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BinocularsVR – A VR experience for the exhibition "From Lake Constance to Africa, a long distance travel with ICARUS"

Björn Sommer[1,2,$], Stefan Feyer[1], Daniel Klinkhammer[1], Karsten Klein[1,6], Jonathan Wieland[1], Daniel Fink[1], Wolfgang Fiedler[3], Andrea Flack[3,4], Mate Nagy[1,3,4,5], Martin Wikelski[1,3,4], Harald Reiterer[1,4], Falk Schreiber[1,4,6]
[1]University of Konstanz, Konstanz, Germany
[2]Royal College of Art, London, UK
[3]Max-Planck-Institute for Ornithology, Radolfzell, Germany
[4]Centre for the Advanced Study of Collective Behaviour, University of Konstanz, Konstanz, Germany
[5]MTA-ELTE Statistical and Biological Physics Research Group, Hungarian Academy of Sciences, Budapest, Hungary
[6]Monash University, Melbourne, Australia
[$] bjoern@CELLmicrocosmos.org

Abstract

Outreach and citizen science are important aspects in research and development. For example, the collection of bird-related data is driven forward by non-professional ornithologists as well as by researchers.

At the exhibition "From Lake Constance to Africa, a long distance travel with ICARUS" which took place during the summer 2018 at the island Mainau in Germany, a Virtual Reality (VR) installation was shown utilizing movement data of a flock of storks. Two VR binoculars were installed which were used by the visitors to observe storks flying, following their way from Lake Constance towards Africa based on GPS data of real storks. In this way, viewers experienced a 360° view on top of the stork "Bubbel" as it flies with 26 flock mates.

The VR binoculars were created as a 3D print equipped with a smartphone, VR headset and other special features enabling the long-term use. The overall project consists of three components: 1) the production software Bird Watcher*, 2) the exhibition-compatible exploration software* Bird 360°*, as well as 3) the hardware setup:* the Sword of Stork Bubbel.

Introduction

Ornithology is an important research area which deals with, e. g., the analysis of bird migration and movement patterns. In the context of the ICARUS[1] project an antenna was installed at the International Space Station (ISS) which will be used to track small animals like birds over long distances, providing timely high resolution data. Fig. 1 shows the operation schema of ICARUS [1].

The tracking data is collected via GPS sensors, and with different settings it can drastically differ in its temporal resolution: data might be recorded once a day, once every 5 minutes, or even as high as once every second. Also, the quality and quantity of the data can strongly differ based on the settings: often only the longitude and latitude are recorded in case the most relevant aspect is the long-distance movement. This used to be the most common practice in collecting bird-related GPS data. But nowadays often the altitude is also taken into account, providing information re-

[1] International Cooperation for Animal Research Using Space

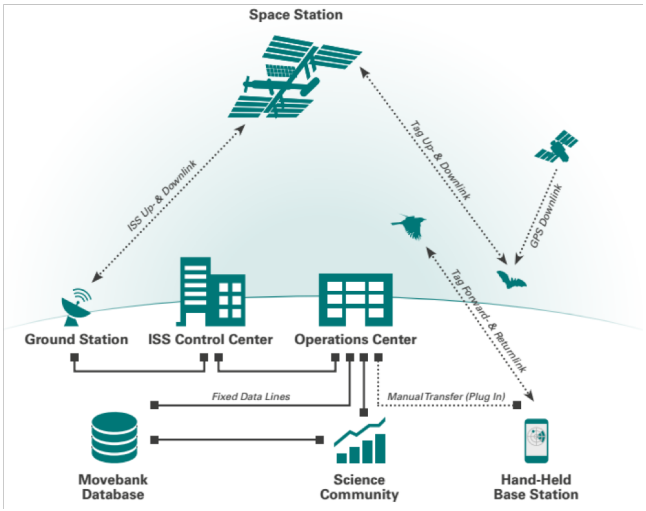

Figure 1. *The ICARUS schema © 2018 MaxCine Radolfzell.*

Figure 2. *Storks equipped with the tracking devices (e-obs GmbH; Munich, Germany) that provided the data visualized in the exhibition © 2014 MaxCine Radolfzell.*

garding the height of the birds [2, 3]. Fig. 2 shows two storks wearing GPS sensors.

The ICARUS project will extend previous approaches by providing two-way software communication making use of ground stations (see Fig. 1), improved and smaller sensors towards 5-g tags, sensors for 3D-acceleration, autonomous energy supply, and so on.

Collecting large amounts of movement data helps answering new research questions. Important questions related to bird movement are:

- How do birds move with the wind?
- Who leads a flock? Which birds are followers?
- Where and how do birds die?
- Can we predict disasters based on animal behavior?

The ICARUS project is partly being developed by the Max Planck Institute (MPI) for Ornithology in Radolfzell and the University of Konstanz. Nowadays, funding agencies are supporting outreach to educate the public regarding new research developments. Moreover, we also believe that ornithology is an interesting topic and should be communicated to the public from first hand. The MPI for Ornithology also has a centre for outreach – MaxCine – lead by Babette Eid, who is in constant contact to school students and enthusiasts. This bilateral approach often also has practical advantages for research, for example, bird-related movement data is often collected by non-professional ornithologists.

The main purpose of the 2018 exhibition at the island of Mainau was to provide detailed insight into the research of the ICARUS project. The title of the exhibition running from June 15^{th} to September 16^{th} 2018 was "From Lake Constance to Africa, a long distance travel with ICARUS" (original: "Vom Bodensee nach Afrika - auf Langstrecke mit ICARUS"). Fig. 3 shows the opening ceremony. The exhibition consisted of a number of different exhibits, information stands and projection setups showing videos, largely based on content from MaxCine collected over many years. We contributed a *Virtual Reality (VR)* setup visualizing the journey of a flock of storks flying from Lake Constance to Africa. In this technical paper, we will discuss the hardware setup, the involved data and software, as well as the obstacles we faced.

Related Work

Scientific Visualization in Virtual Reality

VR technologies come a long way. One of the most important key stones was Ivan Sutherlands "Sword of Damocles" which he presented the first time in 1968 [4]. This is recognized as being the first *Head-Mounted Display (HMD)*. The huge difference to modern HMDs such as the Oculus Rift is the fact that it had to be attached to the ceiling as it was extremely heavy and required a sophisticated power supply. Between the HMD and the ceiling, a mechanical arm was mounted to support the head tracking. During this time, only very simple vector objects could be visualized, such as a cube. But the user was already able to change his perspective by using the head tracking functionality. Moreover, both eyes were already presented with a slightly different perspective, providing stereoscopic vision.

Virtual Reality and Stereoscopic 3D (S3D) technology plays an important role in many research areas, such as in bio-medicine

Figure 3. *The opening of the exhibition "From Lake Constance to Africa, a long distance travel with ICARUS" on the island Mainau. The director of the Max Planck Institute for Ornithology, Martin Wikelski, introduces the ICARUS project to the visitors. Thousands of visitors will visit the exhibition within the following three months.*

or archaeology [5, 6, 7, 8]. An overview of different VR-related technologies useful for bird movement analysis provides our expert evaluation from 2017 [9]. As previously mentioned, bird movement is usually tracked using sensors. Some research has been done in combining sensor data with VR exploration and web technology, for example, in [10] WebGL was used for 3D visualization, which is compatible to most recent web browsers [11, 12]. Data recorded with an external sensor connected to a smart-phone via Bluetooth was uploaded to a webserver and could then be directly explored on-site using a VR cardboard in conjunction with a smart-phone.

Bird Movement Data

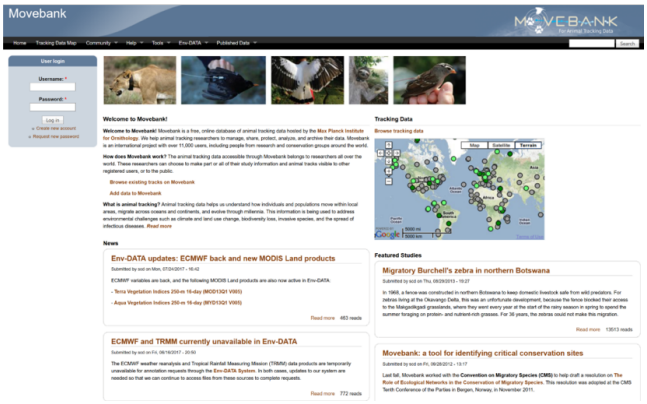

Figure 4. *MoveBank Landing Page. In December 2018, the corresponding database contained more than 1.2 billion locations from approx. 5,000 contributors – researchers as well as non-professional ornithologists.*

A number of repositories for animal movement data exists. One of the leading web resources is the MoveBank, see Fig. 4. In December 2018, the MoveBank contained more than 5,000 studies, 800 taxa, and 1.2 billion locations, and was supported by more than

5,000 contributors [13]. The data is provided by researchers as well as non-professional ornithologists. Moreover, it is planned to establish direct data feeds from the ISS/satellite setup in the context of the ICARUS project.

For the BinocularVR project described here, we used a specific data set featuring high temporal resolution from the MoveBank representing the movement trajectories from a larger group of storks on their way from Lake Constance to Africa [14]. 26 storks were selected which were traveling in close proximity to each other forming a flock. A global view of the data set is shown in Fig. 5. Please note that this data set is not limited to the 26 storks and also does not use the color codes discussed here. The original data set can be directly downloaded from the MoveBank [15]: `https://www.datarepository.movebank.org/handle/10255/move.602`

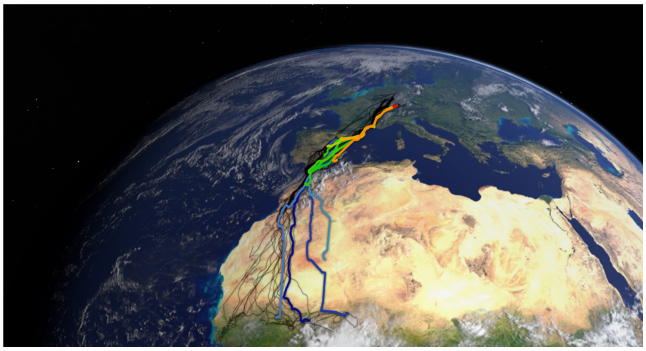

Figure 5. *Trajectories of multiple storks traveling from Lake Constance to Africa – including the storks discussed in this paper.*

Implementation

The project presented here consists of three components:

- *Bird Watcher:* a Unity-based software used to create the 360° visualization.
- *Bird 360°:* an Android-based software used to render and explore the 360° visualization during the exhibition.
- *The Sword of Stork Bubbel:* hardware setup for Bird 360°.

Bird Watcher – A Unity App for the Basis

Bird Watcher was initiated as a student project with the aim to analyze the collective behaviour of a flock of storks. The analyst uses an HTC VIVE® and its two controllers to explore the virtual world of the flock in question. The system was implemented with Unity 2017 [16].

The software streams the landscape and topography beneath the birds from MapBox and animates their behaviour based on the tracking data previously downloaded from MoveBank, as can be seen on the bottom of Fig. 7. MapBox provides an SDK for Unity which was used for the purpose of streaming the terrain data [18]. It is possible to take over the position of any stork in the flock or freely fly - detached from an individual bird - in the virtual environment.

For analytical purposes, the left hand's VIVE controller shows an information panel inside the virtual environment, see Fig. 6 left. It contains information of the currently selected bird, including the name, heading direction, height, ground as well as height speed.

Figure 6. *Bird Watcher: The VIVE controllers, here used to control the stork "Fiffi", see also Fig. 8.*

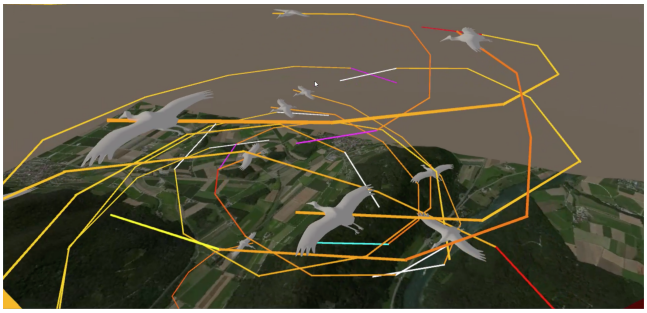

Figure 7. *Bird Watcher: Observing a group of birds. At the bottom the terrain data streamed from MapBox is visible.*

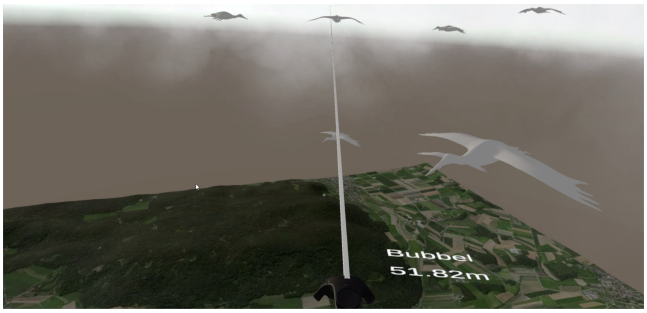

Figure 8. *Bird Watcher: Using the controller of the HTC VIVE the bird "Bubbel" is selected and the distance towards this bird is shown (current bird of the operator: "Fiffi").*

Name	Color
Balou	
Betty	
Conchito	
Cookie	
Crisps	
Ekky	
Ella	
Fanny	
Fiffi	
Flummy	
Frank	
Hannibal	

Kim	
Kristall	
Louis	
Lucky	
Mirabell	
Muffine	
Niclas	
Nils	
Ohnezahn	
Peaches	
Redrunner	
Sonja	
Snowy	

Figure 9. *Color codes for bird trajectories used for the Birds 360° visualization based on Green-Armytage [19]. Bubbel's trajectory was not shown.*

Additionally, behind every bird a trail can be rendered. These trails illustrate the bird's tracking data. Their are four different modes available for rendering the trails: 1) height speed, 2) ground speed, 3) single colour per bird and 4) invisible. The current trail rendering mode is also indicated on the information panel. Height speed is rendered in blue and normalized between light and dark blue. The faster the bird gains height, the darker appears the blue color. The same color shading is used to indicate the pace of the ground speed, but in this case red is the base color. With this visual encoding the analyst can find areas where the flock has high or low ground speed (red color), or areas in which the flock can gain faster height (blue color). The single-color-per-bird-trail mode helps to identify a flight track of a specific bird. Each one of the 26 storks was given an individual color, as shown on Fig. 9.

Observed from a distant point, the trails show how the thermals impact the movement of the birds. The left hand controller is a distance meter, as visible in Fig. 8. The analyst can stop the simulation, i. e., the flock remains in the recent constellation. By pointing with a virtual laser onto a bird, the distance is shown beside the left controller.

To analyze the behavior outside the flock, the analyst can freely fly around the flock. In this mode, the controllers are used to move forward and backward in the direction the analyst is looking, see Fig. 6 left and right. Also, the animation can be stopped by pressing the pause button, see Fig. 6 right.

The Bird Watcher is for expert users and professional analysts and has the intention to be used for immersive analytics studies [8]. To present an idea of such an analytical tool to the public, the functionality of this tool was drastically reduced to be shown in the context of the exhibition discussed here.

Bird 360 °– An Android App for the Exhibition

Using the Bird Watcher software, an individual bird with an interesting flight path was chosen - the stork "Bubbel". This bird was taken as the base for the 360° visualization.

To enable the user to differentiate between the different storks accompanying Bubbel, the previously mentioned color codes based on the work of Green-Armytage were used [19]. As the color alphabet contains exactly 26 colors it was straight forward to apply them to the 26 storks accompanying our stork of interest, Bubbel, see Fig. 9. The trail of Bubbel is not shown during the animation.

Exhibition visitors are a heterogeneous group of users. Therefore, the functionality of the software used in the context of exhibitions had to be drastically reduced. The previously described Bird Watcher software is a tool relevant for immersive data exploration, but it is too complex to be used by exhibition visitors without a detailed introduction. Moreover, the HTC VIVE requires a quite complex setup and would require daily service. Hence, a setup was designed which is easy to use for users as well as maintainers. As an appropriate metaphor "binoculars" was chosen, as most visitors will intuitively know how to handle this setup. The hardware will be discussed in detail in the next section.

Since it was not possible to use an internet connection (low bandwidth, low reliability) an offline solution was implemented which had to be stable over the complete exhibition period of three months (June 15^{th} to September 16^{th} 2018). Using a simple video

Figure 10. *Bird 360°: Top View of stork Bubbel. The visitor is hovering on top of the bird to have a fixation point in the virtual sky.*

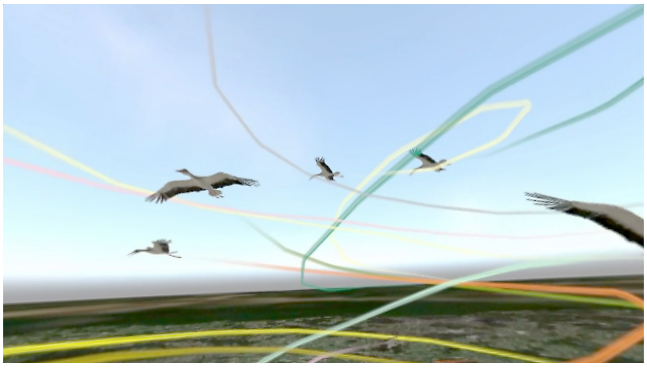

Figure 11. *Bird 360°: Stork Bubbel in Radolfzell, the starting point of the journey of him and his 25 stork mates.*

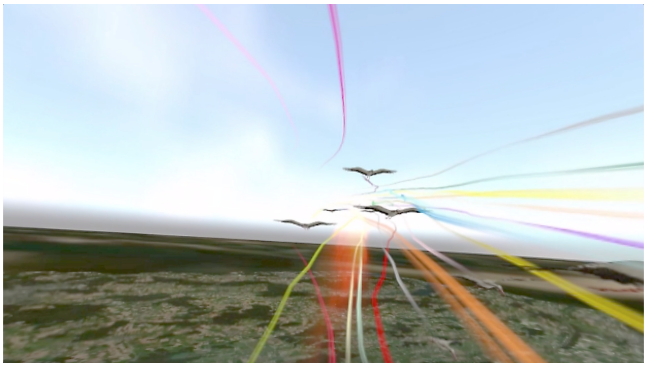

Figure 12. *Bird 360°: Stork Bubbel in Zurich. The storks are flying in relatively straight direction towards Africa.*

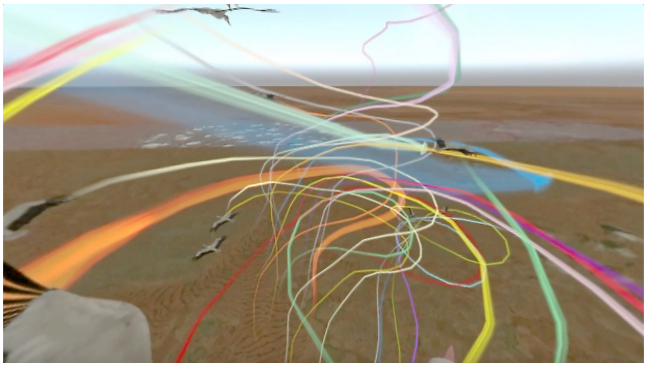

Figure 13. *Bird 360°: Stork Bubbel in the Sahara. Thermals are used to approach the sky, as is illustrated by the spirals-forming trajectories.*

in, e. g., 16:9 format would not provide the possibility to naturally explore the virtual bird world with the binoculars just by looking around. Moreover, it was decided that the user should be able to pause and play the simulation and switch between the three different scenes discussed below.

The first version was a Unity 2017 App [16]. The solution was to render three 360° videos and use the controller to pause, play and switch between the videos. Unfortunately, this was not stable and after several hours of usage the app typically froze.

Therefore, as final solution a native Android app playing the three 360° videos was implemented. With a controller paired with the smart phone it is possible to switch the scenes, as well as to pause the simulation.

Three 360° scenarios were created with the Bird Watcher software. The journey of Bubbel is following three stages:

- Lake Constance (Germany): Fig. 10 and Fig. 11. The storks use a thermal lift to gain height.
- Area nearby Zurich (Switzerland): Fig. 12. The storks are straight hovering at travel height.
- Sahara (Africa): Fig. 13. The storks are using another thermal lift to gain height for the final part of the journey.

The Sword of Stork Bubbel – The Exhibition Setup

Binoculars are a well-known concept which was adopted for the exhibition. A Google Daydream® headset was chosen as the base for the HMD, where the smart-phone – a Google Pixel 1 or Pixel 2® – will be inserted. A similar setup was used in the award-winning "Rebuild Palmyra?" exhibition in 2017, that time in conjunction with 360° monoscopic photos [17]. For the Mainau exhibition described here, some additional issues had to be solved.

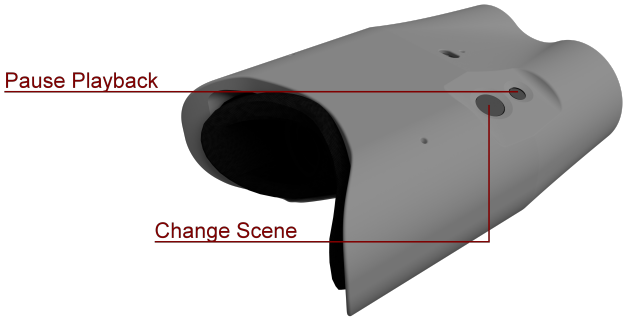

Figure 14. *3D model of the BinocularsVR rendered with Blender showing the available options for the paired Daydream controller.*

The controller had to be integrated into the setup in a way not to be identified as an external part, thereby creating a single device for the user. Showing the VR content requires high performance, which causes heating up of the smart-phone, and often led to automatic deceleration to prevent overheating. Therefore, a cooling system was required. Besides a cooling system, the binoculars required a constant power supply for all-day use.

These requirements led to the construction of a 3D printed binoculars. The 3D model is shown in Fig. 14. In the front the Daydream headset is fixated. Above right, the controller was placed inside a pocket operable through holes in the outer hull. On the other end of the binoculars, two fans blew constantly air

Figure 15. *The exhibition stand with the BinocularsVR inside the castle "Deutschordensschloss" at the island of Mainau. The binoculars are hanging from the ceiling from where it is supplied with power.*

Figure 16. *Burning-in effect observed on the OLED displays of the Google Pixel 2 after three months of use.*

cooling the smart-phone. The power supply was provided by a cable from the top, integrated in the holding wires. The complete setup is shown in Fig. 15. Due to the combination of power supply from the top leading to a ceiling-mounted approach, a visual similarity to the original "Sword of Damocles" is obvious.

Results and Discussion

The exhibition was visited by thousands of visitors. During the three months period, the island Mainau had around 435,000 visitors (data kindly provided by Mainau GmbH). Based on previous experience of the Mainau GmbH, it can be estimated that a quarter of them visited the exhibition, and at least a quarter of them used the BinocularsVR setup as described here. As this setup was one of the main attractions, we can estimate that it was used by approx. 300 people a day. Obviously, the setup was very stable and reliable. During these three months, the involved researchers only had to visit two times the venue for cleaning the devices and exchanging the cushions, as well as restarting the system.

Initial worries that people may experience vertigo and fall down during exploring the virtual world were not proven. As the users were able to look down on Bubbel, they often got the feeling of flying above ground on top of the bird. To have the 3D model of the bird as a fixation point definitively helped to maintain balance. Moreover, another important reason might be that the BinocularsVR were not attached to the head and the user can immediately remove them in case of feeling uncomfortable.

As we found out prior to the exhibition that the Android crashes after a few days without obvious reasons, the app had to be restarted. The solution for this issue was the automatized restarting of the software at midnight. Unfortunately, still the controller had to be manually paired with the smart phone each time. As the custodians did not always do this, the app ran often just as a see-through binoculars without the option to pause or switch the scenes. However, most visitors did not expect this option at all, as long as they did not read the corresponding poster.

Another technical problem we only realized towards the end of the exhibition. As the Google Pixel 2 – which we used throughout the whole exhibition – is based on OLED display technology, a burning-in effect could be observed, see Fig. 16. As the smartphone was playing the videos over the whole day, most of the time a horizon in the top view, and the landscape on the bottom view were shown. This subdivision of the screen (top: bright, bottom: dark) is visible on the OLED screen. The solution for the future will be a simple screen saver which is triggered in case the smartphone is not used for a longer period.

Outlook

The BinocularsVR setup was one of the main attractions of the exhibition. It will be used as a permanent exhibit in the MaxCine Hennhouse in Radolfzell at the Lake Constance as well as for the ICARUS touring exhibition. The setup will be revised and used for future exhibition. The developed pipeline could be used for any bird providing high-resolution 3D movement data is available in the MoveBank. The videos can be rendered with the Bird Watcher software and then explored as a 360° 3D video with the Bird 360°app.

A video documentary can be found at
`http://ervr2019.feyer.de` or
`http://ervr2019.immersive-analytics.org`.

Acknowledgments and Exhibition Team

We would like to thank all involved colleagues supporting this project. Special thanks go to those who did most of the work but are not authors nor did a good job regarding reviewing this manuscript – their names can be found in Fig. 9. In this context: very special thanks go to Bubbel!

We are sorry to say that Bubbel – according to entries in the MoveBank – diseased 2015-01-11 on a landfill in Dos Hermanas with suspicion of poisoning as the cause of death (probably caused by garbage). Two of his three nestlings also died in other landfills.

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- Data Curators:
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- 3D Construction of Binoculars:
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- 3D Bird Rigging and Animation:
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- Exhibition Text:
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  Falk Schreiber – Life Sciences Informatics,
  Martin Wikelski – Max Planck Institute for Ornithology
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- Overall Exhibition Design and Implementation:
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- Overall Exhibition Lead, Financing:
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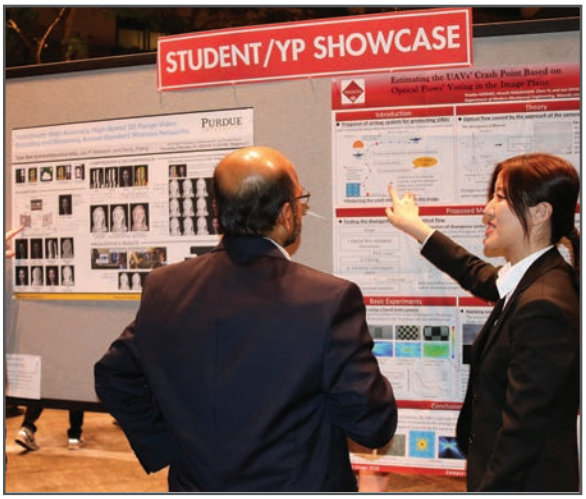

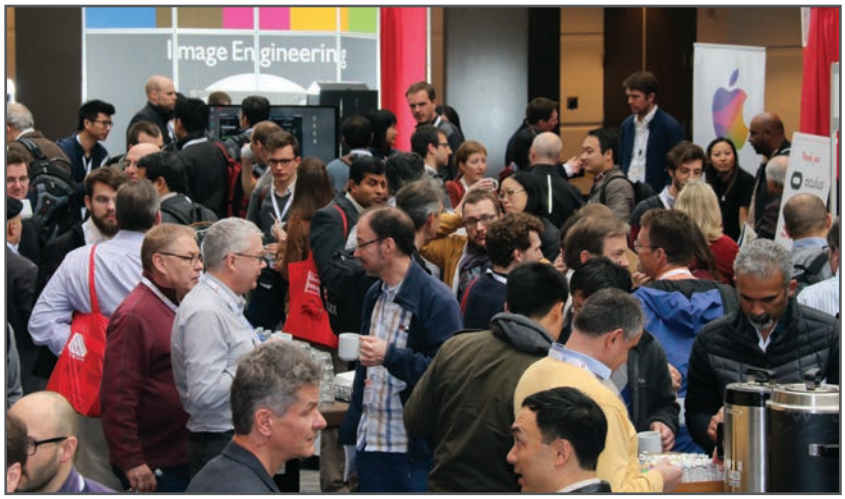

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