1.4. RT-4: Modeling & Simulation

The research theme (RT-4) of Modeling & Simulation (M&S) was established in my program in 2005, focusing on fundamental research of algorithms and mathematical models of computer graphics, visualization and analytics. Projects in this (RT-4) are either stand-alone or derived from/related to projects from the other four research themes. Fig. 4.4 shows selected research results in M&S from my group (HQP and collaborators). In M&S, I have authored/co-authored a total of 23 peer-reviewed publications (i.e., 8 in journals, 15 in conferences), and six theses under my supervision/co-supervision (i.e., 3 MSc, completed, and 3 PhD in progress, to be concluded in 2017/2018, Subs. 3.4).



(a) (b) (c) (d) (e)

Figure 4.4. *Selected* M&S (RT-4) *results from my group (HQP and collaborators)*. **(a)** Vital Brazil *et al.* '10a; Proença *et al.* '07; **(b)** Streit *et al.* '05; **(c)** Brosz *et al.* ['06, '07a]; **(d)** Roberts *et al.* '10; **(e)** Hamdi *et al.* '15a.

My HQP, collaborators and I have been working on several research topics and problems in M&S in two categories:

(1) Computer graphics and visualization, including:
- (a) Terrain synthesis (Brosz '05 [MSc, Subs. 3.4], Brosz *et al.* ['06, '07a]);
- (b) Mapping techniques including texture synthesis for illustrative patterns (dos Passos *et al.* '10) and computational framework for multi-variate visualization (Rocha ('18) [PhD, Subs. 3.4], Rocha *et al.* '17a);
- (c) Volume segmentation for interactive volume manipulation and visualization, in collaboration with medical researchers and clinicians (Chen '07 [MSc, Subs. 3.4], Chen *et al.* '08, Patent: US20090322748), (Roberts '12 [MSc, Subs. 3.4], Roberts *et al.* '10, Patent: US20110074780 A1);
- (d) Multiresolution filters for image and mesh re-construction (Hasan ('18) [PhD, Subs. 3.4], Hasan *et al.* '15);
- (e) Point-set sampling for reconstruction and rendering of implicit surfaces (Proença '07 [MSc, Subs. 3.4], Proença *et al.* '07, Vital Brazil '11 [PhD, Subs. 3.4], Vital Brazil *et al.* '10a); and
- (f) Simulation model for plant growth (Streit *et al.* '05) in collaboration with researchers in botany and biology.

(3) Computational models for geoscience and petroleum engineering, including:
- (a) Geostatistical simulations with conditioning hard and soft data (Hamdi & Costa Sousa '16, Khani *et al.* '17);
- (b) Well-test simulation (Hamdi *et al.* '14) including gas condensate system (Hamdi *et al.* ['13, '15b]);
- (c) Uncertainty quantification for reservoir simulation (Hajizadeh *et al.* '13, Hamdi *et al.* ['15d, '17(a, c)]); and
- (d) Flow diagnostics in unstructured grids (Zhang *et al.* '17(a, b)), related to the RRM project (Subs. 4.2).

4.1.5. RT-5: Human-Data & Computer Interaction

Many tasks requiring interactive data exploration and analysis are increasingly experiencing an exponential growth in data size and complexity. This fact is driving the need to couple visualization with effective interaction techniques and technolgies. In addition, in science and engineering experiment workflows, it is necessary to communicate with an assorted group of individuals who are involved in different stages of studies, analysis, and decision-making. The challenge is to determine the appropriate visual interaction and representation of the information for the user, their experience as well as their role and task. The nature of interactions (e.g., collaborative, remote interactions etc.) also demands the need for using various technologies that can better suit the task needs. My HQP, collaborators and I have been conducting research in the area of human-data & computer interaction (HDCI) to address these challenges.

(a) (b) (c) (d) (e) (f)

Figure 4.5. *Selected* HDCI (RT-5) *results from my group (HQP and collaborators).* **(a)** Sultanum *et al.* ['10, '11]; **(b)** Cabral R Mota *et al.* '16a; **(c)** Li *et al.* '14a; **(d)** Seyed *et al.* '13a; **(e)** Harris *et al.* '11; **(f)** Mostafa *et al.* '15.

The research theme (RT-5) of HDCI was established in my program in 2005. Fig. 4.5 shows selected research results in HDCI from my group (HQP and collaborators). In HDCI, I have authored/co-authored a total of 33 peer-reviewed conference publications and 12 theses under my supervision/co-supervision – i.e., 8 MSc (completed), 4 in progress (three PhD and one MSc) to be concluded in 2017/2018 (Subs. 3.4). My HQP, collaborators and I have been working on research topics and problems in HDCI organized in four categories.

(1) Tabletop and mobile interactions. In this research, we harness the power of multi-touch tables and mobile devices, providing a new interaction paradigm by facilitating collaborative data manipulation and analysis. Projects and case-studies include:
- (a) Reservoir post-processing simulation (Somanath '12 [MSc, Subs. 3.4], Sultanum '11 [MSc, Subs. 3.4], Sultanum *et al.* ['10, '11, '12]);
- (b) Outcrop analogues from LiDAR data (Sultanum *et al.* '13);
- (c) Hydrocarbon microseep data (Burns '13 [MSc, Subs. 3.4], Burns *et al.* ['12(a, b), '13], Seyed '13 [MSc, Subs. 3.4], Seyed *et al.* ['12, '13(a, b, c)]);
- (d) Mobile visualization for 4-D objects (Li '(18) [PhD, Subs. 3.4], Li *et al.* '15a);
- (e) Tabletop-robot integration (Somanath '12 [MSc, Subs. 3.4], Somanath *et al.* '13(a, b)).

(2) Immersive interactions. In this research we investigate the use of virtual reality environments, immersive glasses, mixed and augmented reality. Projects and case-studies include:
- (a) Well placement optimization and reservoir connectivity analysis (Cabral '17 [MSc, Subs. 3.4], Cabral R Mota *et al.* '16a);
- (b) Integrating mixed reality with tabletop interaction (Lapides *et al.* '12);
- (c) Land navigation and geoscientific field studies (Li '(18) [PhD, Subs. 3.4], Li *et al.* '14a, Nittala '15 [MSc, Subs. 3.4], Nittala *et al.* '15);
- (d) Spatial interface for UAV control (Li '(18) [PhD, Subs. 3.4], Li *et al.* '15b);
- (e) Proxemics for interacting with microseismic data (Mostafa '13 [MSc, Subs. 3.4], Mostafa *et al.* '13b);
- (f) Virtual reality training system for placement of offshore oil rigs (Mostafa '13 [MSc, Subs. 3.4], Mostafa *et al.* '15);
- (g) Exploring temporospatiality in virtual environments (Mostafa ('17) [PhD, Subs. 3.4], Mostafa *et al.* ['16, '17]); and
- (h) Integrating mixed reality with sketch-based interfaces (Xin '11 [MSc, Subs. 3.4], Xin *et al.* ['07, '08]).

(3) Tangible interfaces (TUI). In this research, we investigate the use of TUI's that explore the inherent spatiality of the 3D data. Projects and case-studies include:
- (a) Snakey TUI simulating flexible well placement for reservoir simulation studies (Harris *et al.* '11);
- (b) *Tractus* drawing device (Lapides '12 [MSc, Subs. 3.4], Lapides *et al.* '06, Sharlin & Costa Sousa '05), with demonstration examples for controlling a robotics team (Lapides *et al.* '08), and for sketching positional information for plant growth simulation (Streit *et al.* '06); and
- (c) Exploring TUI for DIY (Somanath ('18) [MSc, Subs. 3.4], Somanath *et al.* ['15(a, b), '16, '17]).

(4) Human-robot interaction (HRI). In this research category, we conducted two main HRI experiments. (1) How people judge the trustworthiness of a robot during social Human-Robot Interaction (sHRI) (Cabral '17 [MSc, Subs. 3.4], Cabral R Mota *et al.* '16b); and (2) a robot prototype designed to introduce the capabilities of a virtual reality CAVE facility to human users and visitors (Li '(18) [PhD, Subs. 3.4], Li *et al.* '14b).

4.2. RESEARCH PROGRAMS, PROJECTS & SUPPORT

This subsection provides information about my research program, projects, support – i.e., from the Canadian government, Canadian and international industries, and the U. of Calgary –, and status (in progress or completed). The five research themes (RT) of my program and group (Subs 4.1) provide the foundation for every project.

	Program & Projects	Support			Status	
		Govt.	Industry	UofC	In Prog.	Compl.
1.	**Scalable Reservoir Visualization**	✓	✓	-	✓	-
2.	**Rapid Reservoir Modeling**	-	✓	-	✓	-
3.	**Multi-Scale Visual Processing of Geologic Features**	-	✓	-	✓	-
4.	**Numerical Methods for Reservoir Descriptions**	✓	✓	-	✓	-
5.	**Unmanned Aerial Vehicle (UAV) Data Processing Engine**	✓	✓	-	✓	-
6.	**Multi-Sensor Systems for Navigation and Mapping**	✓	✓	-	✓	-
7.	**Illustrative Graphics & Visualization Program** (3 phases)	✓	-	-	-	✓
8.	**Interactive Visualization Collaboration Centre Infrastructure**	-	✓	-	-	✓
9.	**Non-Photorealistic Rendering** (Start-up Funds Program)	-	-	✓	-	✓
	⌂ **RT-1** ⌂ **RT-2** ⌂ **RT-3** ⌂ **RT-4** ⌂ **RT-5**					

4.2.1. Scalable Reservoir Visualization

Funding Title:	**NSERC/AITF/Foundation CMG Industry Research Chair (IRC) in Scalable Reservoir Visualization**
Principal Applicant:	➢ **Costa Sousa** M (Industry Research Chair): *Computer Sci., U. of Calgary* (CAD)
Funding Org./Prgm.:	• CMG Reservoir Simulation Foundation (Foundation CMG) *Research Chair Program* • Alberta Innovates Technology Futures (AITF) *Industry Research Chair Program* • The Natural Sciences and Engineering Research Council of Canada (NSERC) *Associate Industry Research Chair Program*
Other Supporting Org.:	• Computer Modelling Group Ltd (CAD) • Sky Hunter Consulting Ltd (CAD) • Calgary Scientific, Inc. (CAD) • Endeeper Rock Knowledge Systems (BRA)

4.2.2. Rapid Reservoir Modeling

Funding Title:	**Rapid Reservoir Modeling (RRM): Exploring Uncertainty with Interactive Prototyping of Reservoir Geology and Flow Behaviour** *http://www.rapidreservoir.org*
Co-Principal Applicants:	➢ **Costa Sousa** M (also Project Coordinator): *Computer Sci., U. of Calgary* (CAD) ➢ Geiger, S: *Petroleum Eng., Heriot-Watt U.* (GBR) ➢ Jackson, M: *Earth Sci. & Eng., Imperial College London* (GBR)
Funding Org.:	• Petrobras (BRA) • ExxonMobil Upstream Research Company (USA) • Statoil (NOR) • Shell (NED) • IBM Research (BRA) • IBM Centre for Advanced Studies (CAD)

4.2.3. Multi-Scale Visual Processing of Geologic Features

Funding Title:	**Workflows for Multi-Scale Meshing, Visualization and Analytics of Geologic Features**
Principal Applicant:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD)
Funding Org.:	Aramco Upstream Research Center (URC), Houston, TX, USA

4.2.4. Numerical Methods for Reservoir Descriptions

Funding Title:	**The Enhanced Use of Numerical Methods, Visualization and Analytics for Reservoir Description using Well Test and Production Data**
Principal Applicant:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD)
Funding Org./Prgm.:	• Mitacs (CAD) – *Accelerate & Elevate Programs* • Rock Fluid Dynamics (USA)

4.2.5. Unmanned Aerial Vehicle (UAV) Data Processing Engine

Funding Title:	**The Development of a Web-based UAV Data Processing Engine for Mapping, Monitoring, and Emergency Response Applications**
Principal Applicant:	➢ El-Sheimy, N: *Geomatics Eng., U. of Calgary* (CAD)
Co-Applicants:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD) ➢ Liang, S H-L: *Geomatics Eng., U. of Calgary* (CAD)
Funding Org./Prgm.:	Alberta Innovates Technology Futures (AITF) *Strategic Research Projects*
Other Supporting Org.:	• Micro Engineering Technology Inc. (CAD) • Alberta Agriculture (CAD)

4.2.6. Multi-Sensor Systems for Navigation and Mapping

Funding Title:	**Multi-Sensor Systems for Navigation and Mapping – Training for Technology, Applications and Analytics**
Principal Applicant:	➢ El-Sheimy, N: *Geomatics Eng., U. of Calgary* (CAD)
Co-Applicants:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD) ➢ Hu, Y: *Electrical and Comp. Eng., U. of Calgary* (CAD) ➢ Kattan, L: *Civil Eng., U. of Calgary* (CAD) ➢ Klukas, R: *School of Eng., U. of British Columbia* (CAD) ➢ Liang, S H-L: *Geomatics Eng., U. of Calgary* (CAD) ➢ Nielsen, J: *Electrical and Comp. Eng., U. of Calgary* (CAD) ➢ Noureldin, A: *Electrical and Comp. Eng., U. of Calgary* (CAD) ➢ O'Keefe, K: *Geomatics Eng., U. of Calgary* (CAD) ➢ Petovello, M: *Geomatics Eng., U. of Calgary* (CAD) ➢ Ramirez-Serrano, A: *Mech. and Manufact. Eng., U. of Calgary* (CAD)
Funding Org./Prgm.:	The Natural Sciences and Engineering Research Council of Canada (NSERC) *CREATE (Collaborative Research and Training Experience) Program*
Other Supporting Org.:	• TDK/InvenSense (CAD) • NovAtel Inc (CAD) • Smart Sensing Solutions (CAD) • ApplAnix Inc. (CAD)

4.2.7. Illustrative Graphics & Visualization Program

Funding Title (3 phases):	Phase 1: **Computer-Generated Scientific Illustration** Phase 2: **Illustrative Scientific Visualization** Phase 3: **Interactive Context-Aware Illustrative Visualization**
Principal Applicant:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD)
Funding Org.:	The Natural Sciences and Engineering Research Council of Canada (NSERC) *Discovery Grants Program*

4.2.8. Interactive Visualization Collaboration Centre Infrastructure

Funding Title:	**Interactive Visualization Infrastructure Lab Foundation CMG Frank & Sarah Meyer Collaboration Centre, Calgary Centre of Innovative Technology (CCIT), Schulich School of Engineering, University of Calgary**
Principal Applicant:	➢ Chen J: *Chemical & Petroleum Eng., U. of Calgary* (CAD)
Co-Applicants:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD) ➢ Sharlin E: *Computer Sci., U. of Calgary* (CAD)
Funding Org./Prgm.:	CMG Reservoir Simulation Foundation (Foundation CMG) *Equipment Infrastructure Update Grant Program*

4.2.9. Non-Photorealistic Rendering

Funding Title:	**Non-Photorealsitic Rendering**
Principal Applicant:	➢ **Costa Sousa** M: *Computer Sci., U. of Calgary* (CAD)
Funding Src./Prgm.:	Department of Computer Science, University of Calgary *New Faculty Start-Up Funds Program*