Evaluation Report for the Inria Interaction and Visualization Theme

Held in Paris, October 15-16, 2014

This document reports on the findings and observations of the panel of experts convened to evaluate the Inria project teams in the theme called “Interaction and Visualization.” The meetings between the panel and the project teams took place in Paris on October 15 and 16, 2014.

Panel Composition

The evaluation panel consisted of twelve experts from a range of backgrounds and locations. Nine of the experts were from academia, while the other three were from industry. All of the experts were present for the entire meeting and took part actively and enthusiastically in the discussions. The names and affiliations of the experts are given below.

- Marc Alexa, Technische Universität Berlin, Germany
- Nina Amenta, University of California, Davis, USA
- Farchad Bidgolirad, Ubisoft, France
- Doug Bowman (chair), Virginia Tech, USA
- Steven Feiner, Columbia University, USA
- Victoria Interrante, University of Minnesota, USA
- Nancy Pollard, Carnegie Mellon University, USA
- Ariel Shamir, IDC Herzliya, Israel
- Natalya Tatarchuk, Bungie, Inc., USA
- Indira Thouvenin, University of Technology Compiègne, France
- Jean-Louis Vercher, Aix-Marseille University, France
- Mauricio Vives, Autodesk, USA

Evaluation Panel Report Summary

This report presents the panel’s evaluation of the seminar, the theme as a whole, and each of the individual project themes. Overall, the panel was extremely impressed with the scientific quality of the research in the theme, with the international prominence of the researchers and teams, with the output of the teams (publications, software, and industry transfer), and with the total organization and coverage of the theme. For each team, we identify areas of strength and weakness, and make (mostly minor) recommendations for improvement. Without exception, we give each team and the theme as a whole a positive evaluation.

Seminar Organization

The evaluation seminar was well organized, efficient, and enjoyable for the evaluation panel. The panel appreciated the attention to detail in all aspects of the seminar. Travel arrangements

were handled quickly and easily by Inria staff members. The seminar's website provided all the necessary information as panel members prepared for the meeting. The hotel at which the seminar was convened was very well equipped to handle the requirements of the meeting, although it was a bit difficult to reach from Charles de Gaulle airport for the international members of the panel. Once on site, the seminar flowed very smoothly, having the feel of a small conference in terms of organization. The generous meals provided during the meeting were also much appreciated by the panel. A special table was always reserved for the experts, although some would have appreciated the opportunity to "mix and mingle" more with the Inria team members during mealtimes.

None of the panelists had been part of an Inria evaluation previously, so the opening private session at which the evaluation committee chair and other Inria administrators spoke was extremely helpful. At this session, some of the history and organization of Inria was covered, as well as specifics about the evaluation criteria and procedures. This session also allowed the panelists to get answers to their specific questions about the evaluation. The meeting was especially informative because most of the evaluators were neither familiar with how Inria organizes itself into research domains and themes, nor with the concept of a limited-term project team with both permanent and temporary researchers. This introduction was critical for understanding the structure and lineage of the particular project teams in the theme, and for making sense of the challenges they face. It was also interesting in general, because it presented an alternative to the ways that research projects and teams are typically organized elsewhere, suggesting that other organizations might also rethink these models. One member noted that it would be helpful to include on the website a table showing the history and lineage of the project teams being evaluated.

Following the private meeting, the plenary sessions began. First, Patrick Gros provided an excellent overview of the entire theme and the project teams within it. He related the topics covered in this theme to elements of the current Inria strategic plan. In particular, it was gratifying to see that human-computer interaction (HCI) and "interaction and use" of computers are specifically called out as challenges in this plan. The six recommendations of the previous evaluation panel (in 2010) were also reviewed, along with the actions taken and progress in the last four years. The recommendations were taken seriously and specific changes were implemented to address the concerns. Dr. Gros organized the research topics of the project teams in this theme roughly around the topics of geometry processing, computer graphics, visualization, virtual reality, and HCI, noting that many groups touched on several of these topics and highlighting the collaboration among the teams.

For the remainder of the first day, each project team leader gave an overview presentation of the research in his or her team. These presentations were informative and engaging, and gave the evaluation panel a chance to see the "big picture" of each of the project teams and also the similarities and differences among the teams. The evaluation panel members also had the opportunity to note from these presentations topics that they would like to cover in more detail on the second day. *We suggest that this opportunity to take notes that will be useful in the individual project team meetings should be emphasized in the instructions given to the expert panelists.*

On the second day of the meeting, each project team met with a sub-group of three expert evaluators to allow the teams to provide more detail on their research, personnel, and organization, and to allow the experts to ask specific questions necessary to evaluate the teams' performance. The evaluation committee made it clear on the first day that the agenda and content for these meetings was left to the discretion of the panel of experts, but also indicated that each project team had likely prepared presentations or other materials they could use to go into more detail on particular aspects of their team's work.

These instructions were a bit confusing to the panelists, for two reasons. First, none of the panelists had participated in an Inria evaluation before, so it was not clear what the expectations for these sessions were, or what questions should be asked. Second, some of the project teams did indeed prepare additional presentation material, but other teams were surprised to learn that this was expected. In the end, at the close of Day 1, the panel was able to come up with a common set of questions for each team to address during the sessions on Day 2. While the answers to these questions were useful, teams only had a few hours to think about the questions and formulate responses.

Overall, the process seemed a bit unfair to both the project teams and the evaluation panel. We recommend that the evaluation committee set a more clear agenda for these sessions, while still maintaining some flexibility. For example, the two-hour sessions could include 10 minutes for introductions of the team members and panelists, one hour for additional presentation(s) by the project team related to both research work and internal/external challenges, and 30-40 minutes for detailed questions about the team's research from the panel. This could be followed by 10-20 minutes for the three experts to discuss privately the team's evaluation and reach some consensus related to the evaluation criteria.

Many of the teams had all or most of the permanent team members present for the sessions on the second day, which was extremely helpful to the evaluators, since it allowed them to gain a broader perspective and insight into the level of cooperation among the team members. It was disappointing that only one or two team members were present for a couple of the project teams, however.

The composition of the evaluation panel was excellent, with broad expertise touching all of the areas covered by the theme, including several world-renowned experts. It was very helpful to have industry expertise present on the panel. However, with only three industry members, each of these panelists had a very heavy load, covering four teams each.

Theme Organization, Coverage, and Internal Collaboration

The evaluation panel was very favorably impressed with the overall organization of the interaction and visualization theme. As Patrick Gros made clear in his opening presentation, the project teams in this theme are each related to one or more of the sub-areas of geometry processing, computer graphics, visualization, virtual reality, and HCI, with most teams doing work in at least two of these areas. The project teams seem quite evenly spread among these sub-areas, and teams in the same sub-areas are doing complementary, rather than overlapping, work (as a rule). In general, the theme seemed very well thought-out. Rather than simply being

a collection of individually excellent project teams, the theme seemed to be intentionally designed to ensure even coverage and opportunities for collaboration.

Speaking of collaboration, the amount and quality of collaborative work among the project teams in this theme was highly impressive. Again, this is not a collection of independent research teams working on their own. In nearly every case where it would make sense to suggest a collaborative effort, joint research was already taking place. Again, Patrick Gros demonstrated this convincingly in his opening talk, and this impression was strengthened as the seminar went on.

There were a few areas of research that the evaluation panel felt were underrepresented or needed better organization in the theme. One such area is augmented reality (AR). AR technology, techniques, interfaces, and applications have become a major topic within the graphics, VR, visualization, and HCI communities over the last decade or so, but AR is only touched on tangentially within the Inria interaction and visualization project teams. POTIOC has existing AR work, and In-Situ and MANAO both have AR-related publications, but we note that almost every existing project team has the potential to make contributions in this field.

Second, some evaluation panel members felt that an increased emphasis on applications to health and wellbeing would be wise within this theme, given the importance of these topics in the Inria strategic plan, and the relevance of HCI, visualization, and related research areas to the success of such applications.

Multiple evaluators commented on the area of fabrication and 3D printing. This is emerging as an important area related to geometry processing, device prototyping, and physical visualization. While this area is represented in the theme, with several project teams (notably ALICE, AVIZ, and In-Situ) doing some work in this area, the theme could benefit from a more organized and broader effort, or even the creation of a new project team devoted to this topic (some panel members strongly suggested that a new project team should be developed).

For the teams studying rendering and graphics, a topic that could be addressed more deeply is scalability of graphics algorithms across a variety of platforms, from mobile to high-performance computers. Finally, within VR, it was a bit surprising to see little emphasis on presence and other psychological phenomena in virtual environments.

Overall Theme Evaluation

On the whole, the evaluation panel finds “Interaction and Visualization” to be an extremely well-organized theme with excellence across all of its fields of inquiry. Many of the project teams and researchers are considered to be among the top groups worldwide in their respective fields. Moreover, the whole of the theme is more than the sum of the individual project teams; the way the teams have been positioned within the theme and the strong internal collaborations make the theme stronger. The excellence of the research within the theme gave the evaluation seminar the feel of an international conference, like a “mini-SIGGRAPH” according to one expert.

Particular items that demonstrate the excellence of the theme include:

- Five very selective ERC grants in recent years.
- Strong growth of project teams, from 185 to 250 personnel in the last four years.
- World-class facilities, such as immersive rooms and high-resolution display walls.
- Organization of three major conferences: CHI, VR, and VIS. Each of these is the premier international conference in its topical area.

While there are a few areas deserving of increased attention within the theme, it should be judged primarily on the work currently being done within it, rather than on what it is not covering as well at the moment.

Some evaluators noted that while many of the individual researchers on these project teams were very well known in their research communities, the project teams themselves were less often known by name, or as a coherent group. It would behoove Inria to think about how to maintain the “brands” of successful teams and to present the teams more clearly to the outside world.

The Inria requirements for project teams and their evaluation seem to have a couple of less-than-desirable effects. First, there seems to be a general trend among the teams to try to come up with an overall story or coherent theme for the team, when in reality there are some topics that don’t really fit into that story, but are important to one or two individual researchers in the team.

Second, it is somewhat artificial to expect project teams to be fully distinct from one another when they are working in the same general research space, but in different locations and over different time periods. There is significant overlap among some of the teams, even to the extent that some researchers have floated between two or more teams, and this is to be expected. It is good to have an overall view of the theme, to try to ensure even coverage, and to avoid duplication of effort. But in general, productive researchers should be allowed to pursue topics of interest even if they overlap with other teams’ work or stray slightly from the main focus of their own team.

Overall, project teams seem well-staffed and supported with resources from Inria and external sources. Positions within these teams are attractive to researchers both within and outside France, especially given the permanent positions with immediate “tenure.” In a few cases, however, it seemed difficult or impossible for excellent researchers in temporary positions to move to a permanent position. Some teams could use additional engineering support and increased ability to hire interdisciplinary colleagues.

Theme Recommendations

We summarize our recommendations related to the overall theme:

1. Take advantage of the prominent mention of HCI, VR, and related topics in the Inria strategic plan to further strengthen the project teams and research in this theme.

2. Allow project teams that have reached the end of their lifecycle to evolve naturally into “new” project teams that can continue their excellence in research without being artificially forced to change their research questions too dramatically.

3. Aim for thorough coverage and distinctions between the project teams, without stifling the freedom of productive researchers to pursue topics of interest.

4. Investigate an increased emphasis or stronger organization for 3D printing, AR, and health/wellbeing applications within the theme, both through the creation of new project teams and within the context of existing project teams.

5. Increase support for engineers and technical staff for project teams in the theme, since most of these teams need to build software libraries, hardware, and prototypes to be successful.

6. Allow more flexibility in hiring scientists outside of computer science/informatics, given the highly interdisciplinary nature of work in this theme (e.g., cognitive science, psychology, sociology).

7. Reduce the restrictions on moving scientists with a demonstrated record of excellence from temporary positions to permanent positions.

PROJECT ALICE

Primary Topics and Objectives

The ALICE team focuses on computational techniques for processing geometry. There are two main threads:

1. Geometry: the mathematical underpinnings, fundamental algorithms, and practical programs that act on digital representations of (mostly) geometric objects. This thread has been the central focus of ALICE since its inception.

2. Fabrication: algorithms that support turning digital geometric objects into physical artifacts using the recently available 3d printing technology.

The two main threads have overlap and there is some cross-pollination. In general, in both areas the main objective is to advance the underlying theory and concepts of digital representations of geometry as well as also providing practical tools, with the geometry part tending to the more theoretical and the fabrication part to the more practical side, overall nicely covering a wide spectrum of potential impact of scientific endeavor.

International Standing and Reputation in the Field

The ALICE team has an overall excellent academic standing.

In the area of geometry processing the team is widely considered one of the two top centers worldwide (the other center forming around Profs. Desbrun and Schröder at Caltech). This extraordinary standing is reflected in all countable measures of success (publications, citations, awards, invitations, grants), readily available from websites or reports.

The research in the area of computational aspects of fabrication is just starting and, consequently, there are no established leaders. The recent publications of the team and in particular the available software on slicing make the team one of the most visible and promising worldwide.

Major Achievements and Impact

The impact of the ALICE team comes from profound ideas that have applications. Some prominent examples are:

- Periodic parameterization, now turned to generating coarse quad meshes, which are extremely important in practice
- Meshing with anisotropic Voronoi diagrams, whose computation is made practical with the first quasi-Newton solver
- Hex-meshing that respects features, which is extremely important for applications using FEM

While the methods themselves would have had significant impact alone, it helps tremendously that almost all aspects of them are available in the form of free software. This was seen as an extremely strong aspect of the ALICE team.

The IceSL software is beginning to impact the field as one of the first high-quality, universal slicing tools, providing a platform-independent driver for current 3d printing technology.

Industry Transfer and Partnership

For a project that is mostly concerned with rather fundamental aspects of geometry processing, ALICE has an impressive track record of collaboration with industry. Most prominently, the cooperation with the Gocad consortium has led to tools for oil exploration. The Vorpaline project is specifically targeted to commercialize the results of the geometry processing work done in the ERC GOODSHAPE project. Allegorithmics is a company commercializing the earlier work on texture generation.

There are numerous ties with academic partners, including HKU, Tsinghua, UBC, ETH, the REVES project within the same theme, and others.

The software project IceSL is a promising tool for industry involvement and partnerships with academia.

Training of Personnel

The strong and lasting impact of being part of the ALICE team is best demonstrated at the positions that former team members (Ph.D. students and others) now have in excellent academic institutions or industry (CNRS, Stanford, MSR Asia, WIAS Berlin, and others).

Most permanent team members teach at at universities and/or participate in general audience presentations.

Principal Strengths and Weaknesses

Strengths:

- Geometry part of the project is clearly world-leading in all aspects (papers, software, Ph.D.s produced)
- Digital layered manufacturing is extremely promising and relevant
- High impact of both areas through freely available software
- Strong and prestigious external funding through two ERC grants

Weakness:

- Two rather disparate main research directions (i.e., geometry and fabrication)

Future Plans

In geometry processing, the team plans to focus on the aspects of metrics, differential operators, and most importantly, the relation between discrete and continuous counterparts in geometric settings.

In 3d printing, the overarching goal is to develop a model creation pipeline that takes physical output into account.

Opportunities and Risks

The potential for solving difficult problems using new computational tools for geometry problems and related PDEs is great. As with every new direction, the risk is that the results are not as spectacular as expected.

The potential for any result in 3D printing is enormous. Potential risks are: solutions too closely tied to current technology, problems taken on by big industrial players, reducing the impact of (potentially better) academic solutions.

Recommendations and Suggested Measures of Success

Recommended actions:

- Create a new project group on 3d printing, potentially with Sylvain Lefebvre as scientific lead.
- Focus the remaining group on more fundamental aspects of geometry, discretization, and numerics.
- For the new group: strengthen focus on dissemination by making software available and encourage collaboration with academic partners in closely related subjects as well as relevant industrial partners
- For the remaining group: lessen the focus on tech transfer and provide freedom for more fundamental/theoretical work

Measures of success:

- numerical solutions to problems so far considered impossible to solve
- geometric tools available for all making problem solving on geometry accessible for more researchers
- contribution to ‘gold standard’ tools and formats in 3d printing

PROJECT AVIZ

Primary Topics and Objectives

“Big Data” offers unprecedented opportunities to enable a deeper understanding of multiple facets of the world around us, as well as unprecedented challenges for distilling meaningful insights from the massive quantities of information being generated and aggregated. Algorithmic methods for information extraction hold much promise, but their success is fundamentally dependent on the ability to precisely define the “interesting” features of the data, a task that often depends on human judgment and insight.

The central focus of the AVIZ group is on enabling enhanced information understanding through a combination of: a) fundamental research to elucidate basic principles underlying the development of effective methods for information visualization and improved data understanding; and b) pioneering the development of novel hardware and software paradigms for effective information communication.

Most notable among the key primary topics addressed by the AVIZ group are:

- novel display methods (including animated transitions; expressive visual representation)
- emerging technologies (effectively employing large displays, touch interactions, tangible/physical props)
- leveraging perceptual psychology (e.g., understanding how people perceive information presented on large displays; how to use animation to its best advantage in the context of known human perceptual capabilities and limitations; how to exploit physical action to support cognition; how best to enable an accurate understanding of the uncertainty inherent in some data)
- toolkits to support visualization development, particularly in the context of the current big data challenges
- evaluating visualizations (e.g., defining optimal metrics for assessing the effectiveness of a visualization; highlighting the importance of considering individual differences in visual literacy when comparing visualization methods)

International Standing and Reputation in the Field

The critical importance of the data visualization challenge has been widely recognized and is being actively pursued by multiple groups worldwide; what distinguishes the AVIZ group and sets it apart from the others is its prescient focus on the critical role of *user interaction* in enabling the effective extraction of meaning from data.

By all measures, the AVIZ team is one of the top-performing research groups in the world in the field of information visualization. AVIZ team members have an unbelievably strong publication record, with literally dozens of papers each year, and the majority appearing in the very best

possible venues including ACM CHI and the IEEE Transactions on Visualization and Computer Graphics.

Additionally, AVIZ team members have outstanding national and international visibility, as evidenced by their extensive record of invited talks (including multiple keynote/capstone appearances), steering committee service (including for top conferences such as IEEE Information Visualization), high profile conference organizational roles (including service as general chair and host venue for IEEE Visualization, the premier international conference in the field of visualization), editorial board memberships and guest editorships (for premier journals such as the IEEE Transactions on Visualization and Computer Graphics, and others), and extensive program committee service (AVIZ members are represented on the IPCs of all the top conferences in their research areas, including ACM SIGCHI, IEEE Visualization, IEEE Information Visualization, IEEE VAST, ACM UIST, EuroVis, NPAR/Expressive, and 3DUI among others).

The AVIZ group's exceptional international prominence is further evidenced by their extensive record of productive international collaborations with researchers at top universities (including the University of British Columbia, New York University, the University of Maryland, and the University of Washington, among many others) as well as joint work and financial support for their research from top companies worldwide (including Microsoft Research, Nokia, and Google).

Major Achievements and Impact

The achievements of the AVIZ group over the past four years are far too numerous to permit even a coarse summary listing in the space available; what follows below is a very sparse sampling of some of the outstanding highlights from among the group's major sub-efforts. A comprehensive review of all of the group's work is eloquently provided in their own self-evaluation report.

Novel display methods: The comparative analysis of large brain connectivity networks is a problem of central importance in the field of neuroscience, an area that is receiving heightened attention via major Brain Initiatives in both the EU and US. The AVIZ group's novel techniques for weighted graph comparison, designed to address this issue, won the best paper award at ACM CHI, the premier international conference in human-computer interaction. This example represents just one of 30 different novel representation and interaction techniques developed by the AVIZ group over the past 4 years.

Emerging technologies: Traditional methods for information communication rely heavily, if not exclusively, on the passive consumption of visually presented input. Yet abundant research suggests that perception, cognition and learning are all fundamentally mediated by *embodied interaction* with the world around us: we perceive the world in order to be able to act upon it; our perceptual understanding is inextricably linked to affordances for action, and motor experience fundamentally strengthens visual understanding. Notable among its many efforts on the theme of "visualization beyond the desktop", the AVIZ group is pioneering the concept of *tangible visualizations*, in which information is physically rendered into a manipulable interactive data

sculpture. This transformative concept has the potential to establish a powerful new paradigm for effective information presentation. Tangible visualizations inherently support natural user interaction, which facilitates both control and understanding. Furthermore, natural manipulation of 3D physical artifacts stimulates proprioceptive feedback associated with the body's movements that can support a deeper more intuitive spatial understanding than can be realized from disembodied viewing and abstracted, indirect viewpoint and object control. By engaging multiple perceptual modalities beyond just the visual system, touch interaction and tangible manipulation offer the potential for dramatically more effective information uptake than is possible using conventional displays. The AVIZ group is a world leader in promoting this approach to information visualization.

Leveraging perceptual psychology: The AVIZ group's remarkable success in developing effective new visualization paradigms has its roots, in part, in their concerted efforts to leverage insights from fundamental findings in perceptual psychology, building ties in the process with perceptual psychologists to support those efforts. One of the many successful projects that arose from this sub-theme is the development of a hybrid-image presentation method for large display systems, which effectively supports the collaborative investigation of a large data collection by multiple viewers. By employing a concept similar to that used in photomosaics, hybrid presentation methods allow both global and local information to be perceived from the same static image by relying on user-controlled changes in viewpoint rather than changes in the displayed content to vary the attentional focus. This type of information presentation paradigm is far more effective than traditional methods, which were originally conceived for a single static viewer, that rely on panning and zooming the image, an action that can be disruptive at best and nausea-inducing at worst for other viewers who are not in control of the display changes. In a hybrid-image display, overview information is readily available to viewers at a distance, who can then physically approach the display to discern detailed information within a local context. It is an elegant solution whose simplicity belies the depth of insight required to conceive of it.

Evaluating the effectiveness of a visualization: AVIZ team members have established a leading presence in the area of visualization evaluation; their activity on this topic has been influential in shaping the general approach to this problem taken in the broader field. Among their outstanding contributions are efforts to educate the community on the newly recognized importance in current statistical practice of using effect sizes with confidence intervals, rather than p-values, when quantitatively assessing visualization performance and on the importance of obtaining baseline assessments of visual literacy from participants in human subjects experiments aimed at evaluating visualization effectiveness.

Software infrastructure: The problem of Big Data visualization is probably *the* major grand challenge in the field of visualization today. In addition to developing algorithms to distill the essential features of massive quantities of data into a visual form, there is the need to define a fundamental structural organization of the data that makes accessing it in flexible ways at interactive rates even a feasible proposition. AVIZ team members are among the intellectual leaders striving to make this complex problem tractable, working in cooperation with Data Science specialists at multiple institutions worldwide. Their leadership is evidenced by keynote

talks and book chapters, and their results to date are embodied in two major software toolkits: *Obvious* and *EdiFlow*.

Industry Transfer and Partnership

The AVIZ group has been very successful in collaborating with and securing funding for their research from major international companies such as Microsoft and Google. They have also been involved in strategic collaborations with several smaller local companies (internal to France) to commercialize some of their software. However it is not clear that this particular commercialization model represents an optimal mechanism to promote the wider dissemination and utilization of their software products. Alternative models for successful technology transfer include releasing open source code under a BSD or (L)GPL license, or preparing robust executable applications that people can just run as-is for the next 5-10 years.

Training of Personnel

AVIZ team members are actively engaged in teaching a number of different courses at diverse institutions, and they have a strong track record of successfully training Ph.D. students who have gone on to successful positions at top institutions worldwide.

Principal Strengths and Weaknesses

The principal strength of the AVIZ group is the vitality and synergy of the team. Each of the four principal team members is, individually, a researcher of absolutely outstanding quality, and their joint efforts are a classic instance where the “whole is greater than the sum of the parts.” The team is also involved in lots of great collaborations with other top researchers worldwide, which helps to expand the scope and impact of their research efforts.

It is very difficult to discern any notable weakness in any of the team’s efforts. They might possibly benefit from more internal support for conducting human subjects experiments.

Future Plans

The AVIZ group is well-positioned to continue to make valuable contributions in each of the areas where they are presently engaged. The themes of “visualization beyond the desktop” and software infrastructure development to support big data visual analytics seem particularly promising.

Opportunities and Risks

The current revolution in 3D printing presents an unprecedented opportunity for the concept of tangible visualization to take hold and expand. AVIZ is well-positioned to be the international leader in this area.

In terms of applications, there is significant potential for further impact in a wide range of areas. Among these, medical applications seem at the forefront, particularly bioinformatics and brain science.

Having introduced so many successful visualization methods, it is imperative to establish an effective mechanism for releasing your results. If people can't figure out how to acquire and use your systems, they may just pick up your ideas and try to copy them (with or without proper attribution), and if in the process they fail to replicate the essential features that are critical to the success of your methods, that could muddy the waters and set everything back.

Robust toolkit development requires a huge investment of time and energy, however, and additional staff support is probably needed to productize research results, since core researchers and Ph.D. students need to be spending their time expanding the frontiers of the field and creating new knowledge rather than packaging software to make it robust for broad distribution and general use. However the economic model to support such staff efforts is not clear.

Recommendations and Suggested Measures of Success

We recommend that the leaders of AVIZ continue to build the team, bring in top Ph.D. students, publish at top venues and maintain high visibility. The field of tangible visualization seems poised to explode—it will be good for AVIZ to stay at the forefront of this exciting new area. The team should continue to leverage collaborations with top researchers internationally. Recruiting others to help them execute their great ideas, as they have been doing, will increase their profile as well as their impact.

PROJECT HYBRID

Primary Topics and Objectives of the Team

The HYBRID team, led by Anatole Lecuyer, has been recently created after the splitting of BUNRAKU. The objectives of the team are threefold: design and evaluate new body-based, mind-based and collaborative interactions. There is also a double approach: physically-based and perception-based realism. The team has six participants, but only one permanent Inria researcher. One is a development engineer (contributing to the team at only 20% of his time), one has a starting research position (SRP), the others are also teaching at INSA School of Engineering, with hard teaching and management duties.

International Standing and Reputation in the Field

Hybrid is probably one of the most active, creative and visible teams in the field of multisensory interaction for VR. Over the evaluation period, members of the team published a large number of papers, both in highly ranked international journals and selective conferences. The team has been particularly successful in publishing long and short papers at IEEE VR, the reference conference in virtual reality. The members were often granted with the best paper award at several conferences. The list of responsibilities (at local, national, european and worldwide levels) is just as impressive. Furthermore, team members (even the youngest) are all at least associate editors for international journals, they all contribute to steering committees for high level recurrent conferences, and they participate on Ph.D. juries and hiring committees.

Major Achievements and Impact

Though the evaluation occurs in the middle of a four-year period for this team, the achievements are yet high. They proposed several new interaction tools for navigation and manipulation, both body-based and mind-based (BCI). They developed new ways to simulate, in real time, on hard, soft or liquid objects, physically-realistic object contacts and fractures. Finally, they proposed an architecture to improve training, collaboration and cobotics in the factory context.

These last years the team was particularly successful in getting funding, at all levels: local (Regional Council), industrial (*Technicolor, Orange*), national (ANR, FUI) and European (FP7). In average the team got more than 600 k€ per year to be added to money from Inria and INSA for permanent staff salaries, infrastructure cost, etc.

The team has led the development of three software systems: OpenVIBE is a collaborative, open-source platform for brain-computer interfaces (BCI) used by most of the researchers in the field, as by the industry; GVT is a platform for training sessions in an industrial context; Collaviz is a set of tools for collaborative interactive visualization.

Industry Transfer and Partnership

Nine patents have been written by team members, covering most of their research themes: pseudo-haptic interaction, force-feedback, BCI, and visual rendering. Two transfer actions occurred during the reporting period: several interaction tools were transferred to *Polymorph Studio* and to *MBA multimedia*, which develop applications for multimedia and web design. A start-up was created (*Mensia Technologies*), focusing on wellness and healthcare applications of BCI techniques.

Training of Personnel

There are presently nine Ph.D. students in the team. Eight others already obtained their Ph.D. Most of them got a permanent position in academia or industry, and the others are now in their post-doctoral leave. As said before, most of the team members have heavy teaching duties. They are involved in several Master courses at INSA Rennes (School of Engineering), Rennes University, and ENSAM Laval.

Principal Strengths and Weaknesses

The team is developing original and very creative interaction devices and modes. This is clearly their major strength. The team has also a good knowledge of human perception and motor control, obtained through close collaborations with leading teams (i.e., Collège de France). The latter point clearly helps them in taking into account human factors and needs in designing new tools. The combination of expertise on physically-realistic and perception-based renderings is quite unique in the field and must be preserved and encouraged. A last (but not least) strength is their ability to transfer knowledge to industry. OpenVIBE, the library for developing BCI applications, is becoming a standard in the VR field as well as in Neuroscience.

One major weakness is the low technical support: the engineer in charge of technical and software developments works for the team only 1 day per week. Though they have been very successful in getting national grants, European funding would help them to attract and hire people at an international level. Indeed they need to hire, possibly with a permanent position, at least one more junior permanent researcher (from Inria or CNRS).

Future Plans

The team has only two years of existence. Thus the project remains the same. Probably the most original aspect of their research is the focus on “hybrid” (body and mind) interaction. Though they took good steps toward this objective, hybrid interface utility and usability are still to be proven. To combine sensorimotor (low level) and cognitive (high level) loops is a good idea, but the realization is not trivial and may in some cases be counterproductive. Solving these bottlenecks seems to be a good challenge for the next period. Another challenge will be to recenter their activity on high-level interaction and to reunite all the research axes into one single objective.

Opportunities and Risks

The team takes advantage of a favorable ecosystem in Rennes (Inria, INSA, Université de Rennes and CNRS). In this context, Rennes has become an important node for research in VR in France. All of their projects are conducted in collaboration with other teams, at regional, national and international levels. HYBRID is particularly involved in several collaborative projects with other Inria teams within the theme “Interaction and Visualization”—of course MIMETIC in Rennes, but also POTIOC, REVES and MINT.

The concept of hybrid interaction, at the core of the project, is still quite fuzzy and needs to be better justified. The team is developing, with the help of the newly recruited member, a new line on dynamic adaptive interfaces. Adaptive means here that the interfaces change to follow the growing experience of the user. This is a very challenging, but also risky project: adaptive interaction is often difficult to understand for users who hardly accept it. The major risk comes from the fact that the researcher in charge of this line has a temporary position. Strong strategy, and collaborations are thus needed, i.e., with POTIOC where there is a project to study how humans learn to use BCIs.

Clearly the team does not have enough technical help to develop all of their projects. Though they benefit from support at IRISA lab, they still have to do most of the technical stuff themselves, which is obviously time consuming. Expertise in mechanics, electronics, but also graphic design and, overall, experimental psychology, is highly needed.

HYBRID is clearly focused on VR, but its researchers are concerned that VR is not always considered as a first-class research topic by those outside the team (more as a methodological development). Also, multidisciplinary research is often good for a project, but sometimes risky for individual career evolution.

Recommendations and Suggested Measures of Success

HYBRID is a young team, though with a long history and strong heritage. The former SIAMES team was one of the first to work on VR in France, particularly in collaborative VR in industrial (digital factory) context. The senior members are highly visible both at national and international levels, everyone with his/her specific line of research, which is probably the reason for having three axes (physical realism, perception-based interaction, collaborative interaction). One of the biggest challenges of the team in the next years will be to put together their realizations and to combine the physically-based modelling and perception-based interaction with the collaborative architecture. Currently these topics are not fully integrated into a coherent “story.”

PROJECT IMAGINE

Primary Topics and Objectives

The primary objective of the IMAGINE project was to focus on new CG creation tools based on user centered experience with semantic knowledge. The goal is to make “creative” content creation possible using digital tools which will be more natural to the designer/artist. This idea was pursued in many different fields such as: geometric modeling, animation, narrative expressions, etc.

International Standing and Reputation in the Field

Marie-Paule Cani, Stefanie Hahmann, Rémi Ronfard and other members of the team have a solid reputation in their fields.

Marie-Paule Cani was responsible for the GVR-(Graphics, Vision and Robotics) program in the MOSIG Master[5] in 2011-2012. She has just been nominated at the "Chaire Sciences du numérique" at Collège de France for the year 2014-2015. She also was keynote speaker at SoCG'2014 (Symposium on Computational Geometry) in Kyoto, Japan.

Major Achievements and Impact

The team is very happy with the structure offered by Inria, especially for the ability to do interdisciplinary research: assemble researchers from various fields, find common objectives and apply similar methods to different fields. The team has very good visibility which helps them a lot for their work.

In Implicit Modeling, new results that tackle long outstanding problems in modeling (TOG 2013) were presented. Shape assemblies can offer very good results in transferring from one character to another. This research will be used in anatomical simulation which is grounded by incorporation of an anatomist and neurosurgeon as a core member of the team.

Creating and interacting with virtual prototypes is very useful in sketch-based modeling, sculpting complex content.

Some important results were presented in character animation: The Line of Action: an Intuitive Interface for Expressive Character Posing (SIGGRAPH Asia 2013)

To finish there are some really interesting results in virtual cinematography and actor directing tools.

This is an impressive body of work for a new team.

Industry Transfer and Partnership

During the evaluation period the project-team had several partnerships and industry transfer:

- The FUI project "Dynam'it" gave them the opportunity to transfer their novel physically-based simulation techniques ([GBFP11, FGBP11]) to two companies: TeamTo (an computer animation company) and Artefacts Studio (a videogame company). This method has already been used to animate the feathers in the feature film "Gus" from Teamto (to be issued in December 2014).
- During the SoHuSim ANR project, SOFA and its novel simulation techniques for the design of patient-specific devices in medical applications was promoted. This work is currently leading to the creation of the startup Anatoscope. The goal is to sell personalized biomechanical models to complement traditional medical imagery for a better communication between medical doctors and patients.
- A new approaches to assembly model processing for finite element simulations was developed during the ANR Romma projects and the Airbus contract. One patent was deposited. Further interest for this approach has led to the ongoing partnership with EDF RD.

Training of Personnel

In this team there are several professors who can bring several students. This is very helpful for having good Ph.D. students (and CIFRE Ph.D. students for the industrial collaboration).

For the PostDoc, the salary seems to be a problem. Foreign countries, USA and Switzerland in Europe are more attractive.

So Inria could help identify excellent PhD throughout the program from other projects and facilitate / make more attractive their transfer into other groups for PostDoc position.

Principal Strengths and Weaknesses

The group's research yield is very high. IMAGINE is a very good multidisciplinary team project where each subject has very good results. The combination of geometry processing, anatomical grounding and sincerity in pursuing medical applications, and artistic talents is unique and inspiring.

The principal weakness may also come from the multidisciplinary composition of the team, mainly because it is difficult for them to publish in other research domains, for instance in medicine or anatomy. Though, we believe their research is visionary, unique, and important, and they should continue in that direction.

Even if it may be difficult to handle the focus of such large team and strongly tie research in medicine, CAD and cinematography, we can notice that a common methodology did emerge in the team.

One other point is that there seems to be less support for artistic projects in Inria, for instance Rémi Ronfard should evolve as a "director of research".

Future Plans

The IMAGINE team was accepted in January 2013, so it is a very young team. The plan for the next period is to continue in the same direction: put 3D creation tool into everybody hands, improve the efficiency of CAD models, and enable automatic video editing.

Opportunities and Risks

These new interaction and creation tools are very numerous and really interesting. The project would like to put more efforts on the narrative design. Again, however, they need to have more support on these “non-technical” subjects.

Recommendations and Suggested Measures of Success

IMAGINE is a very large team with diverse background of people. The three main application fields: Modeling and CAD, Medicine (biology), and Narrative expressions are a little too diverse. One possible solution would be to separate the project into two projects: one for narrative expressions, which seem a little further from the other two, namely Modeling and Medical. We believe the new project could be successfully led by Remi Ronfard.

PROJECT IN-SITU

Primary Topics and Objectives

The primary objectives addressed by In-Situ involve the design and development of interactive systems that take into account the context of their users and computers, and the situations in which they are used. The team refers to this concept as *situated interfaces.* To make such systems possible, In-Situ explicitly concentrates on three research themes:

- Interaction and visualization paradigms. These address a wide range of environments from desktop, to hand-held, to rooms containing multi-display walls and tabletop displays, used by one to multiple users.
- Research methods. These include participatory design, in which end users are involved in design, and multidisciplinary design, in which researchers from a range of disciplinary backgrounds work together.
- Engineering interactive systems. This involves the design and implementation of software toolkits that are used to build systems within In-Situ and which are distributed to other groups.

One topic that has been explored within each of these themes is interaction with *extreme users,* whose work, in fields ranging from the sciences to event planning, taxes the limits of current user interfaces.

International Standing and Reputation in the Field

In-Situ has an impressive international reputation, placing it among the top research labs worldwide. Wendy Mackay (team leader) and Michel Beaudouin-Lafon are member of the CHI Academy, an honor bestowed by ACM SIGCHI to “individuals who have made substantial contributions to the field of human-computer interaction.” Mackay also received an ERC Advanced Grant, and the ACM SIGCHI Lifetime Service Award, and Beaudouin-Lafon was inducted as a senior member of the Institut Universitaire de France. Four of the permanent members are on the faculty of Université Paris-Sud, and one former member is now Executive director of Inria Chile. The team’s papers have received six best-paper awards at *CHI*, *MobileHCI*, *Interact*, and *VRST*, and three honorable mentions at *CHI* and *UIST*. Over the evaluation period, they published 23 papers at *CHI* and *UIST*, the top two conferences in HCI, a field in which conference publication is the main way in which research is disseminated.

Team members also played key roles in running *CHI 2013*, the largest and most prestigious HCI conference, with Wendy Mackay as general chair, and Michel Beaudouin-Lafon as Program Co-char. In addition, the other team members have participated extensively in organizing and program committees for many international conferences.

Major Achievements and Impact

In-Situ has been responsible for a number of major achievements:

Development and analysis of interaction techniques. These address pointing, navigation, and multi-touch interaction, including a design space for bimanual interaction with tablets.

Designing and conducting user studies on manual interaction with and physical navigation in rooms with wall-sized displays. These have been carried out within In-Situ's room-sized WILD multi-display environment.

Development and evaluation of tools for extreme users engaged in real-world activities. One example involved collaborative tools for use in WILD to schedule highly parallel activities to avoid temporal conflicts. These tools were created for and successfully applied to the challenging multi-user task of scheduling presentations at *ACM CHI 2013*, with over 1000 presenters. Another example built on the team's earlier research on interactive paper to develop tools used by composers at IRCAM.

Creation and active oversight of two international Masters Programs in HCI. These are a Research Master in Interaction and the European EIT ICT Labs Master in Human-Computer Interaction and Design (a professional Masters degree program).

Industry Transfer and Partnership

The In-Situ team performed research and published with industrial collaborators at Google and Microsoft Research. In addition to extensive interactions with the Inria AVIZ team, and with other universities and research organizations in Paris including Télécom ParisTech and IRCAM, the team has university partnerships with colleagues at University of St. Andrews, University of Copenhagen, University of Manitoba, University of Alberta, Stanford University, Université de Strasbourg, University of Aarhus, UC Berkeley, CMU, MIT, and UCSD. In-Situ members also participate in numerous national and European research projects.

Training of Personnel

In-Situ currently has ten Ph.D. students and four postdocs, and over the evaluation period, eight team members earned Ph.D. and Habilitation degrees. One former postdoc is now assistant professor at Télécom ParisTech, and former Ph.D. students have gone on to positions that include assistant professor at Université Paris VIII, and postdocs at IRCAM, University of Waterloo, and University of Munich.

All permanent In-Situ team members teach extensively at Université Paris-Sud. Beaudouin-Lafon, Bezerianos, Fleury, and Huot are faculty members with a full teaching load, and Appert, Chapuis, Mackay, and Tsandilas each teach from 10–100 hours per year. The staff has also taught courses at Stanford and Polytech Nantes.

Principal Strengths and Weaknesses

In-Situ is a world-class team with many significant strengths. These include:

- Multiple researchers with well-deserved world-class reputations in HCI, evidenced by a large number of high-quality publications, nine of which received best-paper awards or honorable mentions during the evaluation period.
- A broad research plan, addressing infrastructure ranging from hand-held, to desktop, to room-sized, used by individual users, as well as collaborating groups.
- Impressive research infrastructure, including the WILD room with wall-sized multi-monitor display and multi-touch table, and the new DIGISCOPE distributed multi-room, multi-display infrastructure, and FabLab fabrication lab.
- Active collaborations with other strong Inria groups, IRCAM, French and international universities, and industry.
- Major university research and teaching relationships that make it possible to work with talented postdocs and PhD students, as well as students in the Research Master in Interaction program.

The only research weakness that we can find is one of coverage: Although In-Situ has addressed a range of form factors from hand-held to wall-sized, it has not explored wearable computing (e.g., wrist-wear or eye-wear) or outdoor environments. While In-Situ has done a very small amount of high-quality work using augmented reality (C. Liu et al., "Evaluating the benefits of real-time feedback in mobile augmented reality with hand-held devices," *Proceedings of CHI 2012*, pp. 2973–2976, Best paper honorable mention), this was for a hand-held, smartphone-based approach.

We also note several administrative weaknesses:

- In-Situ faculty members manage two English-language Masters programs, but do not have an English-speaking administrator, necessitating that faculty spend time helping students with purely administrative issues.
- Students in the European EIT ICT Labs Master in Human-Computer Interaction and Design professional Masters degree program run by In-Situ faculty are not allowed to participate in internships at In-Situ.
- Creation of the new Université Paris-Saclay could further complicate funding and administration, especially if adequate administrative support is not provided.

Future Plans

In-Situ has reached the end of its 12-year lifespan and two new groups have been proposed to replace it:

- Ex-Situ will concentrate on the needs of extreme users, further exploring interactive paper, and large-scale displays, participatory design, and the use of digital fabrication for prototyping.
- ILDA will address interaction with big data, especially structured data, linked together semantically, emphasizing multi-scale navigation and the use of input technologies including tactile surfaces, 3D motion tracking, and gestural interaction with custom-fabricated devices.

Ex-Situ and ILDA expect to work together on issues involving collaborative interaction, wall-sized displays, and multi-surface interaction, and to continue their existing external

collaborations started during In-Situ's tenure. In particular, there are many opportunities for interaction between ILDA and AVIZ (which was itself originally an In-Situ spin-off), which may challenge the claimed differentation that "AVIZ focuses on the design of novel data visualization techniques" and "ILDA's focus is on exploiting the data's semantics and structure."

Opportunities and Risks

Breaking up a highly successful team is inherently risky, even though it is required by Inria. That the initial team members know each other well and will be able to share infrastructure is clearly a plus. In addition, the need to propose new groups with new foci has provided the opportunity to think about and home in on important HCI research themes that were not originally emphasized by In-Situ: extreme users, and the semantics of big data.

Potential risks have already been suggested:

- Bureaucratic complexities caused by working with a new and very large administrative entity, the Université Paris-Saclay.
- Overlooking the potential of smart watches and smart glasses, and outdoor environments, to change the way in which we interact with information and with each other.

Recommendations and Suggested Measures of Success

We approve of the two new proposed groups, Ex-Situ and ILDA, and believe that their individual goals and expected interactions are, in the large part, soundly motivated. However, we feel that Ex-Situ should reconsider their assumption that "wearable form factors, such as watches and glasses" will not "create the major disruptions already caused by personal computers, smartphones and tablets." While it is difficult to predict when these technologies might become sufficiently mature, it is important not to ignore the potential for hands-free interaction with wearable personal displays, including augmented reality eyewear with larger fields of view than the biggest tablets, and the consequences of being able to use devices of this sort routinely outdoors and on the go. The stated goal of Ex-Situ to address telepresence renders this even more important.

Many of the projects proposed for Ex-Situ and ILDA rely on complex, locally-developed, multi-computer/multi-display environments, requiring high-quality engineering staff. It would be good if there were some way to work within or around current policies that make it challenging to recruit high-quality engineers to develop and maintain this infrastructure because of restrictions on salary ranges and the inability to create permanent staff positions.

Suggested measures of success are in keeping with those with which In-Situ currently evaluates itself: publication of novel research in top venues, best paper and honorable mention awards, productive collaborations, and training of talented postdocs and PhDs who continue on to successful careers.

PROJECT MANAO

Primary Topics and Objectives

MANAO is chiefly concerned with the convergence of the real and virtual worlds. Stated areas of focus and expertise cover four axes: analysis, acquisition, modeling, and rendering. These may sound like overly broad topics, but project effort is directed specifically toward bridging the gap between real optics and digital models and algorithms.

A major concern that is wisely being considered is how to avoid doing too much work, for example acquiring too much useless data, or displaying too much insignificant detail. At the same time, this must be balanced with accuracy: research in this field often resorts to subjective interpretations, and this project introduces more rigor into the process.

International Standing and Reputation in the Field

This is a new project that has not had much time to establish a strong reputation, but it does inherit the solid foundation of the IPARLA project it is based on. Of course, the individual team members also bring their own reputations.

The team has strong connections to both computer science (e.g., University of Bordeaux) and optics (e.g., Institut d'Optique). Collaboration with other Inria projects is extensive, and includes POTIOC, MAVERICK, IMAGINE, and REVES. The team has also proactively looked outside of France for collaboration, and the resulting global reach of the project to Germany, Spain, USA, and elsewhere is impressive.

During the evaluation, the team noted that the project in an intriguing position with respect to the optics community, which often works in two dimensions. There is an opportunity, and perhaps obligation, to show what can be done when the third dimension is considered in optics.

The team has also made extensive contributions to selective conferences and publications since it started, such as SIGGRAPH and Computer Graphics Forum. Participation extends to program committee involvement with over a dozen conferences, which is a remarkable accomplishment considering all of the other output from the project. There is substantial momentum here, and that should be sustained.

Also worth noting is the Eigen linear algebra library which is maintained by the team. The library has been used in dozens of independent projects, and is widely regarded as a stable and high-performance toolkit.

Major Achievements and Impact

Perhaps the most innovative and even eye-catching work of the project so far is on plenoptic imaging, as presented at SIGGRAPH 2013 with the "kaleidoscopic camera." This is appealing to a broad audience, given the pervasiveness of consumer digital photography. The ability to get "new" data out of a seemingly simple image was compelling to the SIGGRAPH audience, but one can easily imagine putting this into the hands of the general public.

Also noteworthy is the work on fitting and compression of measured BRDFs, presented in TVCG 2012. Doing “more with less” is a focus of this project, and this work is representative of that. The distribution of the related ALTA library demonstrates the team’s commitment to this research and making it widely available. The evaluation team also notes increasing industry interest in using measured BRDFs for visualization and visual effects, so this work is quite relevant.

Lastly, the very recent work on accurately representing measured luminaires is also significant. While this is yet to be published, the evaluation team feels this work will be well-received by the automotive and architectural lighting industries, for which such simulations are very important. This demonstrates the project’s relevance to genuine needs.

As a relatively young project pursuing a novel field, the impact of this work has yet to be determined or acknowledged, but is promising. The industrial and consumer appetite for blending the real and virtual will only increase, and the project is well-positioned to address that.

Industry Transfer and Partnership

The project already has a variety of connections to industry. As with academia, this covers both computer graphics and optics.

On the computer graphics side, there are companies like The Foundry and Next Limit, each of which has impressive software products and reputations. On the optics side, the project is working with the likes of Automotive Lighting and Philips, two companies that are tremendously concerned with the performance of their luminaire products. From this, the team has shown a remarkable ability to successfully pursue some of the most relevant consumers of the project’s research.

Somewhat surprising to the evaluation team was the collaboration with cultural heritage and archaeology. The team demonstrated the “revealing flashlight,” a unique augmented reality project that leverages the project’s illustrative shading research, and which is already in a museum installation. This not only demonstrates the project’s bearing on unexpected fields, but also the team’s ability to turn their ideas into a real application.

Future Plans

The project’s stated focus for the next four years is to define and explore the field of computational optics. As stated above, the team appears to be well-positioned to pursue this, given its past experience and relevant industrial and academic connections. In particular, the team has started a new partnership with Institut d’Optique to develop an experimentation facility that should help yield the most rigorous results possible.

The team has defined a few ways to approach this in each of the research axes mentioned below, but they also recognize that this is a relatively unmapped field. Expertise in new areas is needed, especially optical instrumentation. Handling ever-increasing amounts of data while maintaining or improving performance is recognized as a key issue.

It is worth noting that an important topic in computer graphics today is physically-based rendering (PBR), and the project's emerging pursuit of computational optics will likely yield superior results for PBR problems. The work on BRDF fitting and measured light sources is especially appropriate.

Another stated goal of the project is to build a lasting software library, starting with the existing set of tools inherited from previous work. The evaluation team strongly endorses this approach, and in particular the future of the Patate library is promising.

Strengths and Weaknesses

Perhaps the project's greatest strength is the team itself. The evaluation team appreciates that all of the permanent members were present for the evaluation, and it became clear that the team was staffed with motivated and high-energy people. There was concern from the evaluation team that the project members would have difficulty remaining cohesive, given the range of research problems being addressed, but they seemed to appreciate and understand each other's work.

Perhaps the greatest risk facing the project is that bridging the gap between the real and virtual is still a very open problem, and the specific goals are not yet defined. So the main challenge, and indeed opportunity, for the project is to take a leadership role in defining the field of computational optics, and then achieving some of its goals.

Another risk is simply that potential consumers of this research in industry may not yet appreciate that disciplined analysis and measurement yields results closer to reality, and is worth the added effort. To some extent, the project's research is *too* far ahead for an audience that is accustomed to merely plausible results, but this can be mitigated, as described below.

Recommendations

With the aforementioned strengths and weakness in mind, one straightforward task would be to better define the project's mission statement. It is presented as "shortening the distance" between the real and virtual, but that expression was initially confusing to the evaluation team. A better way to describe this is "bridging the gap," at least as an expression in English. When you are trying to open up a new field, this sort of marketing is important.

Another recommendation is to make a concerted effort to show that the project's approach is superior to ad-hoc methods of rendering. Since the effort of analysis and acquisition (e.g. measured BRDFs, camera modifications) may be a concern, it would help for the team to make the process clear, for example by providing ample documentation and reference software.

It may also help to position the project relative to other projects which seem very similar at first, as a way of further explaining the project's objectives. For example, the MAVERICK project is focused on a *plausible* version of reality, but MANAO is interested in a *simulation* of reality.

As noted above, the work on plenoptic imaging is perhaps the most interesting to a broad audience. That means higher expectations as well: more hardware options for acquisition and

more applications would be appreciated. In particular, reducing the size and cost of the acquisition setup would help democratize the research, especially if it can be applied to the cameras on popular mobile devices.

Conversely, the work on illustrative shading is somewhat out of place for a project focused on capturing the real world. It is useful for interpreting the real world, as demonstrated by the museum installation, but it is sufficiently different and large enough that it may be better to spin it off into a new or existing project.

As noted earlier, the evaluation team appreciates what the project is trying to do with the Patate library, and strongly encourages the team to build on what they have started. It would be interesting to see the project's other software components (e.g. BRDF fitting) incorporated into Patate. In addition, the library should be promoted outside of Inria as new capabilities are added. The evaluation team believes at least one additional engineer should be added to project to make this and other software efforts feasible.

The evaluation team also hopes that Inria will do whatever is possible to make the experimentation facility a success. This will no doubt come down to more resources and staff, but this is a unique opportunity in the field that should not be missed.

Finally, given the project's stated future goals, the team should consider submitting more work for optics and vision conferences and publications. This could further improve the project's reputation in those "analog" fields, and yield new opportunities for collaboration.

PROJECT MAVERICK

Primary Topics and Objectives

The MAVERICK team, led by Nicolas Holzschuch, was created in January 2014 as an Inria project team, though the work has begun as early as January 2011 and was converted to a local Inria team in January 2012. This team pursues the area of image synthesis in the domain of four research problems, namely:

- Computer visualization: using a large localized dataset as an input, converting its representation to a user-friendly format, focusing on understanding the key properties of the datasets.
- Expressive rendering: creating alternative artistic representation of virtual worlds
- Illumination simulation: modeling the interaction of light with the objects in the scene
- Complex scenes: rendering and modeling highly complex scenes, focusing on alternative representations and appearance prefiltering.

The overall tenet for this team is the understanding of the core driving factors for impactful pictures, their effects on the user and designing efficient algorithms for synthesizing such images. The team is comprised of fifteen members in full, consisting of seven permanent staff (Inria, CNRS, INPG, UJF), six current Ph.D. candidates, a post-doc, and a temporary research engineer.

International Standing and Reputation in the Field

The MAVERICK team has a strong and impressive pedigree in the domain of computer graphics and visualization. Inria Research Center at Grenoble Rhone-Alpes has a long history in research on rendering and image synthesis for almost two decades. It is regarded as one of the best research groups worldwide in these areas. The team has contributed to the field by proposing many new representations and algorithms along with training of the best researchers in the field. The team members have established themselves as definite leaders and experts in their respective areas, due to their creativity and vision. Over the last four years, this group has also actively collaborated with top research labs and institutes in their fields (MIT, Cornell, UCSD) as well as industry (NVIDIA, RSA Cosmos, IGN, EDF, WetaFX, among others).

Though several areas of the project are large domains of research for computer graphics, this team's contribution stands out due to a large corpus of work on the subject. The project members co-authored a remarkable amount of highly impactful publications in the top-ranked international journals and selective conferences, including SIGGRAPH, Transactions on Graphics, SIGGRAPH Asia, Eurographics, Eurographics Symposium on Rendering, IEEE Transactions on Visualization and Computer Graphics, and ACM SIGGRAPH I3D. Note that these conferences are regarded as the best venues to publish in computer graphics and related areas, and some of these conferences have an acceptance rate of less than 20%. The quality of their work is very high; MAVERICK's publications are widely cited and have spurred a large amount of follow-up research.

During the evaluation period, the team has helped a number of Ph.D. students to successfully defend their thesis work and proceeded to be employed by top industry companies in their respective fields. The team members additionally co-chaired several key conferences and tracks (such as Eurographics and Eurographics Symposium on Rendering) as well as participated in international program committees, as wide-ranging as GD/SPM, EuroVis, ACM SIGGRAPH SI3D, EGSR, Pacific Graphics, and Computational Aesthetics.

Major Achievements and Impact

Though the MAVERICK team is quite young as an official Inria project team, their contributions towards this team's success have begun as early as January 2011. The set of achievements for this team is stellar. They published several seminal publications in the area mentioned above. Some highlights include:

- Gigavoxels (Sparse voxel octrees) (scalable, filterable, on-demand evaluation)
    - Supports efficient rendering
    - Real-time exploration of very large scenes (the universe) using Gigavoxels (a collaboration with RSA Cosmos and Observatoire de Paris) for data generation, transparency, and emission rendering
- Appearance prefiltering
    - Extending existing models to support interdependence depending on visible aspect
- Frequency analysis of light transport (namely compact representation for power spectrum using covariance matrix, a very powerful and efficient representation) as well as extensions to scattering and absorption models
- Perception of depth in volume rendering, visualization of data uncertainty using noise (working with perception specialists to develop user studies and design new algorithms, resulting in a book chapter as well as a panel at VisWeek 2014)
- Published state of the art report on temporal coherence as well as a book chapter
- Working on new tools for vector graphics to enable better vector texture design

Industry Transfer and Partnership

MAVERICK's team excelled at industry transfer during this evaluation period. The team produced multiple instances of highly successful software (Proland, GigaVoxels, and Mobinet). Their software and samples have been widely used and have been successfully integrated into several real-world applications, including the *Crysis* rendering engine and the *Unreal* engine. The technology for GigaVoxels transferred to NVIDIA resulted in further SDK samples available for easy access. On top of that, the team worked with a startup Digisens on GPU-based tomographic reconstruction and visualization software. The team at MAVERICK has strong cooperation with the industry, with such leading companies as NVIDIA, Digisens, WetaFX, EDF, IGN, RSA Cosmos and Eden Games.

Training of Personnel

The MAVERICK team was not only extremely active and creative in projects and publications, but also in training and advising Ph.D. students. During the evaluation period, nine obtained their Ph.D., while two additional students continued their work beyond MAVERICK with a position in the academia or the industry. Many members of the team have heavy teaching duties, with full teaching load as professors, or teaching courses for the Master programs. Several team members have also served as chairs of highly selective conferences and on committees of several international conferences, as mentioned above.

Principal Strengths and Weaknesses

The MAVERICK team has a strong pedigree. They have built a high level of expertise in their respective domains and are widely considered as references on the subjects. Many of the techniques developed by this group are widely used by the industry (integrated to some video game engines and adopted by NVIDIA). The film industry is expressing interest in their work for rendering highly complex scenes. The team has cooperation with both industry for further research (such as programmable vector texture generation or Gigavoxels), and with academia (MIT, Cornell, UCSD, for example for further work for frequency analysis of light transport). The team members are very creative and original researchers, and have been able to strongly impact the field of computer graphics. This is the major strength of this team.

Another unique aspect of the MAVERICK team is the breadth of topics it pursues, from non-photorealistic rendering, to perception analysis for computer visualization, real-time rendering for large datasets, global illumination and participating media, to visualization for laypeople. This diversity can be both a strength and a weakness. Since many of the issues MAVERICK is investigating are cross-cutting research issues in the domains of sampling, filtering, scalability and large data sets, this variety is deserved. However, it has a potential to defocus the team and divert its attention from its main goal. In particular, the area of visualization for laypeople needs further definition (more on that in the risk section).

Having over six of the senior team members teach in the major universities and Master programs is a great strength for the MAVERICK team as they are able to discover and recruit new talent with the teaching program.

This brings us to another potential weakness: the reduction of the overall amount of MAVERICK's team members (from twenty to fifteen in the last three years). Many of the successful team members obtained their Ph.D.s and left the team to place in academia or industry (demonstrating the ability of this team to nurture and develop talent). The remaining Ph.D. students are in the latter part of Ph.D. program (third-year, with a few second years), and may obtain their Ph.D. during the next four years of evaluation. If the team is able to recruit new successful students to participate in this program, this potential weakness would turn into strength, bringing new ideas and fresh thoughts to the project. Recruiting new Ph.D. talent will be important for continuity of project themes.

Future Plans

The project's goals remain steady for the next four years as MAVERICK has only been recently formed, pursuing its originally established four domains.

The team's future focus to design an extensive analysis of the dimensionality of light transport operator, with the goal of devising a new theoretical framework for effective computations of rendering equations solutions, with respect to fast and consistent relighting, and real-time global illumination simulation for real-world applications such as video games, is an ambitious and exciting area of pursuit. Another strong goal for the team is to extend the existing Gigavoxels framework to support animated models. This is a very important consideration for this domain, required to be fully adopted by the real-world application for complex and dynamic scenes. Solving both of these goals is an ambitious undertaking. One related area that might be interesting to investigate is material representation and large-scale datasets for high-performance rendering such as VR (both with respect to stereo representation requirements and extremely low-latency rendering).

Additionally, the team intends to pursue further directions in appearance prefiltering based on curvature and silhouette analysis, and extensions to support volumetric data, to combine sparse voxel octrees with appearance prefiltering. In the domain of illumination simulation, another plan is to devise better models for acquisition and representation of materials, with representations to enable efficient computations, low-cost material acquisition using compressive sensing, and further work in scattering and participating media. In the domain of expressive rendering, the team plans to further pursue programmable vector texture design and its application to cartography. Lastly, in the domain of general computer visualization, the team wishes to make computer visualization accessible to laypeople, to enable a wide audience to access and easily understand large numerical localized databases (such as data from low-cost temperature, pressure, or humidity sensors). Their goal is to continue further research in the application of Morse-Smale complexes to visualization.

Opportunities and Risks

While the team has built tremendous expertise in the areas of their ownership, especially in the domain of light transport, the topic of visualization for the layperson needs the most definition and clarity. Though the application of Morse-Smale complexes to data simplification is clear, the overall direction of intuitive data visualization and the relationship of complex representation analysis need further structure and definition. This direction has the potential to be a very exciting area of research but it most absolutely needs clarity of direction and concrete definition of the problem, in order to relate feature-preserving data simplification to how a lay person might be able to select key properties to simplify. It is perhaps worth moving this into a separate project as this domain is very open and has a lot of potential, but needs more structure to pursue successfully.

Recommendations and Suggested Measures of Success

Our overall recommendation is to continue as planned, with emphasis on specific themes improvements as follows:

- Continue to build the team, bring in top Ph.D. students, publish at top venues and maintain high visibility.
- Maintain in-depth focus on the existing themes and further the state of the art in the pursued domains.
- Continue in-depth exploration of large data sets in real-time but extend the methods to support animated scenes and efficient update of the underlying data structures in real-time. Further strengthen the relationship of the team with industry related to real-time rendering, building on existing relationships with film studios, scientific visualization and map visualization companies, but also build relationships with video game developers for technology exchange and transfer of research to practical applications.
- Clarify the relationship of large-dataset simplification and visualization for laypeople. Define how the goal of making visualization approachable for consumers is attained using intuitive data simplification.
- Explore the application of MAVERICK's algorithms in the space of VR rendering, taking advantage of strong representation of this theme at Inria and recent hardware advancements in that domain.

PROJECT MIMETIC

Primary Topics and Objectives

The topics of the MIMETIC team center around three main areas: (1) analysis of human motion, (2) simulation of human motion, and (3) physical interaction between people and virtual humans. The overall objective of the project is to increase our understanding of human motion, and to create effective physical interactions between real and virtual humans, with applications including sports analysis, rehabilitation, training, and health. The approach the team uses towards this goal is to close the loop from analysis to simulation to deployment in virtual scenarios. A showcase example is a simulated rugby player who employs physical principles discovered through motion analysis to evaluate and train a real human defender.

International Standing and Reputation in the Field

The MIMETIC team is well represented in top publication venues in computer graphics, biomechanics, and sports science. Their research and their research team are well known, the quality of their research is of the highest standard, and the research directions chosen by the team are respected as innovative, ambitious, and important.

Major Achievements and Impact

Major achievements of the project over the last review period are noteworthy for addressing problems that are critically important yet understudied due to their difficulty. Also noteworthy is emphasis on real-world scenarios, thorough evaluation, and potential for impact. Examples of such achievements include:

- contributions to fundamental knowledge on the tennis serve
- new evaluation techniques for shoulder mobility and gait deviation, with emphasis on real-world challenges for in-home deployment (noise, occlusion…)
- explorations of inverse dynamics, contributing a time-dependent cost function to better solve this highly underspecified problem, with evaluation in real-world situations (e.g., meat cutting)
- explorations of balance control models that find existing models cannot predict loss of balance in dynamic situations
- new motion recognition techniques which move towards morphology independence,
- advances in understanding and simulating pedestrian interaction for curved trajectories
- explorations into evaluation of crowd simulations, with a contribution of achieving the best tuning of each algorithm prior to comparison
- assessments of perception in VR, feedback mechanisms for VR, and perception-action coupling in VR, with focus on realistic scenarios and training (e.g., soccer, karate)

Industry Transfer and Partnership

Methods and software, especially related to crowds have been transferred to the successful startup Golaem, which has contributed to numerous films. One additional goal, corresponding to

a recently initiated Inria ADT project is to develop a new platform for virtual human simulation. This direction should be strongly encouraged.

Training of Personnel

Many of the project members are involved in teaching and ability to recruit Ph.D. students is good. Graduating Ph.D. students have been placed well.

Principal Strengths and Weaknesses

Strengths of the project include:

Personnel. The team includes a strong mix of backgrounds in computer graphics, biomechanics, and sports science. Several team members have experience in more than one of these fields and the team works well together. The mix of backgrounds allows large-scale projects to be carried out and helps to ensure relevance and impact.

Equipment and other resources. Facilities (available and planned) are among the best in the world and will provide exceptional experimental platforms, such as the ability to capture a tennis game between a real and virtual tennis player. The goal of the group to capture interactions in realistic settings is important and requires large scale facilities. The resources of this project are unique in this regard. Immersia is one of the largest immersive rooms in the world, and the ImmerMove Stadium is one of the largest academic motion capture and analysis studios.

Theme. The overall research theme of the project is also a strength. The team emphasizes analysis followed by synthesis followed by evaluation. Projects address interaction and real-world scenarios, which can be “messy.” Questions are approached at many different levels from joint kinematics to crowd behavior.

Weaknesses include:

Insufficient support, e.g., engineers and technical staff. Full time staff is needed to maintain the various facilities, run capture sessions, clean motion capture data, and build and maintain software in order to free the research team to pursue their research for maximum impact. The support staff appears inadequate for the level of facilities that are in use by the group.

Two research sites. The project team is separated into two sites; however, they appear to be handling this difficulty well, for example with joint meetings and shared office spaces.

Future Plans

There is a detailed plan in place to continue the project along similar lines, with the addition of new team expertise in perception.

Opportunities and Risks

The following planned research directions can be highlighted for their potential for great impact:

- Determine how low-level simulation can have impact in computer graphics. What is the correct level of simulation to make a difference to realism of virtual characters performing highly dynamic actions, interacting with a real player, interacting with their environment in a physical way?
- More natural, more accurate musculoskeletal level simulations and control algorithms.
- Understanding variation due to different morphologies and variability in motions for a single individual.
- Real-time, meaningful dynamic analysis.
- Evaluation of virtual crowds.

Developing new insights comes with the risk of failing to develop satisfactory models, but the project team has had good success to date.

Recommendations and Suggested Measures of Success

Overall recommendation is to continue as planned, with emphasis on the compelling themes of (a) studies performed in highly realistic scenarios, (b) interaction among characters and between humans and characters in virtual environments, (c) thorough evaluation, and (d) meaningful final outcomes.

There is difficulty maintaining permanent staff, yet long-term staff engineers are needed to maintain the extensive unique facilities associated with this project, to support the running and analysis of experiments in these facilities, and to support development of software tools based on research findings. Anything that can be done to ease this difficulty would positively impact on research output and transfer, especially in important areas of motion analysis, simulation, and control.

PROJECT MINT

Primary Topics and Objectives

The MINT team, led by Laurent Grisoni, was created from members of IN SITU in 2009. The scientific objectives are focused on following topics: fundamental understanding of hand actions and perception, algorithms and tools for high-level hand-based input, haptic feedback.

Designing new forms of interaction means first analyzing human-computer interaction, and then modelling interaction. On the contrary designing new devices for these new forms of interaction means a robust and long term development, driven by prototyping and experiments. The research activities of the team are colored by these aims, from HCI to electronic engineering and virtual reality. From 2011 to 2014, the number of permanent scientists was increased from five to nine, with a total amount of twenty-seven members for the team which suggests a good attractiveness for the project.

The research is mainly focused on gesture interaction, with one or several users and with new systems or with existing systems. Usage aspects are studied on the criteria of speed, accuracy, collaboration, multi users or multi devices, and gesture interaction deployment. It seems that the team is exploring an original association between HCI and electronic engineering (haptics).

International Standing and Reputation in the Field

The visibility of the team is strongly established by international publications in selective conferences of the domain such as ACM CHI and ACM UIST, with prizes for best demo or best papers. The three patents and the seven popular science events show an ability of MINT to complete a process of designing and developing interaction and devices, and to attract a large audience for their innovations.

Interesting and productive collaborations are led with Daniel Vogel, University of Waterloo (Canada), Andy Cockburn (University of Canterbury, New Zealand), and Joaquim Jorge (INESC-ID, Portugal).

A European contribution through an EU FP7 project, Prototouch, focused on future generation devices, serves to position MINT as a major research team in gestural interaction in Europe. The team has historical connections with teams from Inria such as IN SITU (some members are coming from this team), SHACRA, IPARLA, and POTIOC. The research work is not performed individually, but on the contrary, the links with other Inria teams and the local university and institutions indicates good collaboration.

Major Achievements and Impact

A major achievement for the team is the StimTac project, which was a great multidisciplinary work. StimTac shows a great example that between mature research and making it a product there are still challenges to be overcome. Another achievement is in the work on transfer functions: the formalization of the phenomenon of the displacement of the mouse movement

and the pointer between them is clearly defined. MINT is proud of the metamorphe project, to rethink about how we use keyboards.

The Art-science interaction is very relevant for Inria strategy for social and popular science, giving people creativity tools, and helpful computer systems for humans.

Six installations with artists were designed and presented. It makes society interested in this work and make the team expose its work. Audience in France is not much aware of this type of work. For example “La Damassama” (art installation, combination of Kinect and robotics) was interesting because MINT had to develop software that runs continuously throughout the day, thus had to learn better robustness techniques (no crashes), which is new to its process as that is not typical in a research work.

The team is obviously working on two different fields: HCI and haptics/virtual reality. In the field of HCI, the team is well represented by Nicolas Roussel and Gery Casiez, prominent in the French community with AFIHM (French association for HCI) and results published in the best conferences of the domain. In the field of haptics/virtual reality, Betty Lemaire-Semail has a strong competence and Laurent Grisoni addresses new issues in gestural interaction.

Considering the size of the team, the number of high-quality publications is lower than expected. In particular, there was a small number of journal publications. Selective conferences in this domain are important publications, but one would expect there to be some work that is of greater scope that could be published in a journal format.

Industry Transfer and Partnership

Three patents have been successful. The partnership with STmicroelectronics is important. A device has been developed and tested, and many opportunities of industrial partnership are now possible. The team is well positioned for Industry Transfer.

Training of Personnel

During the evaluation period, seven students obtained their Ph.D. and two scientists obtained their HDR. The number of Ph.D. thesis and HDR is more important (factor 2) for haptics compared to HCI.

Principal Strengths and Weaknesses

Strengths:

- Gestural interaction is a young research field. The orientation of the team seems to be very close to electronic engineering, virtual reality, and haptics, and the scientific focus seems very large. The next generation of gestural interfaces will probably be more oriented on the body user experience and not only with the finger or pointing focus. It seems that MINT has the possibility to open ambitious axes in this field regarding the initial project.

- The team attracts artists, and develops a very innovative and robust tactile interface. This is a heavy project to lead, and that is a success for the team.
- An immersive room is available in the local group: this is a facility to fully exploit.

Weaknesses:

- Progress in haptics/ tactile feedback research has been very slow worldwide, and it is not clear that MINT has a brand-new approach that solves huge issues. The evaluation team would like to continue to see haptics research at Inria, but is not sure that this team will have large success.
- Too many issues are addressed, giving an impression of an ambitious project, but one that perhaps lacks focus.
- The design, implementation, and evaluation of haptic devices is a long process, but will this project be able to face this evolution with a low number of members remaining? Will MINT hire new scientists ?
- The evaluation team perceived a real challenge for the project, in the fact that the split of MINT into two teams (MINT and MJOLNIR) will have consequences on the orientations and scientific production of the teams.

Future Plans

In the next period, a new MJOLNIR team is proposed, led by Nicolas Roussel, with a general focus on interaction/HCI, not just on tactile and gesture, to design interfaces that require learning and skill development but provide rich abilities, perception of animation and haptics, and reflective interfaces. The new team involves Gery Casiez, Fanny Chevalier, and three other researchers and will be a joint team Inria–University Lille 1. One question about MJOLNIR is the extent of their collaboration with IN SITU, and their ability to differentiate themselves from IN SITU.

MINT will focus much more on technologies for tactile and gesture interaction, and less on HCI. New questions will challenge the future of multi-touch tactile feedback (not currently solved) such as the bi-touch feedback, ultrasonic vibration to reduce friction, and the human control of the interface. The future work is focused on giving the user the sense that he has the control. The paradigm is not about about a fully automatic computer or a computer reacting as a tool, but a computer as a partner.

This is a natural evolution of the team, since the work to this point has really focused on two separate topical areas. MINT will have the opportunity and challenge to clarify and strengthen its objectives.

Opportunities and Risks

A very interesting expertise on gestural interaction has emerged from this project. It would be interesting to define more clearly a new theoretical framework including hand action and perception. First results have been obtained, this is to encourage.

The development of new tactile interfaces is an important research axis for the theme Interaction and Visualisation. The hardware part of the work and the analysis called “no more bricolage” brings an automatic oriented model, with transfer functions. This could be supplemented with the cognitive sciences background on action / perception.

Considering the greatly reduced size of MINT for the next period, it will be difficult to produce a high level of scientific output. The team should construct close collaborations with academic partners.

Inria seems to encourage exchanges between very different scientific communities (ex: MINT group structure: people from HCI, people from electrical engineering, and virtual reality). This also to consider and to reinforce for very demanding research topics such as gestural interaction.

The MINT project will be split in two new projects: MJOLNIR and MINT. Basically, MINT will keep a “hardware” focus, and MJOLNIR will explore an HCI focus. This raises the question of whether MINT will be able to continue doing haptic perception studies. The record of MINT looks good, especially recently, but how is it likely to look in the next couple of years? It is unclear if the team wants to design and develop new tactile devices, or construct a theory of interaction with tactile devices. Many parts of the studies give an ergonomic point of view. The human behavior, the adaptation and the coupling between human and the machine, should be studied.

Recommendations and Suggested Measures of Success

MINT is exploring an immature field of research compared to other teams, and has to strengthen the competencies of the remaining team. The evaluation team suggests to:

- reinforce the team with a scientist in cognitive science for perception studies
- construct relevant partnerships with companies to develop new gestural interfaces (to find ways to leverage ambient technical level)
- hire a specific person devoted to popular science (demos) for the societal aspect of computer science dissemination
- make a clear analysis of the position of MINT and MJOLNIR compared to other Inria team such as IN SITU, or the future teams coming from it
- give a flexibility on the financial support all along the years to be able to adapt to complex projects and have the possibility to react quickly
- construct a sharable strategy with politicians to build up both a dynamic context for research, and economy

PROJECT POTIOC

Primary Topics and Objectives

POTIOC is a very new Inria project team, having only been established in 2012. Its stated theme is “popular interaction,” which relates to the use of new interfaces, technologies, and HCI techniques by the general public. In other words, POTIOC is designing and evaluating interfaces for everyone. In addition, the team targets the use of novel or advanced technologies and techniques, rather than designing traditional interfaces based on mice, keyboards, and screens. These interfaces are targeted at application areas such as education, end-user content creation, and entertainment. Specific topics of research include interaction using 3D graphics, virtual reality and augmented reality (VR & AR), tangible interaction, and brain-computer interaction (BCI).

International Standing and Reputation in the Field

The work done by POTIOC in certain areas is relatively well known internationally. In particular, the work of Martin Hachet on 3D interaction techniques and devices (e.g., CAT, Navidget, tBox) is highly regarded in the 3D UI and VR research community. Although not all of this work was done since the creation of POTIOC, the team is continuing to work in these areas, and Martin Hachet and his team continue to be world leaders in 3D interaction. This is evidenced by his visibility within these research communities (e.g., steering committee chair and program chair for IEEE 3DUI, general chair for IHM).

Fabien Lotte is an emerging leader in BCI. Although still relatively early in his career, his work is already highly cited and having an impact on both the technical aspects and the design aspects of BCI. Having trained with Anatole Lecuyer and colleagues, Fabien is now able to do both excellent independent work and to continue strong collaborations with team HYBRID.

It is not clear that POTIOC *as a group* has a reputation internationally. This is partially due to its newness, and partially due to the lack of “branding” of Inria project teams—individual researchers are most often known much more than their groups as a whole.

Major Achievements and Impact

Team POTIOC organizes their scientific achievements along three axes: (1) Understanding humans interacting with the digital world; (2) Creating interactive systems; (3) Exploring new applications and usages. Since the team is small, basically all the team members contribute to all three areas.

In area 1, the work on human strategies for interacting with a 2D touchscreen to control 3D objects/scenes is notable, and it led to a powerful contribution in area 2 (tBox). Research using EEG signals to understand mental workload during 3D interaction is also novel and important. Finally, research on how human users learn to use a BCI is a unique and important spin on this research area.

In area 2, beyond the previously mentioned tBox, the Toucheo system is worth noting. There have been several prior systems that allowed users to “reach inside” a stereoscopic display to interact, perhaps with haptic feedback, but we are not aware of prior systems that use touch-based input in such a setting. This system design led to several interesting UI designs and evaluations. The Teegi project is an interesting combination of BCI, tangible interaction, and AR that brought some notoriety to the team.

The collaboration with Cap Sciences is an important achievement in area 3, since it allows the team to test new designs with the general public, and at the same time serves as an outreach mechanism. The team has applied their work in the domains of education, art, and entertainment.

The publication record of the team is outstanding for such a small group of researchers, indicating the significance of the team’s contributions. Papers in UIST, CHI, VR, 3DUI, NIME, and ISMAR are all of high quality and represent the research community’s acceptance of the work of POTIOC as important.

Industry Transfer and Partnership

In one sense, the ability of POTIOC to transfer the results of its research to industry and the “outside world” should be high, since it focuses directly on “popular interaction.” The success with Cap Sciences is a good example of this. Although this Living Lab doesn’t represent a commercial product, it does go a long way toward getting the results of this research into the public eye.

The team also had success in transferring Toucheo to a company, with a commercial product based on this work now available, and a patent has been submitted.

POTIOC’s researchers indicated that it had been difficult to work with companies through Inria’s transfer office, and that some companies had given up on the process due to the amount of bureaucracy involved.

Training of Personnel

POTIOC has graduated several Ph.D. students in the two years since inception, and three more students are currently on the team. Two postdocs have been completed, and a third is currently in the group. Finally, four Ph.D. students from other locations have visited the team during the evaluation period. This is a very reasonable record of training in the first two years of the project team, and it appears that students and postdocs who came through POTIOC were able to find good positions in related areas after leaving the team.

Principal Strengths and Weaknesses

Strengths:

- Several of the interface design projects exhibit a high level of creativity and innovation.

- The team takes a broad view of “effectiveness” in HCI, not simply relying on task performance measures, but also evaluating systems for satisfaction, enjoyment, comfort, etc.
- The project team has deep experience with non-traditional devices and interaction styles, which is not common in most HCI groups.
- AR is an important emerging research topic, and POTIOC is positioned to be the Inria leader in this area.
- The team’s work is being published in top quality conference venues (note: most of the top groups worldwide in related areas prefer top-level peer-reviewed conference papers to journal papers)
- The collaboration with Cap Sciences for the living lab is an important partnership.
- The team is attractive to visitors.
- The team is interdisciplinary in nature, with several cognitive scientists taking part.

Weaknesses:

- As a research theme, “popular interaction” may be ambiguous and problematic. This is not a common term in the research community, nor is it a concept that can easily bound or motivate particular lines of research.
- Perhaps because of this ambiguous theme, the team’s work spans a number of research topics (BCI, physiological signals for evaluation, tangible UIs, spatial AR, touch-based interaction). The work of the team can be seen as a set of projects that are only loosely related, rather than a sustained effort toward answering a small set of research questions. Thus it is unclear if techniques, methodologies, and results can be generalized.
- The team is very small compared to others, and lacks a more senior researcher.
- Because the team is so small, the overhead of administrative duties is more onerous.

Future Plans

Team POTIOC’s plans for the next four years to some degree address the weaknesses identified above (ambiguous theme, set of loosely related projects, lack of generalization). They plan to build on the existing work to more fully develop two topical areas: BCI and spatial AR. For BCI, the focus will be on using physiological (esp. EEG) signals for 3DUI evaluation and designing learnable BCIs. For spatial AR, the research will center on interaction techniques and styles, with tangible interaction a central approach. Learning and education will serve as the application domain for this research.

This plan is much more concrete than the somewhat vague theme of “popular interaction” and the broad objectives of understanding the human, designing interactive systems, and exploring new applications. Since it builds on existing work, there is a high likelihood of success. Because the team will focus on only two specific research topics for the next four years, the opportunities to “go deep” on these topics and make generalizable contributions over time are much greater.

Opportunities and Risks

- Team size: the team needs to grow to be able to achieve its vision.
- Barriers to industry transfer can inhibit the application of the team's work to commercial ventures.

Recommendations and Suggested Measures of Success

Overall, the evaluation panel was impressed with the POTIOC team at this early stage of its work. Although research to this point has been a bit scattered across multiple topics and projects, the plans for the next four years should largely address this issue. The panel had the following recommendations:

- Follow the plan outlined for the next four years. Focus the research efforts on a small number of related research directions, with sustained effort on each, in order to make significant, long-term contributions.
- Reinforce collaborations with neuroscience and psychology researchers in the local area and throughout France.
- In four years, the team should have added at least one and maybe more permanent researchers, with each permanent researcher heading a sub-area of the team's research. It is not necessary for all team members to be a part of every project or sub-area, as long as the areas are complementary.

PROJECT REVES

Primary Topics and Objectives

The primary objective of the REVES project was to develop algorithms and methods for computer rendering while improving the speed and quality of computer-generated images on screen and in virtual and augmented environments. In the last four-year period the focus was on three main topics: image-based methods for rendering and relighting, perception and interaction in the context of image based techniques and material modeling and rendering, and sketch-based modeling for geometry and materials, which was a new direction in the project.

International Standing and Reputation in the Field

George Drettakis, the team leader, is one of the leading figures in the computer graphics field. He is an associate Editor-in-Chief of IEEE TVCG journal. He received the Eurographics outstanding technical achievement award in 2007. He was IPC co-chair of Eurographics 2008 and the SIGGRAPH Asia papers chair in 2010. Adrien Bousseau is a rising young researcher in the field. He received the Eurographics 2011 Ph.D. award. They both served on international program committees of the leading conferences, and have several collaboration with leading international institutes such as MIT, Berkeley, ETH, UBC and more.

Considering the small size of the team (only 2 permanent researchers and up to 9 researchers in total during this period), the research yield of the group is outstanding. Both the works and the researchers in the group are well known.

Major Achievements and Impact

This project resulted in several major technical contributions in rendering and modeling. Most notable are as follows. The work on extracting coherent intrinsic images from photo collections allowing shade removal and relighting, was incorporated into an AutoDesk product. The work on cross shading to infer a normal field of a drawing from simple sketches, and later the 3D shape itself in true2Form were both patented. These works leverage knowledge from artists and designers and allow to change the appearance of material and lighting in the image. The collaboration in EU project VERVE lead to the development of virtual reality software in the cave for treatment and care of Alzheimer patients.

Although the sketch based works were not originally in the scope of the project, the team identified this new research direction and pursued it with great success.

Industry Transfer and Partnerships

The team succeeded very much in creating partnerships both in academia and industry. They have successful collaborations with numerous researchers in leading institutes such as UC Berkeley, MIT, Adobe Research, U. of Toronto, UBC, and ETH Zurich. These collaborations have had a strong effect on the team's research by bringing in new ideas, methodologies and expertise that could not be found within the team. Such collaborations should continue in the

future (i.e. in the new project proposed) as they have a fruitful impact especially considering the small group size.

In terms of technology transfer, several industry partners such as Autodesk, TestaLuna and CMMR have incorporated technology and algorithms developed in the group in commercial products and granted funding for the project. However, such transfers many times need considerable effort (e.g., around a year of engineering effort for implementing intrinsic images technology), and this should not take a major part of the primary researchers' time. A successful model must be to allow the teams to include internal engineers within projects to support such efforts (such as the funded engineer in the EU project CR-PLAY).

The team also issued two patents (crossShade and True2From), although the direct benefit of this for commercialization is not clear. Allowing the technology to be public (e.g., image based rendering) allows simpler distribution that can sometimes lead to higher impact. Good examples for this may be VERVE and CMRR.

Training of Personnel

The project resulted in 4 Ph.D. dissertations and several post-doctoral trainings. For two permanent research scientists this is good.

It was noted that the Inria internship program works very well to attract Master students (4th and 5th year), who then stay on for Ph.D.s and should be continued.

Principal Strengths and Weaknesses of the Project

The group's research yield is very high, the number and quality of publication are high and the visibility of the work and the two permanent research scientists are high. One of the original goals of the project - addressing sound in rendering and VR - was not pursued due to lack of expertise after departing of personal. A new direction was pursued instead, involving sketch based modeling of shape and materials in great success. Technology transfer was also strong resulting in incorporating the technology in commercial products and patents.

The primary weakness is the small number of permanent researchers. The team was clearly trying to recruit at least a third permanent Inria researcher but did not succeed. This caused difficulty in one direction (sound), but also drove the group to seek external collaboration, which were very fruitful and successful.

Future Plans

As this project will end after its 12-year period, we include comments on the new proposed direction, namely "Graphics for Heterogeneous Content." The key observation that there is a need to re-think the graphics pipeline due to new and heterogeneous types of data (that is inaccurate and incomplete) is a strong one and the people in this group are well qualified for researching this task. Similarly, new tools and paradigms for shape and material design is a strong direction that can be supported by the group. However, the connection between these

two themes is not very strong and should be better justified. On the other hand, this team works very well together and this will benefit any future project.

Opportunities and risks/difficulties faced by the project

The main difficulties of this project were manpower and funding. The departing of part of the team and failure to recruit a third permanent researcher resulted in the need to turn to outside experts. This was turned into an opportunity by creating many fruitful collaborations.

In terms of funding, because the basic support ("dotation") had been reduced, the need to search for project-based funding adds overhead and can hinder research.

The overhead of using the CAVE for research was too high. Implementation details and system support are too high given the research outcome. This direction would probably not be continued in future projects.

In terms of work environment, the public transportation was difficult to and from Sophia-Antipolis center. Any pressure that Inria can provide to local authorities would help.

Recommendations and Suggested Measures of Success

REVES has been a very successful project at Inria. The quality of the team is unquestionable, and the results are excellent with a significant impact both on research and industry. The major drawback was the small number of the permanent Inria researchers–only two. This seems a little too small for a project involving Virtual Reality support, substantial collaboration and technical transfers. Future projects of this scale should involve at least three and maybe more researchers.

Similarly, when technical transfer is sought, an engineer position as an integral part of the team is desirable (instead of shared by several teams).

The new research directions identified by the team: dealing with heterogeneous types of data gathered for rendering, and dealing with inaccuracies and incompleteness are very promising. However, the modeling part should be better tied with the main rendering theme. The team works very well as a group and should be encourage to continue working together.

PROJECT TITANE

Primary Topics and Objectives

The TITANE project concerns the extraction of geometric information from data, and the subsequent abstraction and compression of that information into useful forms. The data on which they are currently focused is lidar and images collected from urban environments. Particular challenges are coherent noise and the overall large size of the data. These are important issues often elided in geometry processing research.

International Standing and Reputation in the Field

The research coming out of this group is widely seen as excellent. Publication in venues such as SIGGRAPH, CVPR, PAMI, TOG and SGP (best paper award) is clear evidence of excellence. Their prominent involvement in CGAL also raises their profile.

Major Achievements and Impact

The leadership of Pierre Alliez and Florent Lafarge creates an excellent synthesis of geometry processing and computer vision techniques, very well matched to the focus on extraction of geometric information from urban data such as point clouds and images. This is particularly evident in their co-authored Eurographics 2013 paper.

Primitive detection: One direction they have been pursuing is that the detection of primitives (usually planes) improves the efficiency and the accuracy of large scene reconstruction from 3D point data. They worked on the problem of finding primitives in large scenes represented as point clouds or meshes, on using these primitives to provide structure for surface reconstruction from point clouds, and on using primitives to simplify geometric shapes. Another related contribution is finding more complex primitives through point processes, an extension of Markov random fields.

Surface reconstruction in the presence of noise: In addition to the thrust of using primitives, team has been pursuing surface extraction in the presence of noise using some interesting mathematical tools. One direction applies recent Inria-funded theoretical work on distance functions that are robust to outliers. Another relies on the transportation distance between a triangulation and a point cloud; this approach is interesting but slow.

Mesh generation: Producing good meshes from the arbitrary meshes produced by surface reconstruction algorithms is usually the next step in geometry processing. The group produced some very high-profile work on the construction of quad-meshes. These are more difficult to construct than triangle meshes, but they simplify or speed up some downstream geometry processing tasks. This work was led by former post-doc David Bommes. A second direction in mesh generation was the development of a parallel Delaunay triangulation program for CGAL. Delaunay triangulation is a very basic computational tool, difficult to parallelize. Publishing code in such a well-known package is an important step.

Industry Transfer and Partnership

Industry partnerships are very strong. The group cooperates with Technicolor, a leading supplier of media technology, and support also came from Astrium (now part of Airbus) and Geoimage, a satellite imagery company. One of the quad-meshing algorithms was transferred to Autodesk, the leading manufacturer of CAD tools.

Vigorously publishing software through CGAL not only makes it widely visible and available, but it also makes it commercially available through Geometry Factory, its commercialization arm.

Training of Personnel

The team is training six Ph.D. students and has graduated one. Postdoc David Bommes has gone on to be a Junior professor at Aachen. Florent Lafarge completed his habilitation.

Pierre Alliez and Florent Lafarge both taught the equivalent of about one course per year.

Principal Strengths and Weaknesses

Strengths:

- Addressing important topics in the context of a realistic application; especially recognition and reconstruction in large scenes, man-made structures, and with noise
- World-class expertise in geometry processing
- Connection with computer vision, excellent young researcher in this area
- Good working relationships with industry and great software distribution

Weakness:

- Connection to the LiDAR/remote sensing community could be stronger; the paper in the ISPRS Journal of Photogrammetry and Remote Sensing is a step in this direction

Future Plans

The team plans to continue in the profitable directions it has begun, working on robust geometry processing of data collected not only from airborne devices but through other distributed methods such as consumer photos and video. Assuming or finding structure in unevenly-sampled and noisy data will continue to be a key approach. A new frontier will be considering physical or functional constraints on the models extracted from the data.

Opportunities and Risks

- Risk: focusing on real issues sometimes leads to many small, practical improvements rather than big intellectual advances
- Risk: distribution of results over three communities (geometry processing, computer vision, remote sensing) might make it hard to have an impact in all three

Recommendations and Suggested Measures of Success

The overall structure of the project is excellent.

Recommended actions:

- think about finding a high-profile challenge project to focus the research on robustness and models; the Digital Michelangelo project is a classic example
- reach out to ISPRS/remote sensing community
- continue to pursue mathematical approaches that might lead to breakthroughs

Measures of success:

- the obvious: publication in high-quality venues, production of excellent Ph.D. students, industrial adoption of new technologies