REAL-TIME GEOREGISTRATION OF VIDEO STREAMS FROM MINI OR MICRO UAS USING DIGITAL 3D CITY MODELS

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ABSTRACT:

Over the last few years low-cost micro and mini UAS (Unmanned Aircraft System) equipped with light weight data acquisition sensors like video cameras and with real-time data transmission capability have started to appear on the market. These unmanned systems are mostly instrumented with low-quality INS/GNSS sensors for position and attitude control. Over the same time period virtual globes have evolved and varying 3d geoinformation services based on this technology are operational today. New applications scenarios based on such virtual globe technologies like real-time pipeline inspection, traffic monitoring or event surveillance require the integration of georeferenced imagery in near real-time. Mini and micro UAV (Unmanned Aerial Vehicle) provide cost efficient, rapid and flexibly deployable platforms for the acquisition of such imagery. In this paper two different fully automated video imagery georegistration approaches will be presented and compared. The first georegistration approach is based exclusively on the flight control states provided by the low-quality IMU/GNSS sensors. In the second approach additional 3D city model data – provided by a virtual globe technology – is used to improve the georegistration accuracy.

1. INTRODUCTION

1.1 Motivation

One important shortcoming of today’s virtual globes is the often outdated geospatial base imagery. Especially novel geospatial application scenarios like infrastructure inspection, monitoring applications in conjunction with natural disasters, traffic monitoring, forest fire detection or surveillance of large events all depend on (near) real-time geospatial imagery. Thus, the capability of (near) real-time integration of geospatial imagery – among other geospatial contents – into virtual globe technologies will become an important success factor in the implementation of many future geospatial applications. In terms of acquiring such up-to-date geospatial imagery data, mini and micro unmanned aircraft systems (UAS) could serve as cost efficient, highly flexible and rapidly deployable sensor platforms. Due to the very limited payload capacities of these small platforms only low-quality and low-cost INS/GNSS sensors can be used for flight attitude determination. The goal of this work is to investigate and develop a real-time georeferencing approach for video imagery captured from such light-weight UAS platforms and to optimally integrate this video imagery into a virtual globe. The imagery georeferencing approach presented in this paper is not limited to micro and mini UAS. It can also be used to automatically georegister ground-based video or image data, which is acquired in combination with low-cost position and attitude sensors, to a 3D city or landscape model. This would enable the integration of mobile helmet- or vehicle-mounted video imagery into geospatial decision support environments.

1.2 Related Work

In the photogrammetric community, the prevailing approach for the accurate georegistration of geospatial imagery from mobile platforms is referred to as direct georeferencing (Mostafa and Hutton 2005). The required sensor position and attitude for such applications is normally obtained from a geodetic grade GNSS receiver in combination with a high-quality navigation grade INS. The achievable accuracy of the direct georeferencing solution can be further increased with the additional integration of ground control information. This approach is normally referred to as integrated or combined georeferencing (Cramer 2001a). Other related and interesting algorithms and solutions are introduced in the much larger computer vision community. In this field different approaches and application scenarios are discussed. One important research topic is the field of augmented reality (AR) solutions which deals with a similar way of posing a problem. (Cornelis, Pollefeys et al. 2001) give a good overview and introduction to these solution strategies. Further interesting approaches are discussed under the term video georegistration (Sheikh, Khan et al. 2003). For the georegistration process they use GNSS/INS data in combination with available orthomosaic or digital height model data. In (Neumann, You et al. 2003) an approach is introduced which stabilises a directly georeferenced video stream based on a data fusion with available 3D models.

Figure 1. UAS ‘microdrones md4-200’ with ground control station
1.3 Structure and goals of the paper

The paper commences with an overview of micro and mini UAVs and presents the micro UAV which was used in the acquisition of the test video sequences investigated. In a second part, a short introduction of virtual globe technologies will be provided. Additionally, the quality and accuracy of the 3d city model of the test site is discussed. Subsequently, the fully automated video imagery georegistration approach will be introduced. The presented approach consists of two consecutive integration steps which build the foundation for producing up-to-date or even live georeferenced imagery. The first georegistration approach is based exclusively on the flight control states provided by the low-quality IMU/GPS sensors. In the second approach, additional digital city model data – provided by and through the virtual globe – is used to improve the georegistration accuracy. The underlying algorithm uses a resection-based image-to-model matching process which is discussed in detail. The following part of the paper discusses the achievable georegistration quality of both approaches based on results from selected test flight missions. Furthermore, first results, experiences, advantages and shortcomings of the employed resection based image-to-model matching algorithm are shared. The paper concludes with a look at ongoing and future development steps.

2. CORE TECHNOLOGIES

2.1 Micro and mini unmanned aircraft systems

Micro and mini UAVs are increasingly turning into cost efficient, flexible and rapidly deployable geodata acquisition platforms. Systems with a maximal take-off weight of less than 5kg or 30kg respectively are referred to as micro or mini UAV platforms. Unmanned Vehicle Systems International (UVS International) has drawn up a classification of the different platforms. This classification is presented in (Bento 2008) together with a state-of-the-art overview. Most of the mini or micro UAVs available today integrate a flight control system which autonomously stabilises these platforms and also enables the remotely controlled georeferencing. Several systems additionally integrate an autopilot, which permits an autonomous flight based on predefined waypoints. These flight control systems are typically based on MEMS (Micro-Electro-Mechanical System) IMU systems, navigation-grade GPS receivers, barometers, and magnetic compasses. The different sensor observations are usually integrated to an optimal flight state using Extended Kalman Filter (EKF), which is subsequently used in the flight controller.

For the acquisition of our test video sequences we use the micro UAV platform microdrones md4-200 which is illustrated in Figure 1. The following listing gives an overview of the accuracy of the fused flight attitude states based on a MEMS-INS, navigation-grade GPS receiver, barometer, and magnetic compass.

**Flight attitude accuracy** (After sensor data fusion)
- Position: 2.5 m (CEP)
- Altitude: 5 m (SEP)
- Roll and pitch angle: 1.2° (1σ)
- Yaw angle (Heading): 3.5° (1σ)

Details of the implemented sensor data fusion approach are presented in (Meister, Mönikes et al. 2007). Due to payload restrictions, a low-weight non-metric PAL camera with a resolution of 640x480 pixels is used. The captured video stream and the fused flight attitude data can be transmitted to the ground control station through an analogue data link with 25Hz and 3-4Hz respectively. Details of the UAS used and additionally required system components for video stream and flight data recording and synchronisation are presented in (Eugster and Nebiker 2008).

2.2 Virtual globes and 3d city models

Different web-based 3d geoinformation services based on virtual globes are operational today. Google Earth and Microsoft Virtual Earth are only two prominent examples. Most of the available virtual globe technologies have the possibility to integrate and stream large amounts of geospatial content, like terrain models, orthomosaics, 3D objects, points of interest or multimedia objects. While virtual globes offer an excellent streaming capability for large volumes of geodata, they typically do not provide mechanisms for rapidly updating the base geodata. However, incorporating near up-to-date or even live geodata is a key requirement for application scenarios such as real-time surveillance or disaster management.

Virtual globe technologies and in particular their integrated streaming capability are a key elements in enabling the second georeferencing approach by providing a very efficient input of 3d control geometry. Using a virtual globe technology for directly accessing the 3d city model data – in addition to other geospatial contents – has a number of advantages. The first advantage is the almost unlimited accessibility to 3d geometry, since the 3d data of the virtual globe can be streamed over a network from a potentially very large geospatial database. The second very important advantage is the possibility to provide not only the geometry but also semantics and topology of the 3d city model data, which will be helpful in the subsequent matching process. In Figure 2 the 3d city model of the test site is visualised with the i3D virtual globe technology. This technology is entirely developed at the University of Applied Sciences Northwestern Switzerland (FHNW) and is especially designed for an online integration of geospatial contents.

The test site is a training area for civil defence organisations and is located in Eiken (AG) Switzerland. For one thing, this area is ideal for flying with unmanned aerial systems. For the other thing, it contains several different building types which are not too complex. Thus, it is well suited for testing the newly developed image-to-model matching algorithms in an almost real outdoor situation. The available 3d city model has a vertex accuracy of 10 cm.

Figure 2. Test site Eiken inside i3D virtual globe technology
3. REAL-TIME VIDEO GEOREFERENCING AND GEOFREGISTRATION

In order to support the afore-mentioned monitoring application scenarios within a virtual globe, optimal georegistration accuracy between the captured imagery data and the visualised geodata content is one of the key goals. Figure 3 shows the proposed georeferencing approach and imagery integration process. In the first integration step the well-established direct georeferencing (DG) approach is used and adapted to process low-quality flight attitude states for real-time video georeferencing. In cases where an application scenario requires improved video georegistration accuracy a subsequent second integration step is proposed. The underlying idea is based on the integrated or combined georeferencing (IG) approach known in the photogrammetric community. This approach integrates additional ground control information to estimate remaining biases in the direct georeferencing solution. In contrast to the direct and integrated georeferencing solutions used in traditional photogrammetric mapping applications, adapted processing concepts and algorithms are required which keep in mind the low quality and different characteristics of the flight attitude data of micro and mini UASs. The following subsections introduce both integration steps in detail. Prior to the further discussions the terms georeferencing and georegistration are briefly distinguished. We use the term georeferencing if we speak about absolute georeferencing accuracy with respect to a global geodetic reference system. In contrast, we use the term georegistration if we describe the local registration accuracy of the imagery with respect to 3d city model content available in the virtual globe environment. Especially, for AR solutions the georegistration accuracy is crucial.

3.1 Direct georeferencing - first integration step

In the photogrammetry community the term direct georeferencing refers to the direct measuring of the exterior orientation parameters of an arbitrary geodata acquisition sensor – like a digital imaging camera or a LIDAR sensor – without additional ground control information. The unknown exterior orientation parameters are directly observable with an INS/GNSS sensor configuration. More details of the implemented direct georeferencing solution for real-time video data integration into the i3D virtual globe technology are provided in (Eugster and Nebiker 2008). The main difference between the well investigated direct georeferencing approach (Cramer 2001b) used for traditional mapping applications on the one hand and mini or micro UAV based video stream georeferencing on the other hand is the dramatically reduced accuracy of the registered UAS flight attitude states. Based on this context known procedures for lever arm and sensor misalignment calibration as they are presented, for example, in (Skaloud 1999), will shortly be discussed. Typically achievable flight data accuracies for position and attitude states based on low-quality MEMS-INS and navigation grade GNSS receivers are shown in section 2.1. The specified errors do not describe a true white noise but rather a varying systematic error behaviour which is highly correlated in time. The mentioned effect can be attributed to a number of influences. One error source is the variable satellite constellation and associated uncompensated systematic errors during the observation period which affect the GNSS pseudorange position solution. Another source are high drift rates of the low-quality MEMS-INS sensor fused with the GNSS pseudorange solution resulting in systematic attitude errors. The remaining systematic error characteristics of the resulting direct georeferencing solution can also be observed in the misalignment calibration procedure. For this task traditionally a cross flight pattern is flown over a ground control test field (Figure 4). Based on the differences between the indirectly estimated and the directly measured attitude the misalignment angles can be derived. If we use high-quality INS/GNSS sensor instrumentation the misalignment angles can be reliably estimated because the remaining systematic error of the direct georeferencing solution is significantly smaller than the incorporated misalignment effect. In contrast, if we use a low-quality INS/GNSS instrumentation the misalignment effect is superimposed with the remaining systematic error behaviour of the derived direct georeferencing solution. Additionally, the remaining systematic errors of the direct georeferencing solution and the misalignment angles are highly correlated. In order to illustrate this effect Figure 4 shows results of two misalignment estimation configurations. In configuration a) four frames of each cross flight strip are incorporated into the misalignment estimation. As the residual images show for this case the remaining varying systematic errors between the two flight strips prevent a meaningful misalignment estimation. In comparison, configuration b) incorporates only four frames of one flight strip for misalignment estimation. In this case the estimated misalignment angles compensate the current systematic error state of the direct georeferencing solution together with the highly correlated misalignment angles. The misalignment solution is only valid for the short time period within which the incorporated frames were captured.

Figure 3. Video georegistration and integration data processing workflow
If we use frames over a longer time period for the calibration procedure like configuration a), the systematic error behaviour prevents meaningful misalignment estimation. In conclusion of this discussion: first, the direct georeferencing solution contains a remaining time-varying systematic error which is highly correlated with the misalignment angles and second, the misalignment calibration cannot significantly increase the direct georeferencing accuracy. For low-quality INS/GNSS configurations on micro and mini UAVs the unknown sensor misalignment, lever arm components and the remaining systematic errors of the flight attitude data are highly correlated and cannot easily be decomposed as it is possible for high-quality INS/GNSS instrumentations. This insight builds the basic principal for the proposed integrated georeferencing algorithm. Further details of the implemented flight data processing steps, used camera and misalignment calibration approaches are available in (Eugster and Nebiker 2007).

3.2 Integrated georeferencing - second integration step

In contrast to the first integration step, the second integration step employs additional 3d geodata from an available 3d landscape model to improve the achievable georegistration accuracy between the captured imagery data and (overlaid) objects of the virtual world. If the available 3d landscape model has a sufficient accuracy it is also possible to improve the georeferencing accuracy of the direct georeferencing solution. The idea behind the second integration is that of the integrated or combined georeferencing approach. The goal of this approach is to improve the direct georeferencing solution with additional image observations to available ground control information. With this independent information it is possible to estimate remaining systematic errors in the direct georeferencing solution. If the direct georeferencing solution is derived from high-quality INS/GNSS sensors, normally relatively simple systematic error models can be used to improve the solution. Different approaches for such applications are discussed in (Cramer 2001b) and (Haala 2005). However, integrated georeferencing approaches which are based on such error models are not suitable to improve a direct georeferencing solution derived from low-quality INS/GNSS sensors. The remaining systematic error behaviour of such a solution is very difficult to describe and the same applies to designing an adequate functional description. First, all incorporated errors are strongly correlated and second, the whole remaining systematic error term shows a behaviour similar to a random walk. Based on this finding which is also reflected in the afore-mentioned misalignment calibration issues the following integrated georeferencing procedure is proposed. The basic idea behind our approach is a continuous estimation of the time-variable systematic errors as mentioned before. To do this, we propose a single error term for each exterior orientation parameter which integrates all highly correlated systematic error influences as well as the incorporated misalignment angles and lever arm shifts. The detailed data processing workflow of the proposed second integration step is shown in Figure 5. The process is subdivided into two main processing steps a) image-to-model matching and b) continuous systematic error model estimation. The second step is realised with a complementary Kalman Filter which describes the unknown error term in the state vector. The estimated error term can afterwards be used to correct and improve the direct georeferencing solution. Details of the complementary Kalman Filter design are available in (Brown 1983). The systematic error of each exterior orientation parameter is modelled as random walk. Further implementation details of this processing part are available in (Eugster and Nebiker 2007). To update the state vector the complementary Kalman Filter uses independent vision based exterior orientation observations. These independently computed exterior orientations are derived in the first image-to-model matching step. For each key frame (1-2Hz) of the video stream the exterior orientation parameters are fully automatically estimated with a resection-based image-to-model matching process. This matching process is performed between the available ground control information from the virtual globe and the captured key frame. This process is introduced in detail in section 3.3. In order to support the image-to-model matching algorithm and for accessing 3d control information the available direct georeferencing solution is used as approximation. This architecture enables a continuous system calibration to improve the direct georeferencing solution.
3.3 Resection based image-to-model matching

Goal of this process is the fully automatic assignment of extracted features in video key frames to corresponding 3D landscape model geometry elements in order to derive independently estimated exterior orientation parameters. The term image-to-model matching in this context describes the optimal assignment between the primitives of the image model description $m^{\text{img}}$ and the corresponding primitives of the control geometry model description $m^{\text{mo}}$ through a mapping function $h$.

$$m^{\text{mo}} = h \circ m^{\text{img}}$$ (1)

There is a wide variety of matching strategies and algorithms in existence. A good overview of different approaches is given in (Baltsavias 1991). For different reasons we use the relational matching (RM) approach in our implementation. This approach is computationally expensive compared to a simple feature based matching (FBM) but robust concerning to poor approximation EO values, which is particularly important in the initialisation stage of the second integration step. The proposed resection based image-to-model matching algorithm is presented in detail in Figure 6. Starting position of the image-to-model matching process is a key frame of the video stream with a corresponding approximated exterior orientation. Furthermore, a boundary representation (B-rep) based 3D city model of the region of interest is available from the virtual globe. First, with the aid of the known approximation EO the virtual globe technology performs a real-time re-projection of the 3D geometry into a virtual image plane. Based on the additional topological information contained in the 3D model and on the re-projected geometry the control geometry model description $m^{\text{mo}}$ can be derived. In parallel, with the aid of the Canny edge detection algorithm edge pixels can be detected in the input video key frame. Afterwards, edge primitives can be extracted with the line-based Hough transformation. Based on the extracted edges the image model description $m^{\text{img}}$ can be constructed. Subsequently, based on the two derived model descriptions the optimal mapping function $h$ is searched with the relational matching approach. Details of the relational matching approach and the underlying algorithms are presented in (Vosselman 1992). For our implementation we use an adapted version of the proposed RM algorithm in (Vosselman 1992). Compared to a simple feature-based matching the relational matching approach incorporates additional relations between the primitives of a model description $m$. In our case, the derived model description $m$ consists of $n$ primitives and $k$ relations as follows.

$$m = (P, R)$$

$$P = \{p_1, p_2, ..., p_n\}$$

$$R = \{r_i^c(p_i, p_j), r_i^s(p_i, p_j), ..., r_i^s(p_i, p_j)\}$$

where

- $p_i$: edge primitive
- $r_i^c$: relation between primitives of type $t$

Each edge primitive $p_i$ can be parameterised as follows

$$d = x \cdot \sin(\varphi) + y \cdot \cos(\varphi)$$ (3)

and the following properties can be additionally introduced:

$$\text{center} (p_i) = \begin{cases} x_i^{\text{cen}} = (x_i^{\text{start}} + x_i^{\text{end}})/2 \\ y_i^{\text{cen}} = (y_i^{\text{start}} + y_i^{\text{end}})/2 \end{cases}$$

$$\text{azimut} (p_i) = \phi_i$$ (4)

$$\text{length} (p_i) = \sqrt{(x_i^{\text{start}} - x_i^{\text{end}})^2 + (y_i^{\text{start}} - y_i^{\text{end}})^2}$$

Furthermore, the following two relation types are incorporated:

$$r_i^{\text{con}} (p_i, p_j) = \begin{cases} \text{connected} \\ \text{not connected} \end{cases}$$ (5)

$$r_i^{\text{rel}} (p_i, p_j) = \begin{cases} (\varphi_i = \varphi_j) \Rightarrow \text{offset} = |d_i - d_j| \\ (\varphi_i \neq \varphi_j) \end{cases}$$ (6)

To measure the assignment between the two model descriptions the following functions are used to estimate the merits $M$ between the two feature vectors of a mapping $h$ and of the resulting relations.

$$M_i^{\text{dep}} = F_{\text{dep}} (m_i^{\text{mo}} (\text{center} (p_i)), m_i^{\text{img}} (\text{center} (h(p_i))))$$

$$M_i^{\text{az}} = F_{\text{az}} (m_i^{\text{mo}} (\text{azimut} (p_i)), m_i^{\text{img}} (\text{azimut} (h(p_i))))$$

$$M_i^{\text{len}} = F_{\text{len}} (m_i^{\text{mo}} (\text{length} (p_i)), m_i^{\text{img}} (\text{length} (h(p_i))))$$ (7)

$$M_i^{\text{r}^{\text{con}}} = F_{\text{r}^{\text{con}}} (m_i^{\text{mo}} (r_i^{\text{con}} (p_i, p_j)), m_i^{\text{img}} (r_i^{\text{con}} (h(p_i, p_j))))$$

$$M_i^{\text{r}^{\text{rel}}} = F_{\text{r}^{\text{rel}}} (m_i^{\text{mo}} (r_i^{\text{rel}} (p_i, p_j)), m_i^{\text{img}} (r_i^{\text{rel}} (h(p_i, p_j))))$$

The whole merit of a match between the two model descriptions is computed with following evaluation function:

$$f(n) = \sum_{i=1}^{n} (M_i^{\text{dep}} + M_i^{\text{az}} + M_i^{\text{len}}) + \sum_{i=1}^{n} \sum_{j=1}^{n} (M_i^{\text{r}^{\text{con}}} + M_i^{\text{r}^{\text{rel}}})$$ (8)
The optimal assignment between two model descriptions is reached with maximisation of the evaluation function.

\[ f(n) \Rightarrow \max \] (9)

For the optimisation of the evaluation function the A*-Algorithm is used. In our implementation the following conditions are introduced. First we allow only a one-to-one mapping between to primitives of the two model descriptions and second a wildcard mapping is possible. Further details of the A*-Algorithm for optimisation adapted to a merit function are also explained in (Vosselman 1992). In the last step of the whole image-to-model process the independent exterior orientation parameters can be estimated with a spatial resection where the matched 3d city model is used as control geometry input. The implemented resection estimation algorithm supports direct image edges as observations as well as point observations. Details of the implemented algorithm are available in (Schwermann 1995).

### 4. RESULTS

For testing and assessing the achievable georeferencing and georegistration accuracy of the proposed imagery integration approach test flights over the mentioned test site were carried out. For these tests we used the micro UAS 'microdrones md4-200' introduced in section 2.1. In the following a short overview of the test results are presented and first experiences, advantages and shortcomings of the employed imagery integration approach are given.

#### 4.1 Georeferencing and georegistration accuracy

To assess the achievable georeferencing and georegistration accuracy the following two processing configurations are compared.

a. Direct georeferencing solution based on the available flight attitude data after the first imagery integration step.

b. Integrated georeferencing solution after the second imagery integration step based on the proposed resection-based image-to-model matching algorithm.

In order to investigate the achievable georeferencing accuracy in a global reference system we independently re-project existing check points into the image plane using the processed exterior orientation. In contrast, for the georegistration accuracy investigation available 3d city model vertexes are re-projected. To derive the achievable accuracy the re-projected points are compared with manually obtained point observations in arbitrarily chosen video frames. The accuracies for the two processing configurations are summarised in Table 1. Both configurations consider the calibrated misalignment angles. In Figure 7 the remaining residual vectors of check points are shown for two arbitrarily chosen epochs. Additionally, the georegistration accuracy with the overlaid 3d city model is visualised for the same two epochs.

#### 4.2 Assessment and experiences

As shown in table 1 the proposed integrated georeferencing approach results in a georeferencing accuracy improvement by a factor of 3 to 4 compared to the direct georeferencing solution. The results demonstrate that it is possible to estimate a continuous time-variable system calibration which compensates remaining highly correlated long-term systematic error terms. However, remaining short-term residuals are further included after the second integration step. These residuals can be attributed to uncompensated short-term instabilities of the UAV platform caused especially by wind. In addition, flight attitude states are only available with ~3-4 Hz in real-time by the 'microdrones md4-200' UAS. So, short time attitude changes are not considered in the direct and integrated georeferencing solution. The results show no significant difference between georeferencing and georegistration accuracy. An explanation of this effect can by given by the high absolute accuracy of the 3d city model geometry of the test site. If the 3d city model offers a consistent relative accuracy in itself a georegistration accuracy shown in table 1 can be expected. However, if the 3d city model geometry is systematically shifted compared to an absolute coordinate reference system the expected georeferencing accuracy could significantly degrade. First experiences with the proposed resection-based image-to-model algorithm at different test sequences shows successful results compared to the exterior orientation quality after the first integration step.

<table>
<thead>
<tr>
<th></th>
<th>DG solution (configuration a)</th>
<th>IG solution (configuration b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>avg. object range</td>
<td>~ 55 m</td>
<td>~ 55 m</td>
</tr>
<tr>
<td>Georeferencing accuracy</td>
<td>478 µm (48 px)</td>
<td>142 µm (14 px)</td>
</tr>
<tr>
<td>RMS image space</td>
<td>3.25 m</td>
<td>0.97 m</td>
</tr>
<tr>
<td>Georegistration accuracy</td>
<td>440 µm (44 px)</td>
<td>135 µm (13 px)</td>
</tr>
<tr>
<td>RMS object space</td>
<td>3.0 m</td>
<td>0.92 m</td>
</tr>
</tbody>
</table>

Table 1. Georeferencing vs. georegistration accuracy of test flight missions
Figure 7. Residuals at image plan and visual overlay accuracy direct- vs. integrated georeferencing solution
But the whole algorithm is strongly dependent on many different input parameters which have to be adapted separately for different sequences. Especially the introduced merit functions in Equation (7) resulting in a strong different matching outcome depending on the chosen parameterisation and weighting. In order to reach an optimal matching result this parameterisation has to be adapted for different test sequences due to different outdoor video capturing conditions, the available quality of the direct georeferencing solution or the used UAV platform. Further limitations are introduced by the resection estimation; especially if the edge observations are not distributed over the whole frame and if they are aligned nearly in parallel. In such situations the estimated independent exterior orientation parameters are not stable and reliable enough to provide a useful Kalman-Filter update observation. Concerning real-time video data integration capability: the first integration step allows a full real-time data integration. The second integration step does not yet reach real-time efficiency – especially during the initialisation stage.

5. CONCLUSIONS AND OUTLOOK

This paper discussed georegistration approaches of video streams captured with micro and mini UAS and of a subsequent real-time imagery integration in virtual globe technologies. The proposed approach distinguishes between two consecutive georeferencing or integration levels. The first integration step directly uses the available flight attitude states of the UAS for georeferencing. In the second integration step a resection-based image-to-model algorithm was presented which allows improving the georegistration accuracy with the aid of additionally available 3d city model geometry from a virtual globe technology. The achievable georeferencing accuracy the first integration step directly depends on the recorded flight attitude data quality. For mini and micro UAS we typically achieve a georeferencing accuracy of ~3-4 m in object space on a platform-to-object range of ~50 m. With the second integration step the georeferencing accuracy can be improved by a factor of 3 to 4 and georeferencing accuracy below the 1 m level is possible.

To further increase and stabilise the proposed video data integration approach the following improvements will be implemented and considered. First, a robust resection estimation algorithm could overcome single mismatches in the image-to-model matching algorithm. Second, the remaining sum of residuals of the resection estimation could be additionally used directly as merit function in the RM process as is implied in Figure 6. Furthermore, the resection based exterior orientation estimation could be exchanged with a continuous bundle adjustment algorithm over the last n key frames. Thus, poor control geometry observation constellation can be bridged which means independent stable EO parameters are continually available. However, this approach assumes movement of the video capturing platform, since we only use a monocular imagery sensor configuration. Additionally, in order to prepare the second integration step for real-time application scenarios, different improvements of computational efficiency have to be achieved and further concepts are required. In this context it could be considered to change the image-to-model matching algorithm from RM during the initialisation stage to a computationally cheaper FBM approach after initialisation.

6. REFERENCES


