Proposal Full Title:

Supporting humans in knowledge gathering and question answering w.r.t. marine and environmental monitoring through analysis of multiple video streams

Proposal acronym: Fish4Knowledge

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Challenge 4: Digital Libraries and Content

List of Participants

Participant no.	**Participant organisation**	**Short name**	**Country**
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Abstract

The study of marine ecosystems is vital for understanding environmental effects, such as climate change and the effects of pollution, but is extremely difficult because of the inaccessibility of data. Undersea video data is usable but is tedious to analyse (for both raw video analysis and abstraction over massive sets of observations), and is mainly done by hand or with hand-crafted computational tools. Fish4Knowledge will allow a major increase in the ability to analyse this data: 1) Video analysis will automatically extract information about the observed marine animals which is recorded in an observation database. 2) Interfaces will be designed to allow researchers to formulate and answer higher level questions over that database.

The project will investigate: information abstraction and storage methods for reducing the massive amount of video data (from 10^{15} pixels to 10^{12} units of information), machine and human vocabularies for describing fish, flexible process architectures to process the data and scientific queries and effective specialised user query interfaces. A combination of computer vision, database storage, workflow and human computer interaction methods will be used to achieve this.

The project will use live video feeds from 10 underwater cameras as a testbed for investigating more generally applicable methods for capture, storage, analysis and querying of multiple video streams. We will collate a public database from 2 years containing video summaries of the observed fish and associated descriptors. Expert web-based interfaces will be developed for use by the marine researchers themselves, allowing unprecedented access to live and previously stored videos, or previously extracted information. The marine researcher interface will also allow easy formulation of new queries. Extensive user community evaluations will be carried out to provide information on the accuracy, ease and speed of retrieval of information.

Table of Contents

The Project Proposal

1: Scientific and/or technical quality

1.1 Concept and objectives

One approach to acquiring biological data of insects, fish and animals in their natural setting is to use embedded video cameras to observe the presence and behaviour of the organisms. This presents three problems for the biologists: 1) the quantities of acquired raw data can approach 1-2 gigabyte per hour per camera, even with substantial compression, 2) extracting information from the data can require substantial computer programming skills and 3) adapting the programs as scientific questions evolve or new questions arise can be quite time-consuming. These three problems sit at the heart of the motivations for the Intelligent Information Management workprogram focus.

As a practical framework for focussing and integrating research into issues of Intelligent Information Management, this project will investigate methods for capture, storage, analysis and query of multiple video streams of undersea environmental videos. The video streams are being generated as part of an ecological monitoring effort [41] and also form a resource base for marine biologists. The cameras (*e.g.* 10) generate on the order of 20 gigabytes per hour of video data and, with 12+ hours of usable daylight, this could lead to on the order of 100 terabytes of data per year. This project will investigate methods for how a combination of computer vision, semantic web, database storage and query and workflow methods can be used to extract useful information and make it accessible to non-programming scientists. A typical image from one of the monitored areas is:

This marine monitoring scenario is an application framework that motivates and unifies the scientific research of this project, and which will supply the data for evaluation of that research. Complicating the issue is the 3000 different species of fish that have been observed in the area [83]. However, the core goal of the project is to investigate research issues, in particular, into knowledge and data representation, database indexing, flexible data processing workflow architectures, computer vision based video analysis and query answering. The real issue underlying the project is how to extract useful scientific information from the enormous amount of data provided by the video cameras, and, in fact, see if this enormous amount of data can actually allow marine scientists to answer new sorts of scientific questions. This point is made eloquently in the recent electronic book "The Fourth Paradigm: Data-Intensive Scientific Discovery", Tony Hey, Stewart Tansley, and Kristin Tolle (Eds), online at `http://research.microsoft.com/fourthparadigm`, 2009. The book argues that the next wave of scientific development will be data-driven, as contrasted with observation, theory or simulation driven, and new tools are needed to enable this new wave. While we are not addressing this big issue in general, we are investigating tools that turn raw data into analysable, conceptual units that can be accessed flexibly through a knowledge-driven user interface and efficiently using high-performance computing resources. And the goal is to provide this without requiring the target user scientist (marine biologists here) to also be a programmer.

The particular questions that will be investigated are:

- What are the appropriate forms of ontologies and vocabularies that:
  - describe organisms like the observed fish, their behaviours, the environmental conditions seen in the videos?
  - allow formulation of the questions that the marine biologists are interested in?
  - describe the video data itself?
  - describe the computer algorithm capabilities and processing resources available for use when question answering?

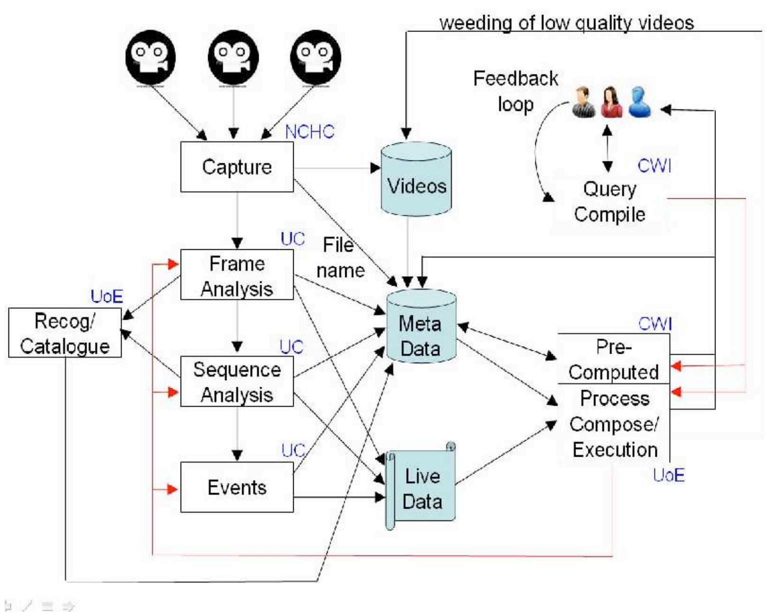
  These ontologies and vocabularies include both computer and human-level descriptions, and are the primary mechanism to ensure that the different project components can interface with a consistent understanding.
- What storage representations allow for:
  - Massive reduction in stored data (*e.g.* only record the extracted fish and a background frame, or perhaps only a description of each fish and a single view of it)?
  - Efficient indexing to fish images and segments within the videos?
  - Effective re-analysis of previously acquired video data to answer new scientific queries?
- What computer vision methods are most effective for describing fish shape, appearance, movement and behaviour? What descriptions are computable for the environmental conditions seen in the videos? What machine learning methods are beneficial for discovering optimal fish detection and categorisation.
- What are the most effective methods for accessing information previously extracted from the videos, combining user text-based query terms, computer vision based descriptions and a semantic ontology linking the two? How can the user generated queries be used to compile new workflow sequences for extracting new information from the video data? Does user feedback during database retrieval provide a benefit here?
- What computer processing structures will allow continuous capture, analysis and storage of the video data without a backlog of unanalysed videos? How might irrelevant information be removed and redundancy reduced to make the recorded data tractable in size, and enable the possibility of increased numbers of cameras in the future?
- How can the processing components be organised to allow flexible real-time reconfiguration of the processing workflow, as users formulate new scientific questions? How can new scientific questions be quickly translated into new processing workflows that extract the answers to the questions in a manner that does not require the user to be a scientific programmer? How can processing resources be redeployed between processing of live *versus* pre-stored data processing?

- Which sorts of queries are most effectively answered, such as fish and behaviour identification or counting? How generally can we allow users to frame queries, *e.g.* using some sort of a logical specification query language? What are the types of query primitives that can be computed accurately?

To help answer the scientific questions listed above, we will undertake research into: 1) computer vision methods (for fish detection, species identification and behaviour recognition), 2) ontology driven semantic user interfaces (to allow non-programming biologist users to specify queries about the video content), 3) ontology and planning driven automatic workflow construction (for on-line automatic construction of computational sequences that answer the biological questions) and 4) computer hardware and software architecture organisations that can acquire and process the massive amount of video data efficiently. We will integrate the individual research components into a publically usable demonstration system. This system will allow a marine biologist to formulate a query in his/her vocabulary (by the semantic interface), which will be translated into a sequence of image processing and database access operations (by the workflow compiler), which are then executed using the database host and query execution machine.

One novel aspect of this project is the location where the data analysis will take place. In the past, scientists downloaded the datasets or bought copies on CDs/DVDs. With up to 10^{12} pieces of data, this is now impossible for most projects. Even with new 1T portable disks, these databases would require dozens, if not hundreds of drives. So, instead, this project takes the scientist's questions to the data. In this case, this means the use of an intelligent web-based user interface, which leads to queries over the database, executed on a HPC computing system co-located with the data.

A schematic architecture for the integrated project and system can be seen here:



At the centre of the diagram are the three data repositories to be developed and hosted by NCHC: a repository of previously recorded video data in a computationally compressed format, a metadata repository of RDF triples recording previously extracted information from the videos, plus an XML database of the videos and associated summaries. The content producers for these repositories are shown at the left side, where image data is captured from multiple cameras, fish are detected and tracked in the video (which will require coping with potential problems like: murky water, algae on the lens, moving background plants and changing lighting conditions). From the tracked fish, the project will develop processes for recognising fish species and distribution, and for inferring interactions between individual fish. The video data could be live or previously captured, depending on the user requests. Partners UCATANIA and UEDIN will be responsible for the image and video analysis research. At the right of the diagram are mainly the user response processes. A marine biologist will be able to phrase a broad range of fish-related queries in a reasonably natural way, with the domain ontologies providing re-interpretation into the system's vocabulary. The queries will lead to either previously computed results being extracted from the RDF metadata store, or new results being computed (which could involve a mixture of processing video data - either previously captured or live - and previously extracted information). The new results will be generated by workflows compiled 'on-the-spot' from the user query and image processing knowledge, using a set of domain, user, fish and capability ontologies. Partners CWI and UEDIN are responsible for the query, planning and workflow construction processes. The workflows would then be executed on a flexible architecture, which may involve more that one processor (NCHC is responsible for this).

An important workflow component is the database query engine. For this project, we do not anticipate undertaking any research into high-performance database query. Because of the quantity of the data, we are planning for a distributed database and distributed subqueries over that data. However, at the moment, we propose to use multiple distributed instances of standard query engines, *i.e.* SPARQL for the RDF component, XQuery for the XML component.

As part of the project, we will develop a public web-accessable database of the videos and their associated computed descriptors (*e.g.* XML and RDF). We will develop a web interface that will allow users anywhere to access live or previously stored videos or compose queries about the previously stored data. Extensive performance experiments will be performed to provide statistics on the accuracy, ease and speed of retrieval of information from the database.

Given a successful outcome, as well as producing new research results, we will demonstrate a potential environmental analysis tool suitable for answering questions like:

- What species and numbers of fish appeared in the last N days?
- What unrecognised fish were detected? Do they cluster by appearance?
- Show me examples of fish from species X?
- Show me examples of a fish with description X?
- What other species were also present when species X was seen?
- Are the observed numbers of species X increasing in the past 3 years?

While the focus of the project is based on very specific marine eco-system video data and environmental study tasks, this has been selected as a particular use case to demonstrate the more general techniques being developed within the project. The strength of the project is not only in going beyond the state of the art in the expertises of the different partners, but in combining their strengths to form an end-to-end solution – a thin bridge over the semantic gap. As a whole, the research undertaken here is partially applicable to other video-based monitoring applications, *e.g.* video-based monitoring of the behaviour of farm and wild land-based animals, people in shops, secure area surveillance, etc. Furthermore, several of the core technologies being investigated and developed here should have wider applicability, such as the knowledge driven expert query interfaces, computational workflow compilation from user task ontologies, hierarchical object recognition, target detection and tracking in unfavourable image data, automatic workflow distribution over multiple processors. While we do not expect that the project results will generalise directly, it is at least clear that the technologies listed just above address research issues encountered in other applications.

Objectives

Overall, the measurable objectives of the project are:

1. Development of methods for detecting targets in noisy environments.
2. Development of methods for characterising interactions between the targets.
3. Development of methods for recognising fish species by integrating multiple 2D perspectively distorted views over time.
4. Development of methods for exploiting ontologies to interpret user queries.
5. Development of methods for exploiting ontologies to convert queries into workflow sequences.
6. Development of methods for storing and accessing massive amounts of video and RDF data in a timely manner.
7. Integration of the research in a publically usable web tool.
8. Creation of a fish database suitable for behavioural and environmental studies.
9. Training of staff in cross-disciplinary methods (computer vision with database and workflow scientists, computer scientists with biologists).

These objectives directly address the issues raised in the "Intelligent Information Management" call, in that we will:

- develop methods based on **ontologies and semantic web** concepts for allowing users access to massive datasets.
- develop processes for handling **massive** video datasets of the size of 10 cameras * 2 years * 365 days * 12 hours/day * 3600 seconds/hour * 10 frames/second = approximately $3 * 10^9$ frames or $3 * 10^{14}$ bytes of raw compressed video data, leading to an estimated $10^{11} - 10^{12}$ RDF triples or pieces of information
- methods to **answer queries** about the estimated 10^{10} fish seen in these frames.
- develop methods to allow **access to this information by non-programming specialists**, with an interface that makes efficient use of the marine biologist's time.
- work with marine biologists to produce **useful answers to biological questions**.
- build a **working prototype** approximately 2/3's of the way through the project, so the final 1/3 of the project can be used for evaluation and developing additional query answering capabilities tailored to questions raised by the marine biologists. This time will also be used to improve web accessability to the data and speed of query answering.

1.2 Progress beyond state-of-the-art

State of the Art on Video-based Object Tracking and Recognition (WP1)

Video Target Detection: Object detection, tracking and recognition are important tasks for machine vision systems. Although many applications have been proposed over the last twenty years, application in uncontrolled conditions, *i.e.* in real-life systems, remains a challenge. Factors causing problems include: sudden light changes, objects that become motionless, large motion relative to the camera, low image constrast, etc. Moreover, time performance must be taken into account.

Since fish detection and tracking is complicated by the variability of the undersea environment, a brief description of the methods we are considering using is listed below. Elhabian *et al* [27] and Porikli [70] divided algorithms for object motion modeling in complex scenes into two groups, based on how the background/foreground (object of interest) is modeled: 1) recursive techniques, [26], [33], [88] that adaptively update either a single or multiple background model(s) based on each input frame at the current time and 2) non-recursive techniques [29], [43], [92], [26] which use a buffer of the previous N video frames for estimating the background image according to the temporal variation of each pixel within the buffer. Fish tracking will face problems of frequent shape changes, inter-fish occlusions and background object-based occlusions. Given the quantity of data and the multiple streams, the fish tracking module must be efficient, reactive to adjust the model to changes of the fish's appearance and robust to occlusions.

Approaches to object tracking in real-time can be classified according to Porikli [70], into: 1) methods that construct the probability density function of object location, *e.g.* Li *et al* in [50] tracked objects in low frame rate videos by coupling a temporal probabilistic combination of discriminative observers with particle filters or mean-shift based methods, such as in Peng *et al* [67] where objects are tracked by a non-parametric density gradient estimator iteratively executed in local search kernels, 2) particle filtering methods, *e.g.* [72] and [54], which are the most popular tracking methods, 3) appearance models, *e.g.* Xu and Puig [99] tracked multiple objects in dynamic and cluttered visual scenes by a hybrid blob-and appearance-based analysis framework, 4) histogram matching based algorithms, *e.g.* Kazuyuki *et al* [44] proposed a hybrid tracking algorithm, including an adaptive feedback loop, based on the statistics of colour histogram models, 5) covariance matrix representation methods robust against noise and sudden lighting changes. A relevant work is proposed by Ross *et al* in [75] where a robust tracker adapts the appearance model online of the target objects, while tracking, to reflect the appearance model changes by using a covariance matrix.

Marine Video Analysis Systems: Understanding fish underwater behaviour in unconstrained environments is important to marine biology. Currently most monitoring is done by human observers, which is tedious because of both rare events and events with many objects. Therefore, automatic systems for detection, tracking, counting and classifying are strongly desired. Image analysis of fish has largely been driven by commercial fish acquaculture, with the goal of non-intrusive estimation of fish numbers and sizes in fishery cages. Vision based systems have been used for different purposes to provide useful feedback for the study of behavioural, locomotion and under different environmental variations. Most research in the last fifteen years has dealt with underwater videos taken in controlled environments or in labs, *e.g.* a fish tank with fixed lighting, cameras, background, fixed objects in the water, known types of fish, known number of fish, etc.

Morais *et al* [60] proposed a system, based on Bayesian filtering techniques, to detect and count fish in a fish tank with fixed number of fish and in a controlled lab, reporting an 81% of success rate. Petrell *et al* [69] and Ruff *et al* [77] proposed video-based systems to measure fish number and average fish size with images taken in bordered cages. Evans [28] detected and counted isolated Southern Bluefin tuna in cages. Fish4Knowledge partners Spampinato *et al.* have previous results [87] with detecting and counting live fish free swimming in an unconstrained ocean environment through use of a video change detection algorithm. Zhou and Clark [104] tracked individual Large Mouth Bass through multiple frames while simultaneously estimating their 3D position and orientation. Walther *et al* [97] developed an automatic machine vision system for animal detection and tracking by using high-resolution video equipment on board an ROV. Di Gesu *et al* [22] detected and tracked starfish in an underwater video sequence, by using a Bayesian network for fish classification based on geometric and morphologic features and the tracking was carried out by matching grey-level textures. Hariharakrishnan and Schonfeld [36] proposed a tracking system based on the prediction of object contour by analysing motion vector information. Naiberg *et al* [63] used stereo to correct for distance scaling, using edge detection and then head/tail feature extraction as applied to caged Pacific sea salmon, where a plain backdrop was added in the cage. Tillett *et al* [91] also used a 3D model fitted to edges extracted from stereo images, to estimate the true sizes. Iqbal *et al* [40] developed an enhancement system based on constrast stretching for solving lighting problems or clarity of water problems. Soori and Arshard [86] identified groups of fish by using Lagrangian particle dynamics derived from fluid mechanics. Crowd flow analysis can be used to analyse fish schooling characteristics, where the school dynamics allows researchers to study fish locomotion, perception and behaviour. Clausen *et al* [17] observed denser groups of caged sea salmon, with the goal of size estimation, using a fitted variational shape model fitted to image edges. It accurately extracted the shape of overlapping fish, but only a few fish were detected when many fish are present and overlapping.

Several projects have addressed discrimination between different fish species. Strachan *et al* [89] achieved 98% correct species recognition of 6 species when viewed flat from above on a conveyor belt. Some species were quite similar *e.g.* plaice, sole and lemon sole. Nagashima *et al* [62] used the fish side speckle patterns to discriminate between mackerel, horse mackerel and pilchard, achieving about 90% on a small database of dead fish. Larsen *et al* [46] classified three similar species (cod, haddock, and whiting) with a 76% classification rate using active appearance models on about 100 dead fish seen from the side. Mokhtarian and Abbasi [59] recognised marine animals, including fish, using a representation based on boundary curvature at multiple scales, from a database containing more than 1000 images. The affine invariant version of their method might supply important boundary shape cues. Benson *et al* [11] developed a computer vision for counting and classifying fish in underwater video images by using a classification method known as Haar classification. In detail they applied the method for the classification of the Scythe Butterfly fish with a performance rate of 89% on a database with about 3500 images for the training and 100 images for the test. Rova *et al* [76] developed an automatic system for classfying two kinds of fish: (a) Striped Trumpeter (b) Western Butterfish. The system is based on the 2D textural appearance in underwater video and reached an accuracy of 90% in a database consisting of 320 images.

Analysis of underwater videos have been carried out for several other purposes such as interesting event detection. Relevant works are the ones developed at the Monterey Bay Aquarium Research Institute (MBARI). Edgington *et al* [25] proposed a system where events are identified by using a model for saliency-based attention in humans., where interesting events are then tracked. Cline [18] developed on a neuromorphic vision approach for ocean event detection. Edgington and Cline *et al* [24] implemented a complete system for detection, tracking and classification of underwater benthic animals. The system was tested on a database with 6000 frames and 200 events with an accuracy of 81.4% in the event detection and 90% in the classification of the Rathbunaster californicus.

Deformable 2D Object Recognition: One key problem addressed in this project is the recognition of fish species. There is a long history of 2D and 3D object recognition in the field of image analysis and computer vision, but here the focus is mostly on recognition of 2D shapes as seen in a 3D context. This is because fish normally swim upright and have a streamlined shape, hence the 2D approximation is appropriate. However, as the fish can have arbitrary position and orientation relative to the camera and usually are some distance from the camera, an affine projection model is probably most useful. Affine invariants are particularly appealing in this context, having the key advantage that these values can be independent of the object's position, orientation, scale and slant. A final point is that, although the goal is to recognise different species, which is a categorisation problem, here all categories are generally quite similar in shape. So, we plan to use a combination of boundary and interior properties to discriminate between different classes. This is in contrast to much image categorisation research [20] that recognises more broadly distinctive classes.

There are three main approaches to 2D affine object recognition: 1) from the boundary, 2) from invariant moments calculated from the interior of the shape and 3) from matching colour and texture of the interior of the shape. Boundary matching assumes that the shape of a category (*i.e.* fish species) is unique to the species and does not vary much between individuals. One approach is to compute and match boundary descriptors, such as semi-differential invariants [68], local projective invariants [74], affine semi-local invariants [80], and more aggregated global shape summaries [105] including Fourier based descriptors [57]. A second approach to boundary matching assumes that there is a deformable transformation between the target boundaries, an assumption that is useful for when there is variation within a species. Yuille *et al* [102] investigated an efficient search-based algorithm and Markovsky *et al* [56] proposed a deformable boundary matching algorithm.

Moment-based algorithms are useful because they are summary properties of the full shape interior, are compact and, with enough moments, allow shape reconstruction. Dirilten and Newman [23] introduced 2 moments suitable for discrimination between aircraft silhouettes. Flusser and Suk [32] extended the set to a family of affine invariant moments, and later to include colour information in the invariants [90].

The final approach reviewed here concerns methods that use the interior of the shape for the matching. For small local shapes, local template matching has been used [71]. If the objects have a natural subcomponent part hierarchy (*e.g.* as in the human body), then a combination of local shape matching of the parts and then matching of the relationships between the parts can be done [10, 9]. UEDIN has experience with 3D class-based recognition and categorisation [14]. It is unclear if the fish have a sufficiently rich subcomponent hierarchy to benefit from these approaches. One useful approach is to exploit the colour and texture properties of the region inside the boundary [49], which could also be transformed into local grey-level invariants before being aggregated. A more literal matching approach uses a triangulated decomposition of the region interior [30, 82] and then applies a deformable matching between the triangles, to effectively template match the shapes.

A particularly interesting approach is the active appearance model [19], which combines an eigendecomposition of the normal modes of variation of both the boundary and the interior intensity patterns. In this approach, both the boundary shape and interior appearance can then be described compactly using the weighting coefficients of the decomposition, and may provide a sufficiently discriminating description between major groups of fish shapes, as well as individual species within the groups.

Content Based Multimedia Retrieval: Many intelligent multimedia retrieval systems have been proposed recently for different applications, *e.g.* sport, medicine, law, etc. Indeed, a huge amount of multimedia data is available because of progress in data capture, storage and network technology. This explosion of multimedia data has created the need for efficient organisation, browsing and retrieval tools. One important approach is Content-Based Multimedia Retrieval (*CBMR*). CBMR has gained a degree of success, and many CBMR systems have been built, for example, Virage [7], MARS [15] and iMedia [78], especially for sport applications, such as for soccer [48], basketball [64] or baseball [65]. A recent approach by Zhang *et al* [103] retrieves personalised sports video by integrating semantic annotation and user preference acquisition. The semantic annotation is made automatically by segmenting web-casting texts retrieved from a sports video database. The sport videos are then retrieved by semantic attributes according to user preference.

No specific multimedia retrieval systems have been developed for underwater applications. In fact, underwater applications would need reliable video analysis system able to handle low quality (contrast) images, unconstrained environments, interactions among fish, crowd scenes and multiple occlusions. Some CBMR has been tested on underwater video sequences such as in [52]. CBMRs have been developed for video and image retrieval in real-life for humans such as in [39], [73].

A key question that we propose to investigate is how to reduce the semantic gap between user and data descriptions, which is essential for effective CBMR. User perceptual features play a crucial role in reducing this gap. Yadav and Aygun [100] helped users search for clips and videos of interest in video databases by providing an intelligent query structuring system (*I-Quest*) to rank clips based on user browsing feedback. Relevance Feedback (RF) technology has been widely applied to bridge the semantic gap as in [84, 51, 79]. Shi *et al* [84] proposed a content-based multimedia retrieval integrating a supervised clustering approach with a relevance feedback mechanism. Koskela *et al* [45] investigated image retrieval through estimating the probability density function of a semantic concept using kernel density estimation.

State of the Art on Interactive Query Interfaces (WP2)

Within the video analysis community, different styles of interface have been developed to search within video repositories, *e.g.* those developed in MediaMill [85], in FacetBrowser [95] and for the Fischlar Digital Video Library [47]. While these systems use the metadata extracted from the content to drive the search engine, it tends not to be displayed at the interface for interaction by the end-user.

While systems exist for displaying images and their associated metadata to an end-user [98, 81], few interfaces using a combination of visual data plus metadata have been designed to support a specific high-level information seeking user task. Among the exceptions is work done on interviewing cultural heritage experts about the information seeking tasks they carry out. Amin et al. [1] found that information gathering was an important type of task that was inadequately served by current tools. Follow-up work selected one specific task, that of comparing sets of objects, and designed a prototype interface on top of linked data sets used by the experts to support this task explicitly [3].

Experiences from this and other [38] work has shown that it is difficult to design new interfaces that have the potential of supporting user tasks at a higher level. Firstly, one needs to understand the underlying tasks experts are attempting to carry out with the, potentially inadequate, technology available to them. For example, an information comparison task such as "Compare collections of artworks by female artists from before and after the 1960s." requires selecting different sets of artworks that the user can then compare. This two-stage task tends not to be supported in current applications, which tend to allow the selection of a single set of artworks, and provide no means of comparing the selected sets [3]. Secondly, one needs to design an interface that supports the underlying higher level tasks, without moving so far from the design of the current tools, that users are unable to use them.

In the Semantic Web community, different interfaces have been developed to support different phases of the retrieval process (namely query formulation, search algorithm and result presentation) [37]. From these and other [38] systems, generic interface building blocks that support specific subtasks can be identified. Facet browsing [101, 95], allowing the selection of sets of objects based on their properties, is an example of an interface building block. Other examples are based around the notions of "who", "what", "where" and "when", since these are familiar concepts that occur in different domains. "Where" and "when" have intrinsic spatial and temporal dimensions, making them amenable to presentation, *e.g.* of thumbnail images, or on maps and timelines, now common-place interface components [81]. For other terms that are related through taxonomies or thesauri, no single interface is appropriate for displaying them to end-users. Studies with cultural heritage experts showed that not only do experts have different reasons for searching in terms [38] but that the different structures of the different vocabularies require different presentations [38, 2].

These interface components that are related to the vocabulary used to link terms, but other techniques can also be used. Autocompletion is a technique that can be used in a semantic setting. For example, autocompletion allows experts to select terms from an existing large vocabulary without having to browse through a hierarchy of the complete set of terms [38]. While autocompletion was intended as support for finding a term to use for annotation, the interface was sufficiently flexible to also allow users to establish whether or not a specific term was already present in the thesaurus.

In the context of the cultural heritage work, after investigation of high-level user tasks, and the appropriateness of the data available, a user interface for comparison search was designed, prototyped and evaluated [3]. Here, an expert user is able to select sets of cultural heritage artifacts (visualised as thumbnail images) and then compare their properties[1].

The research into the interactive query interface proposed for this project will go beyond the state of the art in several ways. Many of the interface components described in the studies above were developed in the context of the cultural heritage domain. Investigating their appropriateness to the domain of marine ecology will contribute to understanding to what extent they can be re-used in other domains, *i.e.* whether the structure of the underlying domain vocabulary can be used to select specific interface components or presentation criteria.

The most complex high-level task investigated in the cultural heritage studies was the design of an interface for comparison search. The query interface is based on the selection of properties and does not, for example, allow the declaration of properties that members of a set should not have. While query languages are able to express this, design effort and interaction with users is needed to incorporate such functionality in an interactive interface, suitable for use by domain experts, without making it overly complex.

The information required to answer a specific user question may require input from different sources in the system, *e.g.* video data, species characteristics and video analysis to identify

[1] `http://e-culture.multimedian.nl/lisa/session/compsearch/tutorial`

individuals. Interaction methods and visual languages will be developed that combine results from visual data queries with those from queries on terms from the expert vocabularies, *e.g.* species taxonomies and their relations with shape properties. Methods for expressing where the information is derived in the system, the provenance, will be developed.

State of the Art on Novel Process Composition, Execution and Learning (WP3)

Process and workflow technologies have long been recognised as powerful tools in the commercial and manufacturing sectors. It is valued for its explicit abilities to describe a complex domain, specify standard operation procedures to streamline work practice, enable detailed analysis to assure quality and enhance performance, and to provide a reliable foundation for automation to increase processing efficiency and effectiveness.

However, there is a gap between the process modelling and the workflow communities. The process modelling community, *e.g.* Petri Net [34] and Pi-Calculus [58], often concentrate on process model construction, the verification and validation of models and running simulations of these models using hypothetical scenarios. On the other hand, the workflow community is more interested in the efficiency and effectiveness of workflow performance and practicalities in solving real-world operations and do not necessarily worry about how to keep the corresponding process model up-to-date or its theoretical properties.

As process models are often described at a higher level of abstraction, once they are to be automated and execution details need to be instantiated, one often finds that they are not sufficient detailed to include all important aspects to fully support automation. As a result, there are often discrepancies between the initial process model and the workflow system. In addition, as there is often no direct and automated synchronisation between the process model and the workflow system, once the workflow system is in operation, it often evolves according to new requirements, eventually rending the process model obsolete. Workflow systems can become very complex over time and difficult to understand to accommodate new modifications, with the design rationale and principles lost in the process. [31]

Traditional workflow systems have several drawbacks, *e.g.* in their inabilities to rapidly react to changes, to support diversified customisable and personalisable process design and workflow execution, to construct workflow automatically (or with user involvement), to improve performance autonomously (or with user involvement) in an incremental manner according to specified goals. To address some of these problems, recent approaches such as BPEL [8] and Taverna [66] separating the process and workflow execution logic. This resolves the rigidness of workflow systems by allowing the automatic change of workflow execution by changing its process logic. However, such approaches are designed mainly to support web services and do not provide an intuitive overview of workflow systems. It is also unclear as to what execution methods are used and how to deal with failure recovery. Triana and Kepler [55, 53] provide a good workflow overview, but are not designed to support 'user-oriented' browsing for producing sets of co-existing customisable (sometimes with conflicted interests) workflows, *e.g.* based on the user's own vocabularies for requirements and goals. There is also no separation of process and workflow logic, nor the provision of automated support in constructing workflows. Pegasus [42] makes use of planning technologies to create a valid plan. It provides automated support for process model construction. When collaborating with Condor DAG, it also provides a separation between process and workflow logic which enables workflow execution. However, it relies on batched workflow execution and does not (easily) support real-time alternative execution routes. It does not allow loop execution which is often required in our intended application context.

None of these recent approaches address all of the above stated problems. In this project, we wish to learn from these techniques and address such problems as far as possible. By using a combination of process model and workflow techniques, we wish to use process models to provide a direct command and control of the workflow system, thereby separate the process and execution logic; while providing the flexibility of the workflow in reaction to changes and maintaining the quality of the process model and the corresponding workflow system. We wish to use ontological based approaches. Therefore, by enhancing the user, technical and application domain knowledge of the workflow system, it can easier accommodate user requirements and provide more suitable workflow system for them. We also plan to develop a knowledge-based planner that communicates with the underlying ontologies and process libraries, so that our workflow system supports automated process composition and workflow execution. It will also take stock of past experiences, so that its performance can be improved incrementally over time, autonomously or with user feedback.

Parallel Data Flow and Storage Realisation (WP4)

The key to real time knowledge discovery from live coral reef ecosystem monitoring using undersea video cameras [93] is handling the enormous amount of either live or legacy data in a timely manner. This is truly a data-centric problem [16]. In the past, most monitoring systems were based on proprietary solutions, which did not allow flexible data exploration and exploitation. In the past decade an open, geographically distributed ICT architecture emerged in the high performance computing community, namely Grids. It allow dynamic composition of ICT resources to form a networked infrastructure, also called a Cyberinfrastructure (CI) [5]. Most initial developments aimed at how to harvest compute cycles from geographically distributed, but networked, supercomputers. Later developments included instrumentation and observatory networks.

Large-scale long term sensor-based observing systems capable of measuring environmental variables in an in-situ fashion and at unprecedented temporal and spatial granularities are being deployed worldwide. They are bringing resources (computers, data storage facilities, equipment for experiments or observations) to researchers, and eliminating distance as a roadblock to usage. Computational and data grid technologies have been built for high-profile scientific studies, such as human genome, drug discovery or the search for fundamental particles. These systems are capable of delivering teraflops of compute cycles and petabytes of storage space. However, how to develop grid technologies to incorporate observation networks with the required performance still remains as a research challenge. In this project, we will adopt the grid-based approach and follow our previous success in building undersea observatory networks to develop a high performance execution architecture to meet the data and processing challenges.

Advances in High Performance Computing hardware can be tracked via the Top 500 every 6 months [6]. The July 2009 report revealed that Intel dominates the high end processor market with 87.7% of quadcore based systems. However, multi-core clusters consume more energy than traditional supercomputers [21]. The energy efficiency issue will drive a new way for multi-core gradually migrating to many core. Another trend is the use of GPUs for repetitive computations, with most results claiming a 10-100 fold decrease in run-times. The current biggest challenges in advancing HPC hardware are how to scale up memory bandwidth and multi-chip 3D packaging. The software challenge is as crucial, which enables optimal use of the designed hardware. The current paradigm advocates parallelism at all levels, including at the compiler code generation level for optimal execution ordering, functional parallelism within a processing node (*e.g.* SMP Threads), and data and task parallelism across nodes (*e.g.* MPI Tasks). Workload balance and synchronisation are the key issues at the application level. Tools, such as Vampire [96], can help analyse where bottlenecks lie. These trends suggest the directions that Fish4Knowledge will take. 1) High performance multi-core processors at the observatory level do the first filtering and bulk compression of the raw video data before transmission across the network. 2) Data and task level parallelism on cluster machines will be used to analyse the video to produce the RDF/XML store content, and execute the query filtering steps that extract content from the RDF/XML store.

Anticipated State-of-Art on Completion

A successful project should result in these scientific advances:

- Methods for reliable detection of marine animals in spite of a cluttered and noisy undersea environment, with changing lighting conditions. Some of the methods developed here may also have applicability to land-based surveillance and monitoring.
- A learning-based method for making subtle class-based recognition amongst objects that do not vary much, especially as one reaches the terminal nodes in the fish species classification hierarchy used here (which may have up to 3000 different species).
- Methods for compilation of effective workflow sequences from user specifications, using knowledge of the domain, user requirements and component capabilities.
- Methods for automatic allocation of multiple components from the workflow to task parallel and pipelined processors and filestores on a HPC architecture to allow fast database search and query answering.
- Methods for allowing domain experts to specify sophisticated data queries without requiring sophisticated programming skills.
- A huge database, *e.g.* 10^{12} observed facts about the fish over two years of observation.
- Parallel methods for efficient storage and retrieval from that database.
- A data collection and query tool specialised for marine biology species identification, inventory and behaviour analysis.

1.3 Scientific/technical methodology and associated workplan

Overall Strategy

The overview of the technical approach to the workplan was presented in Section 1.1, pages 6-7. In terms of the timing, the core elements of the strategy for year 1 is: 1) define the interfaces between components (WP3) and the structure of the video/RDF/XML (WP4) stores at the start of the project, 2) interview marine biologists about their 20 top questions (WP2), 3) start acquiring and storing data (WP4) with a fish detection algorithm that allows greatly reduced data volume (WP1). The main scientific development is planned to finish at the end of year 2, including 1) user interfaces that allow biologists to formulate a variety of questions (WP2), 2) fish tracking, description and recognition algorithms (WP1), 3) a workflow compilation process (WP3) that orders and sets parameters for WP1 components to answer the biologist's question, and 4) algorithms for distributing the workflow across machines (WP4) to obtain results quickly. Year 3 is dedicated to system integration and testing (WP5), evaluation involving the marine biologists (WP5,WP6) and enhancement of the system's capabilities and performance (WP1-4).

WP1: Fish detection, tracking and recognition

The aim of workpackage WP1 is fish/marine animal detection, tracking and recognition. Fish/marine animal detection and tracking will involve three main steps: 1) background modeling; 2) fish occlusion management; 3) fish tracking across consecutive frames.

For background modeling and fish detection, recursive approaches will be investigated, since off-line processing algorithms for background modeling (appearance models) may be too slow. The recursive method should handle background movements, environmental variations, *e.g.* changes in illumination and in water quality. Therefore, to make the system fully automatic an adaptive background modeling method based on statistical assumptions will be required. To both reduce the processing time and make the system robust a pre-processing system that roughly identifies potentially interesting objects based on low-level spatial properties will be integrated. We propose to investigate the use of relevance feedback (RF) methods where feedback samples represent objects. The feature distribution of feedback objects will be used to refine the pre-processing system during system tuning.

After fish detection, an occlusion management system must be investigated. We propose to explore two levels of occlusion management: 1) intraframe level where spatial features, geometric and colour features will be used and, 2) interframe level, where clustering of motion vectors will be analysed. Finally, in the tracking phase (described below), reasoning algorithms to handle full or background/fish occlusions will be investigated. Given the environment variability and the movement of the fish in an unconstrained environment, the tracking module must rely on several features: texture, colour, motion, edges of the detected fish. For this reason the tracking algorithm will be based on covariance matrix representation methods that, as outlined in [70], integrate both spatial and statistical properties of objects keeping track of object erratic and fast motions. Incremental learning algorithms, based on covariance matrix representations that adapt the appearance of the models while tracking progresses, will be investigated. The previous methods will be compared with methods based on multi-kernel probability density function of object location, since they are computationally simple, compatible with real-time and low frame rate video applications. Once a fish is correctly detected and tracked, it must be described. Spatial and statistical features, curvature scale space (CSS) transforms, edge evolution and other properties will be used for fish description. In particular, the CSS transform will allow us to select the best views of a fish to be passed to the recognition step. Finally, we aim to detect movements of groups of fish by exploring particle dynamics theories, in order to identify and analyse trajectories of individual fish in a group.

One component of WP1 is fish species recognition (individual fish recognition is felt to be too hard). Three important steps are required for this process, assuming that the fish have been already detected and segmented from the background: 1) find (or synthesise) the best view of a fish, 2) extract properties useful for recognition and 3) do ontology-based recognition. Step 1 has not been tried before for much other than face recognition from video, however, fish shapes are very different and considerably more varied from heads. We propose to exploit the multiple tracked views of the same fish to identify the largest (therefore most detailed), most orthogonal view of a fish, from which properties will be extracted for recognition. There are a variety of properties to be addressed: boundary shape, colour distributions, special colour features, special boundary features. Custom algorithms will be developed for these, some based on eigendecomposition of boundaries and interiors [19], some based on looking for particular features like colour patches or elongated fins, etc. Fish species will be organised into shape and species hierarchies, so that, even if particular species cannot be identified, more general categories such as genus or families can be identified. The properties extracted above will be used in a mixed probabilistic (general properties) and discrete (special case) recognition algorithm. As about 3000 fish species have been identified in the marine areas being observed, a particularly interesting issue is how deeply down the shape and species hierarchies is it possible for the algorithm to go while still maintaining good performance.

WP1 also investigates methods to cluster fish that are not recognised under the given shape and species hierarchies, which will provide marine biologists a tool for identifying rare observations. The main novelties of this WP component are: recognition of classes with subtle differences (unlike most current class-based recognition), and recognition of moving, deforming, largely 2D, objects under uncontrolled 3D motion. The likely difficulty is identifying small clusters from within a large background of incorrectly rejected known fish, so we propose to initially investigate the use of kernel clustering methods.

UCATANIA will be primarily responsible for the fish detection, tracking and description and video query. UEDIN is primarily responsible for the fish recognition and clustering.

WP2: Interactive User Query Interface

The aim of WP2 is to develop interactive user interfaces that support marine biologists in undertaking complex information analysis tasks, allowing them to explore queries such as "what are the trends in the abundance of species X in the last 3 months", while taking the confidence levels of the feature extraction into account. The WP is divided into different phases: user task identification, prototype interface development and evaluation, advanced user interface development and evaluation, and integration of the interface into the system.

Initially interviews will be carried out with users to establish the information needs for the research they are carrying out and what tools and technologies they currently use. This work will be carried out in close cooperation with WP3. Having identified users' high-level needs, these will be compared with the feature extraction possible to determine which information can be incorporated in a suite of prototype interfaces.

The expectation is that existing components of user interfaces developed for exploring heterogeneous (semantic web) data sets will be useful in fulfilling some of the needs of the users. For example, techniques for autocompletion of terms from pre-defined vocabularies, such as those being developed in WP3. Other examples include time-based visualisations of the data to interpret trends at different temporal scales, or the visual exploration of species-specific properties to allow expert assessment of the reliability of feature detectors.

Interactive mockups of potential functional support will be evaluated with users to determine the utility of the different components and also to allow users to consider other types of high-level support they might find useful. For example, creating several different time-based visualisations and then comparing them. An advanced user interface prototype will be designed on the basis of the evaluations of the component-based prototypes. Given the level of automation in the identification of species by the project, some measure of the confidence level will need to be taken into account. This can be conveyed to end users through search result interfaces that convey provenance and trust levels: by making clear for each result which feature detectors and other software was used to derive the result, and how this was used throughout the workflow. This will require determining types of provenance information users find important and exploring visual/interactive means of making this readily available. Where appropriate, users will be given the option to provide preferences. For example, given the scale of the video data available, it is likely that users will find it useful to specify whether they would like to work with small sets of data as fast as possible, or with larger amounts of data that require longer to process

In cooperation with WP3, user perspectives on the feature analysis results available will be investigated, allowing users to interact with the system to improve correspondences between, *e.g.*, extracted features and domain vocabularies for fish description. This may require the specification of both user and system vocabularies plus a mapping between them. For tasks that require combinations of information from the different (*e.g.* visual and domain) vocabularies, interfaces that allow users to combine visual feature-based queries with term-based queries will be investigated.

For both the component-based prototypes and the advanced prototype, rapid incremental prototyping of a series of interfaces that support the functionality developed in the other technical work packages will be carried out. Every prototype will be made available online ("release soon, release often") and exposed to users for informal testing and fast feedback loops. Results from user experiences with the prototypes will be fed back as requests for improvements in functionality to the other technical WPs. The advanced user interface will be evaluated with users before integrating it into the end-to-end system.

WP3: Novel process composition and execution

The aim of WP3 is to firstly create a rich and flexible workflow framework based on user requirements and then to create a system platform that realises this framework. As this workflow system will used to carry out tasks in a specialised video and image processing domain, it is necessary for the system not only to be sensitive to different user goals and requirements, but it also must possess technical knowledge of the video and image processing (VIP) techniques, so that it can command and control the underlying VIP software modules.

The first task is to understand user requirements. We will engage with our targeted end users and to create end user requirement specifications and obtain sample queries for the workflow system. These user requirements will be used to help the creation of the underlying ontologies that are related to workflow execution and the design of the workflow system itself. In particular, user goals that are relevant to workflow execution and parameters that will be used to communicate with the underlying VIP systems will be defined in several domain ontologies. In parallel, we will be collaborating closely with VIP experts and other relevant scholars in the field to refine and extend our existing technical ontologies. This work is to be coordinated closely with the system user interface specification work described in WP2.

Based on user specifications and domain ontologies, the next step is to create the design of a two layer workflow system: the intelligent and automated process composition layer (based on process model and planning technologies) and the workflow execution layer (based on virtual workflow machine technologies). This will include appropriate mechanisms and considerations to accommodate the evolving and changing user requirements of the system. It will provide mechanisms to record system usage and therefore accommodate different types of needs of the marine biologists. Different types of sample queries and related design issues that are related to computational issues will also be discussed here: *e.g.* is the technology of anytime computing relevant? What types of queries need anytime computing? What types of queries definitely do not need anytime computing? What are the representational issues? What are the challenges and possible solutions to accommodate conflicting user goals and requirements? What are the design issues to promote the flexibility and compatibility of process composition? How to implement the workflow system so that the system is flexible in reaction to changes? How to best record and make use of past experiences, so that the workflow system can learn from them and improve its performance incrementally over time?

We plan to utilise a layer of symbolic based representations to describe process models to separate the process logic and the workflow execution mechanism. These process models are used as a direct input to control workflow systems. This allows us to change the behaviours of a workflow system relatively easily by altering its process model [61]. We plan to create a rich process library for which we will develop a specialised planner to dynamically assess, select and compose an appropriate process model for any given task that is tailored to user goals. This process model will not be used to enact batched workflow. Instead, interactive workflow execution will be designed and used to allow user participation and to choose alternative execution routes, if desirable.

Ultimately, we will develop an intelligent and flexible workflow system based on the user requirements, system design and implementation ambitions. Our initial plan is to develop this system using Prolog with a combination of VIP software modules, but we will make use of other existing systems to assist our work, where appropriate.

We have successfully prototyped some cases of workflow applied to image analysis [87], through collaboration between UEDIN and UCATANIA. PhD student Nadarajan was the central figure in this collaboration and was awarded Google scholar recognition, in part for this work, in both 2008 and 2009. This is extremely encouraging, but that project largely validates the video workflow concept, which now is to be scaled up in this project.

WP4: High Performance Execution Architecture

The underlying project hardware will consist of a number of (*e.g.* 10) undersea cameras linked to local observation stations, generating multiple colour video streams, data networks connecting to the national data infrastructure, storage clusters for the video and extracted facts and geographically distributed computational (GRID) clusters for process composition and execution. Currently, there is an operational prototype, which stores raw video clips with 10 minute clips and provides live video feed. The prototype requires further development to fit the project needs, but will be used as the baseline system. The core issues to be addressed are how to do fast data query and retrieval with Tera-scale coupled repositories for video data and metadata, and how to accelerate the workflow process execution via compute parallelization. In WP4 we will investigate high performance execution architectures that address these issues.

We propose a sustainable and scalable video capture capability that allows adding and removing cameras without disrupting the overall system. This will be addressed at the local observatory level by adding more compute capability to compress in-situ video data and enlarging the storage size for local buffering. A distributed buffering architecture will be investigated for connecting the local and central buffers (at the data service platform), which will be integrated near month 24. The video stream data will be able to migrate from one buffer to another in a transparent manner, which allows smoother streaming and higher availability of the video data. Similar technology will be investigated and implemented as part of the data service platform to provide the video streams that are consumed by the workflow processes.

By month 12, WP1 and WP3 will be generating and accumulating processed video data and video-derived facts. The corresponding RDF triples, XML summaries and processed video data repositories will be built according to the priorities of data generation and consumption. During this phase of development we will work closely with UEDIN, UCATANIA and CWI to match their data use requirements to the repository architecture. This includes the design of the storage datastructures, the interfaces to the data and the data distribution schema. By month 12 the repositories for RDF triples, XML summaries and processed video data will be fully established with the performance of data query and retrieval optimised. To enable to use of the repositories in the transient state before fully integrated into the workflow execution environment, a data service platform will be developed. The workflow computational platform will be developed to provide sufficient compute cycles to process the video data previously collected, as well as new live data. This development is strongly based on the Infrastructure as a Service (IaaS) methodology. The extended baseline system will be online and shared within the group members by the end of month 12.

The next phase of development develops interfaces that allow image and query workflow components to connect to the video and metadata repositories. NCHC will assist with the implementation of workflow components into a distributed pipeline structure. This is an incremental approach first to realise the extended baseline system and then migrate into an intensive co-development as part of WP5. The developed architecture will distribute processes and XML/RDF stores across the infrastructure in a load balanced manner, which will enable parallel queries and parallel processes to run as filters on multiple data streams. We will investigate how to optimise the data I/O between the infrastructure and processes. We will develop 'anytime' processes that run as long as the user allows, and delivers what it has found in the allotted time. As performance bottlenecks cannot always be tackled by adding parallel processes, some code parallelisation will be investigated in months 24-36.

WP5: Integration and Evaluation

Because of the previously untried combination of distributed workflow computations, compiled from user-specified queries, using a knowledge driven interface, as applied to a large database of video-derived facts, the final third of the project time is dedicated to system integration and evaluation. The integration activity will actually start at the beginning of the project, with the formal definition of each of the main project components, and with a fully specified interface between each component. All inter-component data and control flows will be defined. These will be documented on the project wiki, which will ease the problem of maintaining a consistent project view of the interfaces as the technical components evolve. The wiki will also ease the communication between partners.

Shortly after the definition of the components and interfaces, NCHC will start to develop the distributed multi-process architecture framework that will execute the final components; however, in the early months these components will be non-functioning 'black-boxes' that consume resources but produce simulated outputs rather than real ones. This early architecture effort should lead to the architecture being ready as functional components are entered.

The main integration phase is to start about month 24, at which point all of the main components should be ready for integration. Partial integration of the fish detection component will occur as soon as possible so that the raw data storage could start to be reduced and properly managed as early on in the project as possible, and also the back-log of raw video start to be processed. As the fish tracking processes are developed, then these will again be integrated to further reduce the storage and raw data backlog.

To further enable the integration process, all of the datastore RDF/XML structures will be defined early in the project, as will the ontology representation. With these early phase decisions, we believe that some incremental integration can take place, the underlying high performance architecture can be developed and month 24 integration will be smoother.

In parallel, during the first months of the project, the consortium will also develop a detailed scientific question and experiment plan.

The marine biology portion of the scientific evaluation plan will define the:

1. Nameable entities: *e.g.* fish species, environmental objects, fish behaviours, time quanta, measures (like fish sizes, speeds, densities), etc that are relevant to the marine biologists. These are constrained by what the consortium believes is measurable.
2. Ontology of entities, such as the species and shape hierarchies.
3. Nameable operations over the named entities: *e.g.* count, average, rate change over time, satisfying constraint X, etc.
4. An initial sample set of 20 scientific question schemas that a potential marine biologist could ask (such as the sorts of questions posed in Section 1.1).
5. Evaluation criteria to assess how well the scientific questions are being answered. (This may require some hand-coded special purpose programs that answer a single question, perhaps in a more carefully tuned manner.)

As part of this planning, we will enrol a small (*e.g.* 4) group of European and Asian marine biologists who will participate in the project. Their role is two-fold: 1) to help identify the most important scientific questions, in marine biology, that they would like to have the answers to, perhaps tailored to the type of evidence available from the proposed camera locations. 2) to evaluate the system's ability to answer the questions, using the web-based user interface to the database. The marine biologists on the Scientific Advisory Board will help with nominating and recruiting these participants.

The ICT portion of the scientific evaluation plan will define:

1. The performance measures: precision, accuracy, recall, FP/FN rates, speeds and scalability, user interface clarity, etc.
2. The components for which these will be measured: *e.g.* the fish detection, tracking, classification and recognition components, the workflow planning, composition and execution components, the database query search, the usability of the query interface.
3. The test methodology, *e.g.* a set of precaptured videos will have fish detected, tracked and classified by hand to compare against the data and result flows through the system.
4. Evaluation criteria to assess how well the components perform and their achievements compared to previously published results (*e.g.* for the database search).

The evaluation plans in the early project phase will help focus the development and evaluation of the individual components.

The integration and evaluation is expected to occur in 2 phases. The main integration effort will occur about month 24, when all components are to be assembled and then made to work. A first evaluation phase will occur, with the results reported by month 30. The completion of substantial ground-truth test data will be part of this phase. The scientific user volunteers will participate in an estimated day of interaction during this phase.

Depending on the outcome of this first evaluation phase, the project will spend the remaining 6 months improving system performance (*e.g.* improving process speeds or accuracies, increasing the ability to distribute workflow in parallel, enhancing the clarity or accuracy of the queries) or enhancing the capabilities (*e.g.* increasing the richness of the fish descriptions, increasing the number of species identified, increasing the complexity and types of user query conditions and operators, etc). A second execution of the evaluation plan will occur, with the results reported by month 36. The test suites from the first evaluation will be used again, enhanced with additional data. The scientific user volunteers will again participate for an estimated day of interaction during this phase.

WP6: Dissemination

The two most important dissemination activities are the creation of two public web-based interfaces and the collation and publication of the collected data on the web. The first interface will be for scientific use and will allow the marine biologists to ask queries of the video data and receive answers in a suitable form. The main engine for interpreting the queries and generating the results will be workpackages WP1-WP3, and this WP6 will develop a usable GUI on top of the technical components. The second interface is through SecondLife, with the goal of allowing public viewing of the live and stored video data, as well as some of the marine biology exploration capabilities and results (perhaps pre-computed). The target audience is primarily secondary school and young adults.

The consortium will construct a publically accessible database of the acquired data, including some samples of the raw video, a collection of snapshots of the detected fish and an XML/RDF datastore summarising the results of fish detection, tracking and classification. We estimate that there will be on the order of 10^{10} detected fish over 2 years, with an analysis record for each of them. This dataset will be accessible both through the first user interface described above, and also by partial downloading (we estimate on the order of 5 Tbytes of total data). As part of this workpackage, we will investigate methods for recording as much of the useful raw fish image data as possible, in a tradeoff between usability and disk storage. For example, it might be possible to record, in compressed form, cut out snapshots of all detected fish without the background over time, plus just a periodic background image (*e.g.* only once an hour). This would allow a somewhat realistic recreation of the original video, but costing only 1% or less of the original video storage.

The consortium will construct a web-site containing information about the project and partners and a collection of published papers arising from the project. It will also have the links to the interfaces and dataset described above.

Each year we will organise a workshop oriented to one of the project themes, which will be linked to a major international conference. The three proposed themes are visual analysis of marine environments, workflow compilation and knowledge driven user query interface. A fourth workshop will bring marine biologists and computer scientists together.

The scientific user interface will be installed at NCHC, which will be responsible for hosting and maintaining it for at least 3 years after the completion of the project. This should allow for continuous data collection and analysis beyond the end of the project, and the continuation of access to the data by the marine biology community. NCHC will also receive all of the code from the project, and will be free to adapt and extend it.

Work package list

Work Package No	Work Package title	Type of activity	Lead partic No	Lead partic. short name	Person-months	Start m'th	End m'th
WP1	Video Data Analysis	RTD	3	UCATANIA	80	1	24
WP2	Interactive User Query Interface	RTD	2	CWI	42	1	36
WP3	Process Composition & Execution	RTD	1	UEDIN	45	4	26
WP4	High Performance Storage & Execution Architecture	RTD	4	NCHC	38	1	36
WP5	Integration & Evaluation	RTD	1	UEDIN	38	1	36
WP6	Dissemination	MGT	1	UEDIN	12	1	36
WP7	Management	MGT	1	UEDIN	6	1	36
	Total	-	-	-	261	-	-

List of Deliverables

Del no	Deliverable name	WP no.	Nature	Dissem level	Deliv Month
D7.1	Consortium Agreement	WP7	R	CO	0
D7.2	Organisation and documentation of Project Start-Up Meeting	WP7	R	PU	1
D6.1	Project web site and data repository	WP6	RP	PU	2
D2.1	User information needs	WP2	R	PU	3
D5.1	Component Interface and Integration Plan	WP5	R	PU	3
D5.2	RDF/XML Datastore Definition	WP5	R	PU	3
D5.3	Scientific Question and Experiment Plan	WP5	R	PU	3
D2.2	Identified user scenarios and implementation plan	WP2	R	PU	6
D1.1	Fish detection and tracking	WP1	RP	PU	9
D3.1	Process, goal, capability and environment ontologies	WP3	R	PU	10
D6.2	First workshops	WP6	R	PU	12
D4.1	Video and RDF store, plus access	WP4	RP	PU	12
D4.2	Workflow computational platform	WP4	RP	PU	12
D7.4	Annual Financial and Scientific Reporting to EC	WP7	R	PU	14
D2.3	Component-based prototypes available	WP2	RP	PU	15
D1.2	Fish and environment property description	WP1	RP	PU	18
D3.2	Process planning and composition	WP3	RP	PU	18
D1.3	Fish clustering and recognition	WP1	RP	PU	24
D2.4	First advanced UI prototypes available	WP2	RP	PU	24
D4.3	Process execution	WP4	RP	PU	24
D6.2	Second workshops	WP6	R	PU	24
D3.3	Process execution and control	WP3	RP	PU	26
D7.4	Annual Financial and Scientific Reporting to EC	WP7	R	PU	26
D5.4	Experimental evaluation report 1	WP5	R	PU	30
D6.3	Public query interface	WP6	RP	PU	30
D6.2	Third workshops	WP6	R	PU	30
D2.5	UI components integrated into end-to-end system	WP2	RP	PU	36
D5.5	Experimental evaluation report 2	WP5	R	PU	36
D6.2	Fourth workshops	WP6	R	PU	36
D7.4	Annual Financial and Scientific Reporting to EC	WP7	R	PU	38
D7.3	4 monthly consortium meetings organised and documented	WP7	R	PU	5,9,13,17 21,25,29,33

Milestones

Milestone number	Milestone name	WPs	Date	Means of verification
M1	Project Website Operational	W6	2	URL fetch
M2	Fish detected and tracked	W1	9	demonstration videos
M3	Fish data into RDF/XML store	W1,W4	15	datastore examination
M4	Prototype User Interface	W2	18	URL fetch
M5	Fish species recognition	W1	24	Sci. Adv. Board
M6	Operational User Interface	W2	24	URL fetch
M7	Workflow compilation from text	W3	24	Query execution
M8	Parallel distributed workflow	W4	24	Performance statistics
M9	Workflow compilation from user	W2,W3	26	Query execution
M10	Full prototype system	W5	26	URL fetch
M11	First full system evaluation	W5	30	Report
M12	SecondLife Interface Operational	W6	30	URL fetch
M13	Final system evaluation	W5	36	Report
M14	Marine biology workshop	W6	36	Workshop proceedings

Work package 1 description

Workpackage number	WP1	Start date or starting event:					1
Work package title	Video data analysis						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	40	0	40	0			

Objectives

O1.1 - Successfully detect and track fish and other marine animals in varying undersea conditions.
O1.2 - Extract a varied set of general and special purpose properties for describing fish.
O1.3 - Recognise a majority of the fish observed in the videos and identify clusters of unrecognised fish.

Description of Work

T1.1 - Fish detection algorithm: This task will be based on the integration between a preprocessing system, which will perform a coarse detection based on low-level features, and an adaptive statistical background modeling. This system will be provided with a reliable occlusion management algorithm based on reasoning methods. Finally, groups of fish detection will be performed by particle dynamics methods. (UCATANIA)
T1.2 - Fish tracking algorithm: Novel covariance matrix representation methods will be compared with custom algorithms of probability density function estimation in order to obtain the best balance between accuracy and processing time. (UCATANIA)
T1.3 - Fish description algorithms: Classical and novel statistical and spatial properties (colour histograms in different colour spaces, Fourier descriptors, texture descriptors) will used to describe fish. Variation of the CSS transform, and edges/boundaries descriptors will be used to obtain the best views of fish useful for the recognition step. (UCATANIA)
T1.4 - Fish recognition and clustering algorithm: This task will investigate methods for fish species classification, using a combination of special purpose methods (*e.g.* head, tail, fin size estimates), general colour texture classification and active appearance models. Probabilistic models of feature distributions and classification methods will be used. Species and shape hierarchies will be used to allow recognition at some level even if precise species determination is not possible. Clustering will be applied to fish achieving only a low classification probability to identify unmodelled categories of fish (or other marine life). (UEDIN)

Deliverables

D1.1: (month 9 - P3) Fish detection and tracking
D1.2: (month 18 - P3) Fish and environment property description
D1.3: (month 24 - P1) Fish clustering and recognition

Work package 2 description

Workpackage number	WP2	Start date or starting event:					1
Work package title	Interactive User Query Interface						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	4	38	0	0			

Objectives

O2.1 - Establish high-level user information needs for querying video data and extracted metadata.
O2.2 - Create initial component-based prototypes to establish their usefulness.
O2.3 - Create advanced prototypes that fulfill specific high-level user information needs.
O2.4 - Integrate user interface components into end-to-end system.

Description of Work

T2.1 - Establish user information needs: interview users to identify concrete examples of information needs, focussing on high-level tasks that are feasible with F4K feature detection (in cooperation with WP1). Map these user needs to workflow and feature analysis functionality provided by the other F4K WPs. Develop concrete usage scenarios that deploy this functionality to better support end-users with combining visual and metadata information to meet high-level information needs.
T2.2 - Explore component-based prototypes: Design and develop web-based user interface prototypes for identified tasks, *e.g.*, time-based, feature-based, metadata-based, species-oriented and combinations of these.
T2.3 - Create support for high-level information needs. Based on identified user information needs, extracted metadata and results from the feedback on the component-based prototypes, design and develop web-based user interface prototypes that support high-level information needs. For example, develop search result presentation interfaces that convey provenance, confidence and trust levels by making clear for each result which feature detectors and other software was used to derive the result, and how this was used throughout the workflow.
T2.4 - End-to-end system: Ensure integration of user components in an end-to-end system with video data servers, metadata servers and retrieval engines.
T2.5 - Carry out evaluation and *in situ* user testing on end-to-end system. This is also part of WP5, however usability by marine biologists is so central to the project that this task is emphasised in this workpackage.

Deliverables

D2.1: (month 3 - P2) User information needs
D2.2: (month 6 - P2) Identified user scenarios and implementation plan
D2.3: (month 15 - P2) Component-based prototypes available
D2.4: (month 24 - P2) First advanced UI prototypes available
D2.5: (month 36 - P2) UI components integrated into end-to-end system

Work package 3 description

Workpackage number	WP3	Start date or starting event:					4
Work package title	Process Composition and Execution						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	42	0	3	0			

Objectives

O3.1 - to understand user requirements and formulate them using computational understandable and processable notations, *i.e.* ontologies.
O3.2 - to create a system design to address the complex and maybe diversified user requirements.
O3.3 - to create a rich and flexible workflow system that meets user requirements.

Description of Work

T3.1 - ontologies: to create a set of suitable domain ontologies that are based on user requirements for our intelligent workflow system. This work is to be coordinated with the system user interface specification work that is described in WP2.
T3.2 - workflow system design framework: based on user specifications and domain ontologies as described in T3.1, this task creates the design of a workflow system of two layers: the intelligent and automated process composition layer (based on process model and planning technologies) and the workflow execution layer (based virtual workflow machine technologies).
T3.3 - based on the system design as described in T3.2, this task develops the intelligent workflow system.

Deliverables

D3.1: (month 8 - P1) Process, goal, capability and environment ontologies
D3.2: (month 12 - P1) Process planning and composition
D3.3: (month 26 - P1) Process execution and control

Work package 4 description

Workpackage number	WP4	Start date or starting event:					1
Work package title	High Performance Storage and Execution Architecture						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	4	0	4	30			

Objectives

O4.1 - Achieve scalable long term real time capturing and buffering for multiple undersea video stream.
O4.2 - Build a Tera-scale data service platform consisting of repositories for the video data, for the metadata, for the processed data and for the live stream data, and a computational cluster to support analysis.
O4.3 - Achieve high performance data store and computation access for the data service platform.

Description of Work

T4.1 Enhance the efficiency of the current video capturing and buffering by means of in-situ data compression and distributed and dynamic buffering.
T4.2 Build additional repositories for RDF triples, XML summaries and processed data according to input from UEDIN, UCATANIA and CWI. Develop a transitional data service platform to enable the in time use of the repositories during the collaborative development.
T4.3 Implement interfaces defined by UEDIN, UCATANIA and CWI to connect analysis components to the repositories and work with UEDIN to implement workflow execution to incorporate the existing computational resources that NCHC provided.
T4.4 Develop high performance distributed data store and access methods and implement an optimal one to handle Tera-scale RDF triples and XML summaries that this project will encounter.
T4.5 Support code parallelisation to accelerate process execution in the workflows.

Deliverables

D4.1: (month 12 - P4) Video and RDF store, plus access
D4.2: (month 12 - P4) Workflow computational platform
D4.3: (month 24 - P4) Process execution

Work package 5 description

Workpackage number	WP5	Start date or starting event:					1
Work package title	Integration and Evaluation						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	20	6	6	6			

Objectives

The three objectives for this package are:
O5.1 - Define component and datastructure interfaces so that component integration occurs quickly
O5.2 - Define an evaluation plan, with targets, from both the research and marine biology perspectives
O5.3 - Achieve a successful component integration
O5.4 - Achieve a successful evaluation

Description of Work

T5.1 - Define component interfaces: this is the data and control interfaces for each independently executable function, so that they can combined easily at integration time, and so that they can be executed in a data parallel or pipeline manner. The definition includes the types of data, the control options and an estimate of running time.
T5.2 - Complete integration and evaluation planning: this is a plan of the order each component to be integrated, including temporary substitute modules (*e.g.* a user-interface replacement that allows hard-coded data requests) or preselected data results that allow components to be tested independently. A set of 20+ important questions will be selected in consultation with the marine biologist advisors, and will be used to focus development of the query answering components. A set of tests will be designed to evaluate the accuracy and speed of the system.
T5.3 - Undertake integration and first evaluation phase: The full set of components will be connected together and made to execute together. After this, the 20 marine biology questions will be attempted along with the performance testing. After debugging, the marine biologist advisors will be invited to experiment with the system.
T5.4 - Undertake refinement and second evaluation phase: based on the scientific and performance testing of T5.3, effort will be spent to make the components more accurate and faster, and increase the range of queries. The marine biologist advisors will be invited to experiment with the system a second time.

Deliverables

D5.1 - (month 3 - P1) Component Interface and Integration Plan
D5.2 - (month 3 - P1) RDF/XML Datastore Definition
D5.3 - (month 3 - P1) Scientific Question and Experiment Plan
D5.4 - (month 30 - P1,2,3,4) Experimental evaluation report 1
D5.5 - (month 36 - P1,2,3,4) Experimental evaluation report 2

Work package 6 description

Workpackage number	WP6	Start date or starting event:					1
Work package title	Dissemination						
Activity type	RTD						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	4	5	1	2			

Objectives

O6.1 - Develop a project web site including data repositories
O6.2 - Organise 4 workshops
O6.3 - Develop public data exploration interfaces
O6.4 - Promote the methodology to the marine biology community

Description of Work

T6.1 - We will create a web site containing: information about the project and partners, a collection of published papers arising from the project, a publically downloadable collection of video, description and recognition data acquired or computed by the project. (primarily UEDIN).
T6.2 - We will organise four public workshops, one each on visual analysis of marine environments, workflow compilation knowledge driven user query interface and a final workshop on Knowledge Based Methods for Marine Fish Monitoring and Analysis, where we will promote our results to the marine biologists and others doing similar developments. (UCATANIA,UEDIN,CWI,NCHC).
T6.3 - We will develop two web-mounted user interfaces: 1) a query interface tailored to marine biologists and 2) a video and fish exploration interface in SecondLife tailored to the general public. (CWI,UEDIN).
T6.4 - As well as the workshops in T6.2, we will be interacting with the marine biology community through both the members of the Scientific Advisory Board and through the biologists enrolled as part of T5.3 and T5.4 of the Evaluation workpackage (WP5).

Deliverables

D6.1: (month 2 - P1) Project web site and data repository
D6.2: (months 12,24,30,36 - P1,P2,P3,P4) Four workshops
D6.3: (month 30 - P2) Public query interface

Work package 7 description

Workpackage number	WP7	Start date or starting event:					1
Work package title	Project Management						
Activity type	MGT						
Participant number	P1	P2	P3	P4			
Participant short name	UEDIN	CWI	UCATANIA	NCHC			
Person-months per participant	3	1	1	1			

Objectives

O7.1 - To ensure the effective and timely management of the project
O7.2 - To facilitate the scientific work
O7.3 - To collate and deliver Deliverables and Management Reports
O7.4 - To maintain necessary financial and other consortium records and documents

Description of Work

This workpackage entails: organising the periodic management and scientific meetings, maintaining oversight of the project progress, producing agreed project documents, including the Consortium Agreement, organising the annual reporting to the EC, and generally facilitating the scientific work of the project.

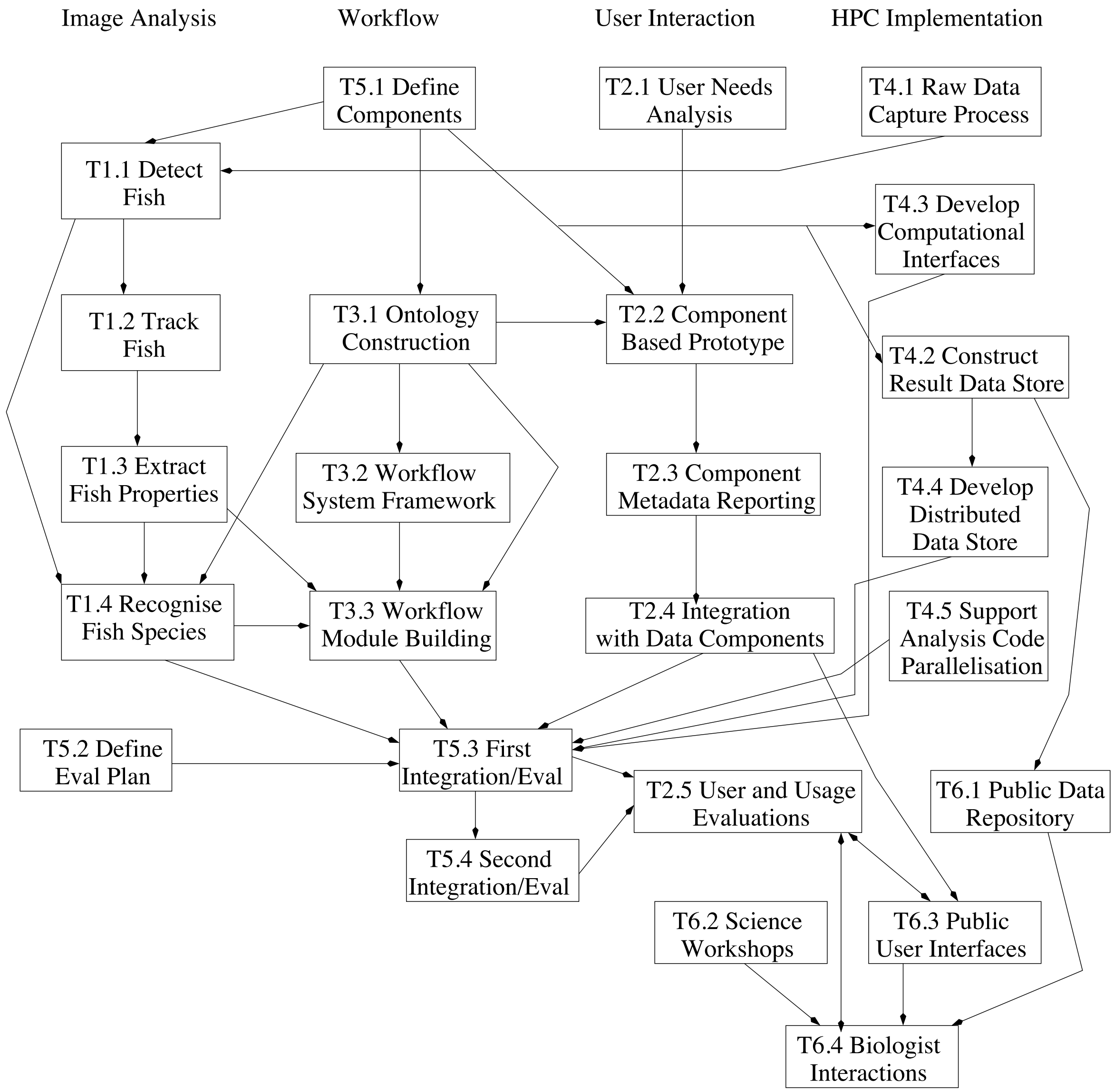
Deliverables

D7.1 - Consortium Agreement (M0)
D7.2 - Organisation and documentation of Project Start-Up Meeting (M1)
D7.3 - Consortium meetings organised and documented (M5,9,13,17,21,25,29,33)
D7.4 - Annual Financial and Scientific Reporting to EC (M12, M24, M36)

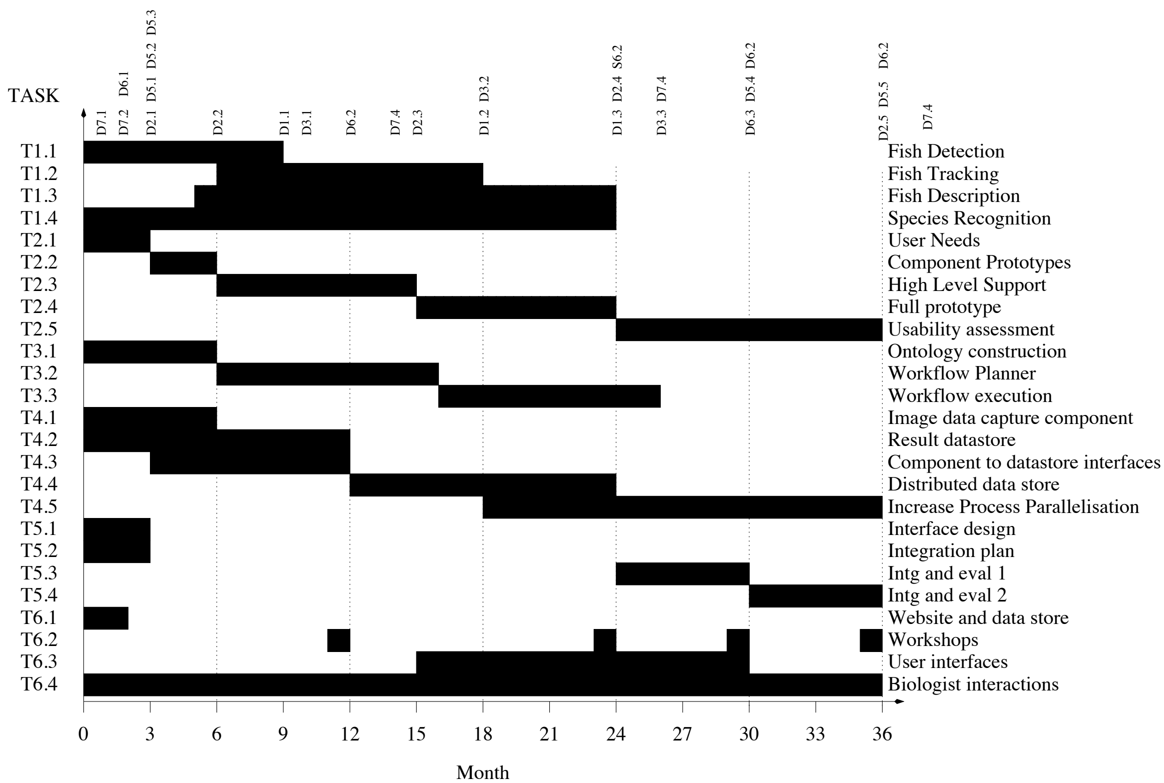
Summary of effort

Partic no	Partic short name	WP1 Video	WP2 UI	WP3 Work flow	WP4 Arch	WP5 Intg	WP6 Des	WP7 Mgt	Total person months
P1	UEDIN	40	4	42	4	20	4	3	117
P2	CWI	0	38			6	5	1	50
P3	UCATANIA	40		3	4	6	1	1	55
P4	NCHC	0			30	6	2	1	39
Total		80	42	45	38	38	12	6	261

Project Workflow



Project Timing



2: Implementation

2.1 Management structure and procedures

As this is a small project, a lightweight management procedure is proposed:

- The project will be led by the Management Board (MB), which will consist of the 5 PIs, one from each of CWI (Hardman), NCHC (Lin), UCATANIA (Giordano) and two from UEDIN (Fisher leading the vision research, Chen-Burger leading the ontology-based workflow research). Provisionally, the person fulfilling that role is identified above. The MB will be chaired by Fisher.

- There will be a meeting of the MB every 6 months, usually aligned with a technical meeting. All researchers on the project will be allowed to attend as well as the MB, in order to keep them engaged with the project and help with training for future leadership roles.

- Decision making will be by consensus; however, if a vote is necessary, each of the 5 PIs has a single vote.

- The project will set up listserve email lists for project wide day-to-day communications. In particular, two lists are initially proposed: 1) an administrative issues list to communicate amongst the PIs, 2) a general list to communicate amongst all project staff. A project web page will also record all project personnel along with contact email addresses.

- A project wiki will be created to record ideas, design decisions, outstanding issues, etc. This will provide a collaborative noteboard for use inside the project. It is not intended for external communications. It will also be useful for maintaining coordination with NCHC, because time zone synchronisation is not as convenient as with the European partners.

- There will be quarterly 1-2 day technical meetings to present and review research progress. Normally, representatives from all partners will attend.

- We will set up a Skype communication procedure, particularly for keeping in close contact with NCHC.

- There will be a set of web pages (the public portion is discussed more under Section 1.3 (WP6) and Section 3.2), which will also help all project members with execution of the project, through maintaining focus, containing project documents and datasets, useful URLs and other information, etc.

- There will be a project Scientific Advisory Board (SAB), which will be invited to an annual scientific project meeting. The purpose of the SAB is to review the project approaches, achievements and plans, and to help keep the project informed of developments in the wider context. Four people have agreed to participate on the SAB:

    1. Prof. Kwang-Tsao Shao (Biodiversity Research Center, Academica Sinica) - who specialises in marine biology, in particular Asian fish species

2. Prof. Monique Thonnat (INRIA) - who specialises in visual interpretation guided by ontologies
3. Prof. Steffen Staab (Univ. Koblenz) - who specialises in semantic web, knowledge management
4. Prof. Konstantinos Stergiou (Aristotle Univ. Thessaloniki) - who specialises in marine biology, particularly biodiversity and sustainability

- The project will have a Quality Assurance procedure. Each Deliverable document, dataset and software component will have an identified person from another project partner who will be responsible for reviewing the content or performance of the deliverable.

Risk Management Plan

The two primary goals of the project are:

1. to develop a scientific data collection and analysis tool usable by marine biologists and
2. to investigate and extend the methods needed for massive video-based data collection, analysis and query.

As such, the main risks can be considered under: component technical *competence*, component technical *performance*, system technical *performance*, system technical *performance* and expert *usability*.

- **Component technical competence:** the issues here relate to the ability of the individual components to achieve sufficiently high accuracy, etc.

  1. **Fish detection and tracking accuracy low**: increase prefiltering of image environment types and develop more specialised algorithms for each type of scene.
  2. **Fish species recognition rate low**: identify discriminating properties, enhance recognition hierarchy to allow intermediate classes of fish with higher classification rates.
  3. **Features needed by domain experts cannot be detected by project tools to a sufficiently high quality level**: Discuss with other partners those most likely to be available within the project timespan and progress work using simulated analysis results.
  4. **Domain expert vocabulary too conceptually different to map to feature-based vocabulary.**: Focus on specific tasks before potentially broadening out again at a later stage.
  5. **User feedback on workflow does not increase competence**: increase helpful diagnostic information, investigate if increase is possible if given perfect advice.
  6. **Automatic workflow generation produces low competence algorithms**: identify main weak components and replace with better alternatives, increase specifications about when to use the component.
  7. **Sense data availability**: For any undersea video monitoring system, due to the high cost to maintain and to store huge amount of image data, it is usually difficult to sustain the system alive. The live undersea video monitoring system at Kenting,

a southern coastal area of Taiwan with abundance of coral reefs, and raw video data repository, located currently at NCHC Taichung machine room, is constructed and operated by NCHC. The internal network at the on-site observatory currently has ADSL upload bandwidth at 8Mbps, which enables to stream four video channels at 640x480 pixels resolution and 20 fps. The higher frequency and quality is important to the marine fish biological study as well as wild field image analysis. NCHC is committed for the next 5 years to maintain and expand the site.

- **Component technical performance:** the issues here relate to the ability of the individual components to execute sufficiently quickly, etc.

  1. **Fish detection, tracking and species recognition too slow to keep up with live data rates**: increase modularisation to allow increased parallelism (pipeline and data parallel).
  2. **RDF/XML store too large for queries**: increase distribution of data, identify possible redundancies, apply redundancy coding, develop filters for bad/weak data.
  3. **Storage retrieval speed too slow**: increase distribution of data and search processes, change indexing to focus on standard searches.
  4. **Database query answering slow**: investigate precomputing common query intersections and merges, cache standard result sets.
  5. **Workflow compilation slow**: precompute standard workflows, allow offline compilation, investigate parallel search algorithms during compilation.

- **System technical competence:** the issues here relate to the integrated system being unable to meet user quality expectations.

  1. **User queries cannot be easily mapped onto live workflows:** consider enhancing query terminology, directly code some standard queries
  2. **Components' individual competences are good, but their interaction after integration produces low competence:** If the problem largely arises from false negatives, consider methods to increase to data volume, and estimate what percentage of targets/behaviours are missed. If the problem largely arises from false positives, consider additional constraints/filters that identify and remove problematic cases.

- **System technical performance:** the issues here relate to the integrated system being unable to execute sufficiently quickly to engage users.

  1. **Slow system speed**: investigate how to increase the parallel distribution of the required processing.
  2. **Too much data**: this relates to the previous risk, and we will investigate how to increase the distribution of the database and offline precomputation of results.

- **Expert usability:** The risk here is that the system largely works, but does not provide the expert user with useful information in a timely manner. The potential causes and remedies are likely to be:

1. **Cannot answer interesting questions**: we hope to preempt this risk by engaging the Scientific Advisory Board during the design of user interface and data analysis components. We will keep the SAB engaged to advise on how to increase capability.
2. **User interface requires too much computer-expert skill**: we hope to preempt this risk by engaging the Scientific Advisory Board during the design of user interface and data analysis components. We will keep the SAB engaged to advise on how to increase usability.
3. **Unable to determine sufficiently coherent high-level tasks that domain experts carry out to warrant effort of creating costly advanced interface**: Concentrate on supporting low-level tasks as well as possible and instead provide "mix and match" palette of task support.

2.2 Individual participants

2.2.1: The University of Edinburgh

The fish species recognition research will be undertaken in Prof. Robert Fisher's research group and the workflow planning and control in Dr. Yun-Heh Chen-Burger's research group, both in the School of Informatics.

The University of Edinburgh is one of the largest and most successful universities in the UK, with an international reputation as a centre of academic excellence, with researchers and students coming from over 120 different countries. It is the leading research university in Scotland and one of the top in the UK; almost all members of academic staff are active researchers. A recent Times (Newspaper) Higher Education Supplement ranked Edinburgh in the top 30 universities worldwide. The recent published results of the UK's 2008 Research Assessment Exercise (RAE) confirmed that the School of Informatics is, once again, both the largest and the strongest in the UK for research in Informatics and Computer Science. The School of Informatics as a whole has about 80 academic staff, 150 post-doctoral researchers and over 300 postgraduate research (PhD) students.

Prof. Robert Fisher's research group has been investigating topics in computer vision for over 25 years. Much of that research has been on 3D image analysis and more recently on video sequence analysis. Representative samples of their recent video image analysis work are: "Semi-supervised learning for Anomalous Trajectory Detection" (Sillito & Fisher 2008); "Non Parametric Classification of Human Interaction" (Blunsden, Andrade & Fisher 2007); "Modelling Crowd Scenes for Event Detection" (Andrade, Blunsden & Fisher 2007). The group has participated in 3 EC training networks (including one led by Prof. Fisher), 5 EC networks and two EC STREP-equivalent projects (one by Prof. Fisher). The group currently participates in the ChiRoPing STREP and euCognitionII network. Prof. Fisher received a B.S. with Honors (Mathematics) from California Institute of Technology (1974) and a M.S. (Computer Science) from Stanford University (1978). He received his PhD from University of Edinburgh (1987). Since then, Bob has been an academic at Edinburgh University, now in the School of Informatics, where helped found the Institute of Perception, Action and Behaviour. Recently, he has been researching video sequence understanding, in particular attempting to understand observed behaviour. He has a passion for on-line teaching and research resources for the computer vision community, leading to several well-used text and interactive exploration resources. He has published 6 books and about 250 scientific articles.

Dr. Yun-Heh Chen-Burger has worked on topics in process and conceptual modelling and workflow automation for over 14 years. Much of the research focuses on using semi-formal modelling techniques that are automated using declarative logical programs to achieve semantics-based inferencing and virtual workflow machine execution. Recently, her research has incorporated inter-disciplinary techniques, *e.g.* to decipher the content and infer meanings of video images rapidly by using semantics-based workflow techniques in partnership with image processing experts. This group has participated in two EC projects, one as coordinator. More recently, she has also been assisting with knowledge transfer. Dr. Chen-Burger received two MSc degrees: one in Computer Science, Univ. of Missouri, USA and one in Artificial Intelligence, Univ. of Edinburgh and a PhD at the Univ. of Edinburgh. She is a permanent research fellow. She has published a book and over 50 scientific articles.

2.2.2: Centrum Wiskunde & Informatica

The semantic media interface design and evaluation in the project will be carried out by the Intelligent Information Access group at CWI. CWI is the Dutch national research institute for Mathematics and Computer Science, a private, non-profit organisation founded in 1946 (as Mathematisch Centrum). CWI aims at fostering mathematics and computer science research in The Netherlands. CWI has always been very successful in European research programs (e.g., ESPRIT, ACTS, TELEMATICS, BRITE, TMR, IST) and has extensive experience in managing these international collaborative research efforts. Annually CWI hosts some 200 visiting scientists from abroad. CWI has a staff of 210 FTE, 160 of whom are scientific staff. CWI operates on an annual budget of 13M Euros.

The Intelligent Information Access group researches user interface development for semantically annotated media repositories in the cultural heritage and news domains. Research topics have dealt with data heterogeneity in the user interface, exploiting formal and semi-formal background knowledge in the user interface, media-specific annotations and end-user evaluations of novel interaction methods supporting complex information needs. Example results include the semantic search demonstrator that won the 2006 International Semantic Web Challenge (Schreiber et al., Semantic Annotation and Search Of Cultural-Heritage Collections: The MultimediaN E-Culture Demonstrator, Journal of Web Semantics), the COMM multimedia ontology (Arndt, Troncy, Staab, Hardman and Vacura: COMM: Designing a Well-Founded Multimedia Ontology for the Web, ISWC 2007), end-user search requirements analysis (Amin, Van Ossenbruggen, Hardman, and Van Nispen: Understanding Cultural Heritage Experts' Information Seeking Needs, JCDL 2008).

Members of the group played key roles in national and European projects, including the K-Space European Network of Excellence, the Vitalas FP6 project and EuropeanaConnect. They have a strong track record in disseminating research results through publically available demonstrators, open source software and active participation in W3C working groups.

Prof. Lynda Hardman received her PhD from the University of Amsterdam in 1998. From the eighties, Hardman has been working on user interfaces for hypertext, multimedia and hypermedia browsing and authoring systems. Her current research efforts are focused on improving design methods for human interaction for emerging technologies, with specific projects in annotated media repositories. She is part-time professor at the University of Amsterdam.

Prof. Arjen R. de Vries's research interests include structured document retrieval and entity ranking, multimedia information retrieval, the application of information retrieval theory to recommendation systems and social media, the integration of information retrieval and database technology, and the evaluation methodologies needed in these novel information retrieval application areas. Prof. De Vries coordinated the TREC Enterprise Track and initiated the entity ranking track at INEX. He is part-time professor at Delft University of Technology.

Dr. Jacco van Ossenbruggen received his PhD from the VU University Amsterdam in 2001. He has worked on structured hypermedia documents on the Web and intelligent user interfaces for heterogeneously annotated media repositories. He is an expert in integrating large cultural heritage data sets and played a key role in developing the award-winning MultimediaN E-Culture Demonstrator. He is currently active in the EuropeanaConnect project, where he works on the semantic layer for the cultural heritage search engine. He is part-time assistant professor at the VU University.

2.2.3: Università Degli Studi di Catania

The research group of the University of Catania, Italy, will be largely involved in fish detection, tracking and description. The University of Catania was founded in 1434 and is one of the most important universities in Southern Italy, with more than 55,000 students, over 1,500 professors and 12 faculties. The University participates in the Project through the Department of Informatics and Telecommunications Engineering that was founded in 1975 and was involved in designing and implementing the first European Informatics Network (EIN). The department has been instrumental for the development of the technological district known as Etna Valley that currently aggregates over 150 companies operating in the field of advanced information and communication technology. The main R&D areas of the group involved in the project, coordinated by Prof. Daniela Giordano, are within the fields of artificial intelligence, human-computer interaction, bioinformatics and computer vision.

In the last 5 years the team has carried out research dealing with: 1) object detection in complex scenes, such as evaluating traffic parameters in a metropolitan area (Faro, Giordano & Spampinato, 2008) and in underwater environments (Spampinato, Chen-Burger, Nadarajan & Fisher, 2008); 2) object tracking with multiple feature integration, for object tracking "Adaptive Objects Tracking by using Statistical Features Shape Modeling and Histogram Analysis" (Spampinato, 2008); 3) image enhancement and data mining techniques for knowledge discovery in the biomedical field, *e.g.* mining specialised literature for gene-disease associations (Faro, Giordano, Maiorana & Spampinato, 2009). Recently the research group has been involved in two EU projects: I-trace (2005-2007) (led by Prof. Giordano) and the Best Practice Network mEducator (2009-2012) dealing with content retrieval in the medical field.

Prof. Daniela Giordano holds a Laurea degree in Electronic Engineering, grade 110/110 cum laude, from the University of Catania, (1990), and a Ph.D. in Educational Technology from Concordia University, Montreal (1998). For her PhD work dealing with a content sharing system for learning analysis and design skills she received the Prix d'excellence du CIPTE - Canada for the best doctoral thesis in Educational Technology (1997-1998). Since 2001 she has been professor of Cognitive Systems and Human Computer Interaction at the University of Catania. Prof. Giordano has published over 100 scientific articles in the following research areas: Design Methodologies for Interactive Systems, Distributed Information Retrieval, Image Processing for biomedical applications.

Prof. Alberto Faro received the Laurea degree in nuclear engineering from Politecnico of Milan. Currently, he is full professor of Artificial Intelligence at the University of Catania, where he is also the Dean of the Computer Engineering degree. Prof. Faro was one of the founders of the Department of Informatics and Telecomunication Engineering. Also, he has served, for many years, as the director of the Graduate Programs in Electronics Engineering and in Computer Engineering at the same University. He has published over 200 scientific articles in fields such as computer networks, system engineering and distributed systems. His current research interests include dynamic systems theory of cognition, intelligent learning environments, computer vision for bioinformatics and mobility information systems.

Dr. Concetto Spampinato received the Laurea degree, grade 110/110 cum laude, and the PhD in Computer Engineering from University of Catania in 2008 where, currently, he is Research Assistant. He has worked actively on object detection and tracking algorithms for video analysis and image processing techniques for biomedical applications. He has published a book and about 40 scientific articles.

2.2.4: National Center for High-Performance Computing

The undersea observatory and the computing facility will be provided by the National Center for High-Performance Computing (NCHC), where Dr. Fang-Pang Lin and his research group will develop the proposed data repositories and efficient data query and management.

NCHC was established in 1991 as a national computing resources and research center to provide Taiwan's academia high performance computing services, and also to conduct fundamental and applied research in high performance computing and networking. Since 1997, NCHC has planned, built and operated Taiwan's academic research network. The center transitioned into a non-profit organisation under Taiwan's National Applied Research Laboratories (NARL). NCHC was commissioned to build a national cyberinfrastructure in 2003 due to its leadership in Taiwan's HPC, storage and networking. This led to a new 20Gbps optical backbone, the Taiwan Advanced Research and Education Network (TWAREN) and an integration of distributed national computational resources - the Knowledge Innovation National Grid (KING). NCHC has strong and extensive international collaboration with global HPC related communities. It has been collaborating with the University of Edinburgh since 2004 in terms of knowledge discovery in a long term ecological research grid, namely Ecogrid.

Dr Fang-Pang Lin is the head of Grid Applications Division in NCHC. He is one of the key developers of KING project and was the Executive PI of KING in 2003. He initiated the SARS grid development in 2003, the first of its kind in the world. He also initiated the Ecogrid project, and co-founded Global Lake Environmental Observatory Network (GLEON) and Coral Reef Environmental Observatory Network (CREON) in 2004. Both communities grew into true international communities, involving more than 300 biologists, ecologists and computer scientists and research institutes from 19 countries across 5 continents. CREON members include Australian Institute of Marine Science (AIMS) for Great Barrier Reef and University of California Santa Barbara (UCSB) and San Diego (UCSD) for the long term ecological research into the coral reef ecosystem at Moorea island. Before his work in KING, he was a long term collaborator with HLRS (in Germany) on Metacomputing and collaborative visualisation since 1999. Dr. Fang-Pang Lin obtained his PhD in University of Wales at Swansea, UK. He worked in the Rolls-Royce University Computing Center in Oxford University as a research scientist after a one-year postdoctoral research contract in Swansea. He joined NCHC in October 1997 and has been working in numerical simulation and software engineering for application integration. He has published 50 scientific articles. He was awarded a '2006 Outstanding Achievement Award in Science and Technology'.

2.3 Consortium as a whole

There are five teams (over 4 partners) in the consortium, each with a well-defined and complementary role. Each team will be primarily responsible for one of the core research topics of the project. We have ordered the teams here to reflect part of the dataflow through the project, which makes it clear that each partner has an important role, and that all components of the project are being investigated.

CWI - Intelligent Data Management and Query Interface: CWI has much experience [35] with structuring knowledge and working with large interlinked data stores. They have also considerable strengths in developing knowledge supported intelligent interfaces. Their contribution here will be the development of an interface that links the intentions, concepts and vocabulary of the user to the formal goal specification needed by the data analysis components of the project. They will also be creating the intermediate-language description of the solution to the user's query.

UEDIN - Query Workflow Compilation: UEDIN's Intelligent Workflow team has much experience with translating goal specifications into computational process specifications. In particular, they have experience [61] with constructing workflow sequences to process underwater video and perform simple tasks like fish counting. Their contribution here will be to develop methods for composing workflows that answer richer queries, such as correlating spatial and temporal data, and workflows that involve both previously analysed video and live video.

UCATANIA - Fish Detection and Tracking: UCATANIA has much experience with low-level image and video analysis, including prior expertise with target detection in underwater video [87]. UCATANIA's contribution here will be to develop an efficient and accurate fish detection, tracking and description capability, plus components that compute summary statistics of the detected fish and environment over time. They will also investigate how to maximise the amount of storage of raw fish imagery within the storage and processing capacity. This team is responsible for producing the majority of the fact knowledge base acquired in the project, which feeds into the query answering process.

UEDIN - Species Recognition and Discovery: UEDIN's Machine Vision group has much experience with a broad range of image analysis problems, including species discrimination [14] and behaviour analysis in video [4, 13], including some experience with underwater video [87]. Their contribution here will be to develop methods for fish species recognition using the detected fish and associated descriptions from the UCATANIA team, as well new computing descriptions. The team will also investigate methods for identifying clusters of previously uncategorisable fish. The results of the component will flow into the fact knowledge base and query answering process.

NCHC - Knowledge and Processing Resource Management: NCHC has much experience with the undersea sensors and with collection of the raw data. As part of a High Performance Computing centre, they also have much experience with the sort of computing and storage resources needed for fast execution of the marine biology queries. Their contribution will be twofold: 1) to manage the computational devices underpinning access to the data and knowledge stores so that the information can be extracted quickly, and 2) to manage the computing resources so that the conceptual workflow constructed by UEDIN in response to CWI's query formulation, can be executed on multiple processors using multiple instances of UCATANIA's and UEDIN's image data analysis modules.

As well as having individual and complementary strengths, many of the teams have collaborated together previously. Dr. Lin's and Dr. Chen-Burger's teams have been worked together on the implementation of Edinburgh's I-X intelligent system. Dr. Chen-Burger's, Prof. Fisher's and Dr. Giordano's teams have worked together through the joint supervision of PhD student Nadarajan, resulting in several joint publications. Prof. Fisher and Dr. Chen-Burger visited Dr. Lin's group several years ago to develop potential ideas on collaboration.

This previous experience with joint activities means that the groups should start to work as a team more easily. This will be particularly important during the integration and evaluation phase of the project, which is the main activity in the third year of the project.

Consortium Management

The Project Coordinator (Fisher) has participated in many European project and network activities (*e.g.* SMART, SMART II, ECVISION, euCognition, CHIROPING), including being the consortium coordinator of CAMERA and CAVIAR. The three European PIs have participated in previous European projects and network activities so are familiar with EC procedures. The School of Informatics and the University of Edinburgh have many EC funded projects and have contractual and financial specialists for these types of projects.

Subcontracting

The only expected subcontracting is for financial auditing.

Other Countries

Partner 4, NCHC, is based in Taiwan. They will be a full partner in the project, but will be funded by their local science council. Their responsibilities will include organising access to the protected marine sites.

2.4 Resources to be committed

Existing Resources

NCHC's Environmental Grids team, with eight members of staff, will align their Ecogrid development on coral reef observation with the project's work packages, and share their experiences and resources with the project members. The Environmental Grids team will provide raw image data both from live undersea video stream feed and the historical data repository. The current high performance storage capacity dedicated to the team is 6 TB and can be extended if required. It will be used for the project. NCHC will provide a virtualised research cluster for the project. Additional computing power will be provided to the project via the joint project of the National Science Council of Taiwan. NCHC operates Taiwan Advanced Research and Educational Network (TWAREN). It provides 5 Gbps international connection via New York connecting with GEANT (DANTE).

NCHC will provide an in-house cluster with 80 dual AMD Opteron DualCore PCs (i.e. 320 2.2GHz CPU-Cores), 8GB RAM each, connected on a private subnet with 1000 Mbits/s Gigabit Ethernet. Also, due to the involvement of National Science Council, the project is entitled to have accounts on an IBM Cluster 1350, which consists of 512 nodes, each an Intel Woodcrest 3.0GHz Quad-Core, with 2048 cores in total. The performance measurements are Rmax 15.97TF and Rpeak 24.6TF. The storage will be EMC CLARiiON CX700 High Efficiency Disk Storage Array with EMC Connectrix (DS4100) Fiber Optics Exchange, whose capacity can reach 60 TB. A small size cluster, with 10-40 DuoCore PCs and 2GB memory size for each will be also provided for project use.

UEDIN and UCATANIA have been investigating workflow compilation for fish detection and tracking processes under UEDIN PhD student Nadarajan. The ontologies, resource descriptions and image analysis modules developed under that project will be usable by Fish4Knowledge,

UEDIN has a supported Second Life site called the Virtual University of Edinburgh (`http:\\vue.ed.ac.uk`). This resource will be used for the Second Life interactive gallery being developed in WP6. UEDIN has technical support that can be used to help with the development.

CWI will contribute software frameworks for supporting user-oriented query interfaces, namely RDF-based Cliopatria `http://e-culture.multimedian.nl/software/ClioPatria.shtml` and XML-based PF/Tijah (Pathfinder/Tijah, pronounce as "Pee Ef Teeja")
`http://dbappl.cs.utwente.nl/pftijah/`,
`http://dbappl.cs.utwente.nl/pftijah/Main/FeaturesAndGoals`.

New Resources

UEDIN: requests funding for one post-doctoral researcher to undertake the workflow research, one PhD student to undertake the fish species classification research, and one post-doctoral researcher to focus on the system-building, integration and evaluation efforts to link the consortium efforts together. Some funding is for Prof. Fisher and Dr. Chen-Burger, a small amount of computing support, and a 1/3 time secretary to support the consortium. Travel costs are for (each of the 5 team members) 2 trips to Taiwan, 10 consortium meetings and 2 conferences. Other costs include 10K for computing equipment, 12K for infrastructure costs and 5K for consumables.

CWI: requests funding for one PhD student to undertake the user interviews, design the user interface mockups and test them with users and one post-doctoral researcher to coordinate this work with the process composition and execution work and to contribute to the user-oriented data management issues in the project. Some funding is for Prof. Hardman, Prof. de Vries and Dr. Van Ossenbruggen, plus 2 laptops for the new members of staff. Travel costs are for 4 trips to Taiwan to meet with users, 10 consortium meetings and 3 conferences. Other costs include 4K for computing equipment.

UCATANIA: requests funding for one post-doctoral researcher (three years) to undertake fish detection, tracking and description and one senior scientists to investigate fish detection, grouping and event detection. Additional funding is requested for computing support. 6K is requested for computing equipment and consumables. Travel costs (51K) are for (2 researchers) 2 trips to Taiwan, 10 consortium meetings and 3 conferences.

NCHC: is not asking for any resources as these will be requested from their national science council.

3. Impact

3.1 Expected impacts listed in the work programme

- **Significant advances in easily customisable access services to scientific digital resources, improved uses, experiencing and understandings:** We will deploy an alternative to the use of 2D/3D TV wall or its web equivalent currently developed and offered by NCHC. This imagery based TV browsing wall is easy to use and can be made available via web-based click-and-view actions. We also plan to augment it by providing knowledge-powered queries. As a part of this project, we plan to design and implement new state-of-the-art user goal and experience sensitive query-based access services that are open to the public. These web based services will be able to support both historical as well as real-time video and image processing and associated structural textual display. On the one hand, we wish to offer the precious coral reef marine life information to marine biologists and the public alike that was previously not available to them. On the other hand, we wish to provide a showcase window where cross-disciplinary innovative technologies are being brought together in one platform. Such technologies are video and image processing, advanced knowledge modelling and semantics-based technologies, human computer interaction and visualisation systems and high performance computing and workflow execution technologies.

- **Reinforced capacity for organisations to preserve digital content in a more effective and cost-efficient manner, safeguarding the authenticity and integrity of these records:** We plan to use Visual Image Processing (VIP) powered automated methods to intelligently select and preserve useful digital content, including both videos, images and textual data. Less significant and not so useful videos and images will be discarded, although their automatically generated meta-data may be preserved, to save storage space and also to enable more efficient and effective query-answering and information retrieval. This automated selection process is guided by underlying domain knowledge bases. Experts in marine biology are invited to participate to provide guidance in this selection process so that this selection process is revised and improved over time. This approach will also help the sustainability of data curation and preservation in the long run, due to the large amount of storage required to store the continuous video filming. It will also automatically preserve the provenance of data, as a part of our standard procedures.

- **Significant reduction in the loss of irreplaceable information and new opportunities for its re-use, contributing to efficient knowledge production:** Currently, due to limited storage space available, NCHC, the main project data curator is deleting legacy videos in a non-discriminating manner, *i.e.* according to their temporal order and without knowing what data has been deleted. However, it was seen in the past that through random sampling, new fish species and behaviours have been discovered that were either previously unknown or wroongly defined. Through our intelligent selection and filtering process, we plan to identify and preserve valuable video clips and make them available to all interested parties. We will provide user friendly interfaces to encourage the use of the digital content. The experiences and platform developed for this project may also be re-useable and re-purposed for a different domain, *e.g.* digital art or other types of video oriented data. In addition to the preservation of significant amounts of video data, the project will generate a large amount of computed data about the observed fish. This is estimated to be on the order of 10^{15} RDF triples (or an estimated 5 terabytes of XML equivalents).

- **Leading edge research in Europe strengthened through restructuring of the digital libraries and digital preservation research landscape. Leveraged impact of research results:** This research will make use of and extending beyond currently leading edge VIP processing technologies. Previous fish video and image processes were done in a relatively control environment, *e.g.* in a lab or in a closed body of well-conditioned water. This research is carried out on videos shot in open sea that it is subject to all types of natural disruptions. However, our initial results already shown great promises, *i.e.* 80+% accuracy rate, which is extremely encouraging.

  This above work is also closely combined with the innovative knowledge based virtual workflow machine that composes, controls and executes the underlying VIP software modules guided by its underlying knowledge models, enabling rapid prototyping of a "good enough" video processing system in a relatively short period of time, *e.g.* in a matter of minutes or hours. This is revolutionary when compared with the traditional VIP systems that typically require a team of VIP experts and man-months to man-years to produce. The traditional approach is not suitable to rapidly adapt to meet a changing environment where vast amount of diversified data may be collected from varying conditions.

  In addition, the proposed workflow system is also designed to be easily by marine biologists, in that it hides the complexity of VIP systems and allows users to fine-tune and change their operations without requiring computing expert help. The system will also be user-goal and experience sensitive, in that it is able to "learn" over time and provide incremental system performance improvements based on experience. This ability will allow it to be tailored to the requirements of a particular user or a group of similar users, which is a capability not available to VIP systems previously.

- **Impact on marine biology:** As has been seen, since the non-intrusive, 24 hourly, under-water video filming were put in place about 3 years ago, new marine species and behaviours were discovered contrary to previous belief. However, only a minute amount of these videos have been reviewed by marine experts, due to scarce expertise and time limitations. By providing a publically available knowledge based portal, interested marine biologists can now view selective content and compare notes. Of particular value is the ability to allow the marine biologists to formulate queries in a reasonably natural manner, which are then executed by the system. This provides a new and unique opportunity for further new discoveries and studies that was not available before.

- **Impact on the public: education and conservation:** Through the digital web portal, we will provide high quality stored videos and live-feed of beautiful coral reef marine life. It should naturally cause public interest and admiration of marine life. We therefore hope to have a positive effect on promoting conservation of marine life and environment in the long run.

- **Impact on video image processing communities:** Through our state-of-the-art intelligent workflow VIP system, we aim to unleash much demanded VIP software capabilities to a wider audience. This is especially timely as today lots of images and videos are available through public web portals and private resources. However, the vast majority of them are not analysed, understood nor annotated to enable efficient and effective interpretation to support specific application goals. Our project aims to partially help achieve this goal. Although marine fish observation is the target application in this project, Fish4Knowledge is developing VIP processes that can be more broadly used, including the target detection, scene gisting, massive data summary and query enabling descriptions.

- **Impact on digital media communities:** We wish to present our digital content through leading edge visualisation user interfaces and use them as a showcase to demonstrate how complex and inter-disciplinary technologies and domain information may be integrated and work with each other to provide rich multi-dimensional and user-centric support in browsing, communicating and working using rich digital content. This useful and complex approach is ambitious, but its impact may revolutionise the traditional way of static browsing, non-intelligent content selection and presentation, non-collaborative use of digital media content.

- **Impact on workflow communities and interdisciplinary work:** Workflow technologies have long been recognised as a powerful tool in the commercial and manufacturing sectors. In this project, we further demonstrate how the different knowledge modelling, knowledge libraries, experience cases, VIP technologies and workflow virtual machines may be integrated to realise rich, flexible, effective workflow systems. If successful, this project will be another triumph for the workflow communities. It will show case how workflow based methodologies, by closely collaborating with a very different but much demanded technical VIP communities, are able to unlock the conventional specialised and reserved VIP systems and bring their benefits to a much wider ranges of users and achieving VIP tasks that were not possible before.

- **Impact on High Performance Computing communities:** Through the development of workflow methods, we hope to stimulate the use of HPC resources into novel process parallel execution and resource allocation models. With the collection of up to 10^9 bytes of data per second, through to 10^5 new facts per second, leading to on the order of 10^{12} new facts over the project lifetime, we hope to stimulate research into the computationally efficient and timely storage and analysis of this data.

Related Projects

There are three projects relevant to the proposed one:

- **JUMAS - Audio and video knowledge management for e-government and e-justice**. The aim of this project is to build an infrastructure for workflow management in the judicial domain. Models and methods for analysing, extracting and representing embedded semantics derived from multiple data sources (*e.g.* audio and video enclosed in multimedia trial folders) are explored in order to collect, enrich and share multimedia documents annotated with the extracted semantics and to provide novel information retrieval systems on judicial audio and video recordings.

- **e-LICO** The goal of the e-LICO project is to build a virtual laboratory for interdisciplinary collaborative research in data mining and data-intensive sciences. The proposed e-lab comprises three layers: the e-science layer and the data mining layer form a generic knowledge discovery platform that can be adapted to different scientific domains by customising the application layer. The relevant part, for Fish4Knowledge, is the knowledge discovery platform where the use of data-mining tools is ensured by a knowledge-driven, planner-based data mining assistant, which relies on a data mining ontology to plan the data mining process and propose ranked workflows for a given application problem.

- **APIDIS - Event Recognition and Resource Management**. The aim of this project is to develop methods for automatic collection, distribution and production of video summaries for controlled scenarios (sports events or surveillance). It investigates the possibility to extract digital content from networks of multi-modal sensors and to automate the production of video content for controlled scenarios (sport, surveillance, etc.).

3.2 Dissemination and/or exploitation of project results, and management of intellectual property

The key messages of this project are several fold: to demonstrate several advanced innovative technologies, to bring them together in an integrated platform using coherent research frameworks; and to showcase and share project results to the relevant technical, scientific, marine biologists and the generic public.

More concretely, we plan to carry out following tasks to achieve the goals described above:

- Build and run a well-maintained project web site that provides a centralised place to hold all relevant project information and our findings;
- Develop a sophisticated, knowledge-centric 1D, 2D and 3D long-term-sustainable web based system to allow browsing and interaction with the digital content. In the long run, it aims to provide a foundation to allow feedback and continuous enrichment of targeted digital content through our automated platform that allows humans in the loop. NCHC will take over maintenance, support and extension of the developed software and public web-sites, so that new species will be identified, new query types supported, additional data collected, continued use of the system by marine biologists are supported. This implies the investment of about one person-year over the 3 years following the end of the project.
- Publish papers in relevant professional workshops, conferences and journals that are related to the fields of video and image processing, Semantic Web, Web technologies, knowledge management, digital media content management and libraries, artificial intelligence, workflow management, high performance computing, collaborative systems, knowledge systems, etc. Example conferences are ICCV, CVPR, WACV, BMVC, ECAI, IJCAI, Pragma, KMIS, eKnow, KES-AMSTA, etc.
- Edit a book that serves as a project handbook that gives an overview of our work and other relevant works. Example content includes a description of the targeted problem domain and its timely importance, the motivation, our overall research framework and how the different techniques fit in with each other to create a coherent system, literature survey of each of the involved technical fields, showcase of relevant works done by others, description of works that have been carried out, future works to be explored, project

and evaluation results. This book will be published via a credible academic publisher, *e.g.* Springer or IGI Global.

- Hold three technical workshops, to create focused communication platforms to help targeted knowledge sharing, project promotion, results dissemination and consolidation of relevant technologies in the field. The three identified technical areas for workshops are video and image processing of living organisms, intelligent workflow and grid computing, and semantics-based human computer interaction and visualisation.

- Near the end of the project, we will organise a fourth international workshop oriented around the acquisition and analysis of marine video data, with a cross-set of attendees from marine biologists (user community) to computer scientists (developer community). The aims of this event are to: 1) promote the results of the Fish4Knowledge project, 2) create a context for the presentation and discussion of new tools for video-based marine biology and 3) trade experience with the developer community.

- A special virtual 3D exhibition gallery will be built for this project. An initial proposal is to build this gallery on the virtual land of the Virtual University of Edinburgh (VUE) that is currently owned and maintained by the University of Edinburgh. VUE is currently built using Second Life as the platform. This is a novel and still experimental communication platform for project dissemination that is out of our project for evaluating its effectiveness. However, due to its rich interactive communication methods, it has received wide attention from educators, commercial sectors, young and old computer users, government agencies. VUE itself has also received much media publicity. It is therefore a great and novel outlet to be used to attract and promote enthusiasm for this project and its results.

- We plan to promote this project and use its results through AIAI's normal knowledge transfer and consultancy projects, as appropriate. Artificial Intelligence Applications Institute, University of Edinburgh is a world leading AI applications institute and one of the oldest of its kind. Its main mission is to develop leading edge AI technologies and to apply and tailor generic AI methodologies to create specific solutions to resolve real-world problems via its knowledge transfer, education, consultancy and system development projects.

- Project results will be advocated and made available to the Liaison Office (ILO), the knowledge transfer arm of the University of Catania. It, as a part of its normal functions, will use such results to support business, institute and university communities in the areas of scientific-technical innovation and operational system development to benefit the Sicily Region.

On the issue of the management of intellectual property, as this is primarily a research project, technical papers will be written and published into the public domain. Developed systems and tools will be made open source and free to use for the academics and research communities. NCHC will be provided with a copy the software developed by partners free of charge and will use them to provide a web-based system to support the continuous use of the underlying rich marine data. The extensive fish knowledge base will be freely accessable by all. By default, each partner will retain the IPR of their own work, unless stated otherwise. Where IPR is jointly created by more than one partners, such IPR is subject to negotiations and formal agreements between partners regarding IPR ownership and the actual mechanism of IPR exploitation.

4. Ethical Issues

The project will be observing fish, but the observations are passive using existing non-intrusive cameras. Therefore, in the table below, the ‘animal’ questions are answered ‘no’.

ETHICAL ISSUES TABLE

	YES	PAGE
Informed Consent		
* Does the proposal involve children?	NO	
* Does the proposal involve patients or persons not able to give consent?	NO	
* Does the proposal involve adult healthy volunteers?	NO	
* Does the proposal involve Human Genetic Material?	NO	
* Does the proposal involve Human biological samples?	NO	
* Does the proposal involve Human data collection?	NO	
Research on Human embryo/foetus		
* Does the proposal involve Human Embryos?	NO	
* Does the proposal involve Human Foetal Tissue / Cells?	NO	
* Does the proposal involve Human Embryonic Stem Cells?	NO	
Privacy		
* Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)	NO	
* Does the proposal involve tracking the location or observation of people?	NO	
Research on Animals		
* Does the proposal involve research on animals?	NO	
* Are those animals transgenic small laboratory animals?	NO	
* Are those animals transgenic farm animals?	NO	
* Are those animals cloned farm animals?	NO	
* Are those animals non-human primates?	NO	
Research Involving Developing Countries		
* Use of local resources (genetic, animal, plant etc)	NO	
* Impact on local community	NO	
Dual Use		
* Research having direct military application	NO	
* Research having the potential for terrorist abuse	NO	
ICT Implants		
* Does the proposal involve clinical trials of ICT implants?	NO	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

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