GENERAL APPROACH FOR THE MOUNTING PARAMETERS CALIBRATION OF PHOTOGRAMMETRIC MOBILE MAPPING SYSTEMS

Ana Paula Kersting[1], Ayman Habib[2], Jiann-Yeou Rau[3]

[1]Graduate Student, [2]Professor, Department of Geomatics Engineering, University of Calgary
2500 University Drive NW, T2N 1N4, Calgary, Canada; Tel: +1-403-220-7105
Email: ana.kersting@ucalgary.ca, ahabib@ucalgary.ca
[3]Assistant Professor, Department of Geomatics, National Cheng Kung University
No.1 University Road, Tainan City 701, Taiwan; Tel: +886-6-237-0876
Email: jyrau@mail.ncku.edu.tw

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ABSTRACT: Currently, modern mapping systems consist of multi-sensor systems, usually referred to as Mobile Mapping Systems (MMS), encompassing a GPS/INS and imaging sensors. System calibration is a crucial process to achieve the expected accuracy of such systems. It involves individual sensor calibration and the mounting parameters calibration (i.e., lever-arm offset and boresight angles) relating the system components. In this paper, a general approach for the mounting parameters calibration of photogrammetric mobile mapping systems is proposed. The proposed method consists of a single-step procedure, which is suitable for single and multi-camera systems. It utilizes a general least squares adjustment concept, i.e., the involved quantities in the mathematical model can be treated either as unknowns, stochastic variables, or error free parameters. The utilization of such concept opens up the possibility of the utilization of the same implementation for different mathematical models which can be considered as special cases of a general model. The implemented procedure consists of an Integrated Sensor Orientation (ISO) where the GPS/INS derived position and orientation information and the system mounting parameters are directly incorporated in the collinearity equations (i.e., modified collinearity equations are utilized). The most general mathematical model can incorporate prior information about the Relative Orientation Parameters (ROP) among the cameras in the ISO. More specifically, the mounting parameters relating the IMU body frame and the reference camera, whose ROP with respect to the other cameras are known, are estimated. The feasibility of the proposed method is demonstrated through experimental results using simulated datasets.

1. INTRODUCTION

The collection and updating of geospatial information of the road environment information have been commonly performed by topographic mapping from large scale aerial photos and/or site surveying. Since detailed information is not possible to obtain using large scale aerial photos only, site surveying is usually required. The problems associated with site surveying are numerous: intrusive, labor intensive, among others; leading to an inefficient data collection. Technological advances in the last decades have made possible the emergence of Mobile Mapping System (MMS), which allow efficient, flexible, and cost-effective acquisition of road environment information with the required accuracy and reliability. MMS can be defined as moving platforms which integrates a set of imaging sensors and a Position and Orientation System (POS). The POS is the most expensive component and crucial for the direct orientation of the system's imaging sensors.

Direct sensor orientation of photogrammetric mobile mapping systems can be performed in two different ways: (i) Integrated Sensor Orientation (ISO) and (ii) direct geo-referencing (Jacobsen, 2004). In the ISO, the GPS/INS derived position and attitude information are used as prior information in the bundle adjustment procedure together with the image coordinates of tie points. This simultaneous adjustment allows for further improvement in the cameras' Exterior Orientation Parameters (EOP) and can be performed with or without ground control points. Also, in the ISO procedure, the system mounting parameters can be estimated if appropriate data acquisition and ground control configurations are available. In the direct geo-referencing, on the other hand, the object space coordinates of the image points are obtained from a space intersection procedure using the GPS/INS position and orientation information as well as the system mounting parameters. There are several factors that might affect the performance of the direct sensor orientation. For instance, the quality of photogrammetric system calibration (i.e., camera and mounting parameters calibration), the GPS data quality (which is mainly dependent on the distance from the base station, satellite geometry, and continuity of the GPS lock), the type of the IMU system used, and the quality of the GPS/INS integration process. Investigations into the performance of GPS/INS-assisted photogrammetric systems have demonstrated that the accuracy of direct sensor orientation is mainly limited by the quality of the GPS/INS derived position and orientation as well as the quality of the photogrammetric system calibration. The photogrammetric system calibration comprises the camera and the mounting parameters calibration. Methodologies for the photogrammetric system calibration have been proposed by several authors (El-Sheimy, 1992; Cramer and Stallmann, 2002; Pinto and Forlani, 2002; Honkavara, 2003; Habib el. al, 2010).

For multi-camera systems, the mounting parameters encompass two sets of Relative Orientation Parameters (ROP) (El-Sheimy, 1992): the ROP among the cameras as well as the lever-arm offsets and boresight angles between the cameras and the navigation sensors (i.e., the IMU body frame as the navigation solution usually refers to its coordinate frame). The estimation of the lever-arm offsets and boresight angles between the cameras and the navigation sensors is necessary for directly-oriented multi-camera systems. Since the cameras and the navigation sensors are rigidly mounted on a platform, their geometric relationships are assumed to be invariant. The mounting parameters, which describe their spatial relationships, can be determined using either a two-step or single-step procedure. The two-step procedure for the estimation of the mounting parameters relating the cameras and the IMU body frame is based on comparing the cameras' EOP, which are determined through a conventional bundle adjustment (indirect geo-referencing) procedure, with the GPS/INS derived position and orientation information of the platform at the moments of exposure. Similarly, the estimation of the ROP among the cameras can be established by comparing the cameras' EOP determined through an indirect geo-referencing procedure. Although such procedures are easy to implement, its reliability is highly dependent on the imaging configuration as well as the number and distribution of tie and control points since these factors control the accuracy of the estimated EOP. The single-step procedure, on the other hand, incorporates the system mounting parameters and the POS-based information in the ISO procedure. The commonly used single-step procedure in previous work consists of extending existing bundle adjustment procedures with constraint equations (e.g., Cramer and Stallmann, 2002; Honkavaara et. al., 2003). Although for single-camera systems such approach is appropriate, when dealing with multi-camera systems, dependent observation equations are introduced. In the absence of GPS/INS data, constraint equations have been commonly used for multi-camera systems to enforce/estimate the invariant geometric relationship among the cameras (El-Sheimy, 1992; Lerma et. al, 2010; King, 1992). The drawback of incorporating these constraints to enforce consistent ROP among the cameras is the associated complicated procedure for doing that, e.g., extensive partial derivatives as well as manual formatting of the camera pairs to be utilized in the relative orientation constraints (ROC). These complexities are intensified as the number of cameras onboard gets larger.

In this paper, a general approach for the mounting parameters calibration of photogrammetric mobile mapping systems, which is suitable for single and multi-camera systems, is proposed. The proposed method utilizes the concept of modified collinearity equations, which has already been used by some authors in ISO procedures involving single-camera systems (Ellum, 2003; Pinto and Forlani, 2002; Habib et. al, 2010). It utilizes a general least squares adjustment model, allowing for the utilization of the same implementation for different mathematical models which can be considered as special cases of a general model. The most general mathematical model can incorporate prior information about the ROP among the cameras in the ISO. More specifically, the mounting parameters relating the IMU body frame and the reference camera, whose ROP with respect to the other cameras are known, are estimated. This general model is implemented in such a way that the following special cases can be derived: (i) Estimation of the mounting parameters among all the cameras and the navigation sensors, and (ii) Estimation of the ROP among the cameras in the absence of GPS/INS position and orientation information. One should note that the proposed method is simple to implement and is not affected by the number of the involved cameras and the number of utilized epochs. The proposed method is explained in the next section. Then experimental results are presented to test the feasibility of the proposed photogrammetric system calibration using simulated datasets. Finally, the paper presents some conclusions and recommendations for future work.

2. MODIFIED COLLINEARITY EQUATIONS FOR MULTI-CAMERA SYSTEMS

As already mentioned, the single-step estimation of the system mounting parameters is performed through an ISO procedure. The incorporation of the GPS/INS position and orientation information as well as the mounting parameters in the ISO can be done by adding constraints or by directly incorporating them in the collinearity equations. The latter method has been already used for single-camera systems and has been adapted in this research for use in systems composed of several synchronized cameras since it is the most appropriate solution and allows for easier implementation. The most general mathematical model utilized in the proposed method is shown in (1). This mathematical model is obtained through the summation of the vectors illustrated in Figure 1. In this model, one of the cameras is selected as the reference camera (*cr*) whose geometric relationship w.r.t. the IMU body frame is to be estimated. This model can incorporate prior information on the ROP between the reference and the other cameras.

$$\vec{r}_I^{\,m} = \vec{r}_b^{\,m}(t) + R_b^m(t)\vec{r}_{cr}^{\,b} + R_b^m(t)R_{cr}^b\vec{r}_{cj}^{\,cr} + \lambda_i[cj(t)]R_b^m(t)R_{cr}^b R_{cj}^{cr}\vec{r}_i^{\,cj} \tag{1}$$

Where:

- $\vec{r}_I^{\,m}$: is the position vector of an object point (*I*) relative to a local mapping frame (*M*),
- $\vec{r}_b^{\,m}(t)$: is the position vector of the IMU body frame relative to the local mapping frame at a given time (t), derived through the GPS/INS integration process,
- $R_b^m(t)$: is the rotation matrix relating the local mapping frame and the IMU body frame (derived through the GPS/INS integration process) at time (*t*) defined by (ω, φ, κ),

- $\vec{r}^{\,b}_{cr}$: is the lever-arm offset vector between the IMU body frame and the reference camera (*cr*) perspective center, defined relative to the IMU body frame,
- R^{b}_{cr} : is the rotation matrix relating the IMU and the reference camera coordinate systems,
- $\vec{r}^{\,cr}_{cj}$: is the lever-arm offset vector between the reference camera (*cr*) and the *jth* camera perspective centers, defined relative to the reference camera,
- R^{cr}_{cj} : is the rotation matrix relating the reference camera and the j^{th} camera coordinate systems,
- $\lambda_i[cj(t)]$: is the scale factor, which is the ratio between the magnitudes of the object vector – i.e., the vector connecting the perspective center and the object point (*I*) – and the image vector – i.e., the vector connecting the perspective center to the image point (*i*) captured by camera *cj* at time *t*.
- $\vec{r}^{\,cj}_{i} = \begin{bmatrix} x^{cj}_i - x^{cj}_p - \Delta x^{cj} \\ y^{cj}_i - y^{cj}_p - \Delta y^{cj} \\ -c^{cj} \end{bmatrix}$: is the vector from the perspective center to the image point (*i*) with respect to the j^{th} camera coordinate system. Note that Δx^{cj} and Δy^{cj} are defined according to the utilized distortion model. A distortion model is the mathematical representation of the corrections that compensate for various deviations from the assumed collinearity condition.

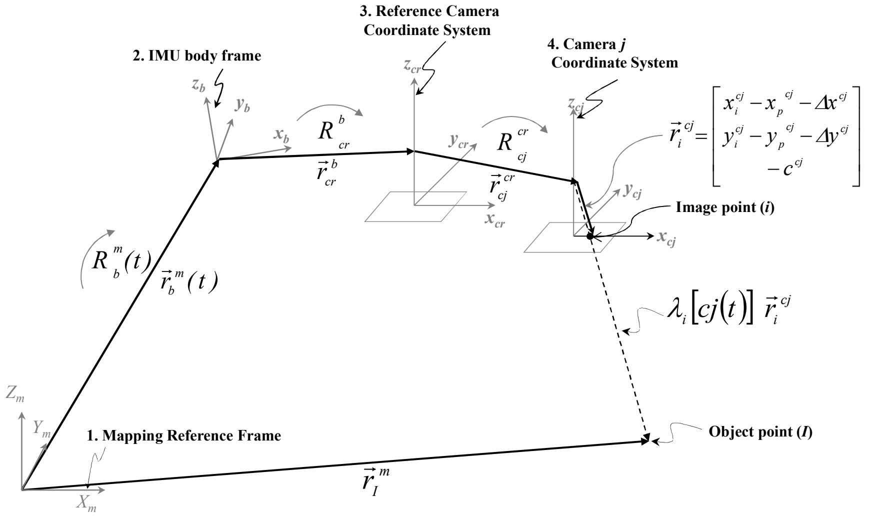


Figure 1. Coordinate systems and involved vectors in the proposed general mathematical model.

By rearranging the terms in (1), i.e., moving the term $\vec{r}^{\,cj}_{i}$ to the left side of the equation, we can get the form in (2). The observation equations in their final form, i.e., the modified collinearity equations, are shown in (3). These equations can be obtained by dividing the first two equations in (2) by the third one while moving the terms (x^{cj}_p, Δx^{cj}) and (y^{cj}_p, Δy^{cj}) to the left side of the equations. One should note that the scale factor ($\lambda_i[cj(t)]$) is eliminated through the division process.

$$\vec{r}^{\,cj}_{i} = \begin{bmatrix} x^{cj}_i - x^{cj}_p - \Delta x^{cj} \\ y^{cj}_i - y^{cj}_p - \Delta y^{cj} \\ -c^{cj} \end{bmatrix} = \frac{1}{\lambda_i[cj(t)]} R^{cj}_{cr}\left(R^{cr}_{b}\left[R^{b}_{m}(t)\left(\vec{r}^{\,m}_{I} - \vec{r}^{\,m}_{b}(t)\right) - \vec{r}^{\,b}_{cr}\right] - \vec{r}^{\,cr}_{cj}\right) = \frac{1}{\lambda_i[cj(t)]} \begin{bmatrix} N^{cj}_x \\ N^{cj}_y \\ D^{cj} \end{bmatrix} \quad (2)$$

$$x^{cj}_i = x^{cj}_p - c^{cj}\frac{N^{cj}_x}{D^{cj}} + \Delta x^{cj} \quad (3a)$$

$$y^{cj}_i = y^{cj}_p - c^{cj}\frac{N^{cj}_y}{D^{cj}} + \Delta y^{cj} \quad (3b)$$

The ISO is implemented through a general Least Squares Adjustment (LSA) procedure, i.e., the involved quantities in the mathematical model can be treated either as unknowns, stochastic variables, or error free (constant) parameters. Initially, all the quantities on the right side of equations (3) are treated as unknowns. In order to treat any of these quantities as stochastic variables, pseudo observation equations can be added for such parameters. An example of pseudo-observation equations for treating the GPS/INS derived positions as stochastic variables is shown in (4).

$$\vec{r}_{GPS/INS}(t) = \vec{r}_b^m(t) + e_{GPS/INS} \tag{4}$$

On the other hand, to treat a specific parameter as a constant (e.g., the parameter corresponding to the i^{th} row of x), zero values are set for all the elements occupying the i^{th} row and i^{th} column of the normal equations matrix, except for the element occupying the i^{th} diagonal element, which is set as one. Also, the i^{th} row of the normal equation vector is also set to zero. This implementation allows the derivation of the following special cases:

(i) Estimation of the mounting parameters among all the cameras and the IMU body frame (i.e., no prior information of the ROP among the cameras is available): In this case, the boresight angles of the reference camera w.r.t the IMU body frame are fixed to zeros, i.e., R_{cr}^b = Identity Matrix. Also, the lever-arm offset vector between the IMU body frame and the reference camera $\vec{r}_{cr}^b$ is fixed to zero. This means that the reference camera position and orientation coincides with the IMU body frame and all the terms referring to the reference camera should be read as referring to the IMU body frame as shown in (5).

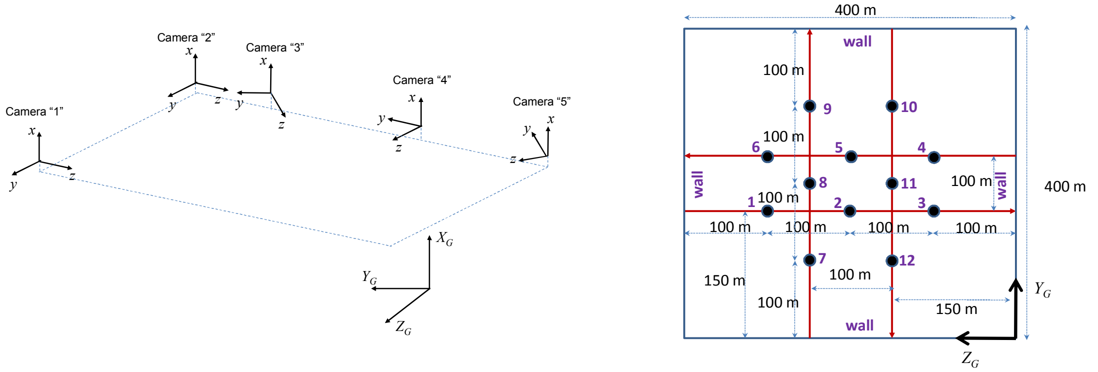
$$\vec{r}_I^m = \vec{r}_b^m(t) + R_b^m(t)\vec{r}_{cj}^b + \lambda_i[cj(t)]R_b^m(t)R_{cj}^b\vec{r}_i^{cj} \tag{5}$$

(ii) Estimation of the ROP among the cameras in the absence of GPS/INS position and orientation: This is a special case of (i), where one of the cameras can be used as a reference for defining the position and the orientation of the platform, which are considered as unknowns and therefore determined in the bundle adjustment along with the ROP relating the other cameras to the reference one. In such a case, the terms $\vec{r}_b^m(t)$and $R_b^m(t)$ in (6) should be regarded as the position and orientation of the reference camera (cr): $\vec{r}_{cr}^m(t)$ and $R_{cr}^m(t)$, respectively. Similarly, the terms $\vec{r}_{cj}^b$ and R_{cj}^b in (5) should be regarded as the ROP of the jth camera (cj) w.r.t. the reference one: $\vec{r}_{cj}^{cr}$ and R_{cj}^{cr}, respectively, as shown in (6). Such procedure is denoted in this paper as “Indirect Geo-referencing with ROC”, which is a single-step procedure for the estimation of the ROP among the cameras.

$$\vec{r}_I^m = \vec{r}_{cr}^m(t) + R_{cr}^m(t)\vec{r}_{cj}^{cr} + \lambda_i[cj(t)]R_{cr}^m(t)R_{cj}^{cr}\vec{r}_i^{cj} \tag{6}$$

3. EXPERIMENTAL RESULTS

In this section, experimental results using simulated data are presented to test the validity of the introduced single-step procedure. Besides testing the feasibility of the proposed method, we would like to check whether the utilization of prior information about the ROP among the cameras improves the quality of the estimated mounting parameters in the ISO for different scenarios. Figure 2a illustrates the simulated land-based multi-camera mobile mapping system along with the utilized definition for the ground and the image coordinate systems. The system consists of five frame cameras with CCD size of 7.1456x5.4296mm, pixel size of 4.4µm, and focal length of 10.833mm. The simulated data acquisition configuration is shown in Figure 2b. It comprises 60 images acquired at 12 epochs from 4 different directions (Figure 2b). The simulated object space is composed of well distributed points along four walls. Five control points with accuracy of ±5cm are utilized. The noise in the image measurements is ±4.4µm, the IOP noise is ±1µm, and the GPS/INS noise is ±10cm/±100sec, respectively.



(a) (b)

Figure 2. (a) Configuration of the simulated land-based MMS and the utilized definition for the ground and image coordinate systems, and (b) top view of the simulated imaging configuration.

Table 1. Estimated lever-arm offsets and boresight angles w.r.t. camera "1" using the indirect georeferencing with ROC procedure.

	Δω (º±″) diff (″)	Δφ (º±″) diff (″)	Δκ (º±″) diff (″)	ΔX (m±m) diff (m)	ΔY (m±m) diff (m)	ΔZ (m±m) diff (m)
"2"	1.00726	-0.51046	-1.99529	-0.05	-1.45	0.05
	±24.8	±25.2	±17.9	±0.0011	±0.0024	±0.0028
	26.1	-37.6	17.0	0.00	0.00	0.00
"3"	-40.99046	-0.20617	-0.98933	-0.05	-1.50	0.60
	±31.2	±34.8	±45.4	±0.0025	±0.0036	±0.0040
	34.3	-22.2	38.4	0.00	0.00	0.00
"4"	-88.99505	1.97783	-0.68205	-0.05	-1.51	1.69
	±45.3	±54.5	±59.8	±0.0034	±0.0051	±0.0052
	17.8	-79.8	64.6	0.00	-0.01	-0.01
"5"	-127.99759	0.47521	-0.39339	-0.05	-1.46	2.44
	±41.6	±84.1	±49.3	±0.0039	±0.0063	±0.0051
	8.7	-89.3	23.8	0.00	-0.01	-0.01

Prior to performing the ISO, the relative orientation parameters among the cameras have been estimated using the proposed indirect geo-referencing with ROC procedure, which utilizes the mathematical model in (6). The simulated acquisition geometry to estimate the ROP among the cameras is the same as the one shown in Figure 2b except that the object distances as 10 times smaller. This is to illustrate a situation where we might have a calibration field allowing for a better data acquisition configuration for the estimation of the ROP among the cameras but performing the ISO is not possible due to blockage of the GPS signal. Table 1 reports the estimated ROP among the cameras, their standard deviations, and their difference from the simulated parameters. In the reported results, camera "1" was taken as the reference camera (i.e., the position and the orientation of the platform refer to the position and orientation of camera "1").

To test the validity of the proposed ISO (with and without prior information on the ROP among the cameras) two sets of experiments have been performed. In the first set, good distribution of the points in the imagery is available while in the second set of experiments the distribution of the points is degraded leading to a poor tying among the images. More specifically, only the points located in the center of the image ($|x| < 1.5$mm and $|y|<2.5$mm) in all the images were considered in the adjustment procedure. Table 2 presents the lever-arm and boresight angles of the cameras w.r.t. the IMU body frame, their standard deviations, and their difference from the simulated parameter obtained using the different ISO procedures. In the experiments using prior information regarding the ROP (i.e., the most general mathematical model), camera "1" is the reference camera since the known ROP are defined relative to that camera (reported in Table 1). The outcome from this ISO model is the lever-arm and boresight angles of the reference camera (i.e., camera "1") w.r.t. to the IMU body frame and adjusted values for the ROP among the cameras. Note that Table 2 reports the lever-arm and boresight angles of the cameras w.r.t. the IMU body frame. Those values have been computed using the estimated mounting parameters of the reference camera and the adjusted ROP values obtained using the general ISO procedure. Therefore, only the standard deviations for the reference camera (i.e., camera "1") are reported for this ISO model. When using the ISO without prior information, the mounting parameters w.r.t. the IMU body frame are directly the outcome from the adjustment procedure. We can observe in Table 2 that for the first set of experiments compatible results are observed for the two ISO models. In such a case, the use of prior information on the ROP among the cameras hasn't led to improvements in the estimated parameters. One should note that the proposed ISO implicitly enforces the invariant geometric relationship among the cameras, and therefore, for a reasonable imaging configuration it is expected that the use of prior information on the ROP among the cameras will not promote significant improvements. A closer look at the results from the second set of experiments reveals that, in the scenario where we have a poor tying among the images, the use of ROP prior information leads to more significant improvements in the estimated parameters (refer to the highlighted cells in Table 2).

3. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

In this paper, a novel general single-step procedure for calibration of photogrammetric mobile mapping systems has been introduced. The most general mathematical model can incorporate prior information about the ROP among the cameras in the ISO. This general model is implemented in such a way that the following special cases can be derived: (i) Estimation of the mounting parameters among all the cameras and the navigation sensors, and (ii) Estimation of the ROP among the cameras in the absence of GPS/INS position and orientation. The experimental results have shown that in the presence of a reasonable imaging geometry and good tying among the images the use of prior ROP information does not lead to significant improvements in the accuracy of the estimated parameters. On the other hand, under the scenario where a poor tying among the images is present, more significant improvements are observed. Future work will focus on more testing using simulated and real datasets.

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Table 2. Estimated system mounting parameters using the proposed ISO procedure with and without ROP prior information.

Cam.	ISO						ISO with ROP prior information					
	Δω (°±″) diff (″)	Δφ (°±″) diff (″)	Δκ (°±″) diff (″)	ΔX (m±m) diff (m)	ΔY (m±m) diff (m)	ΔZ (m±m) diff (m)	Δω (°±″) diff (″)	Δφ (°±″) diff (″)	Δκ (°±″) diff (″)	ΔX (m±m) diff (m)	ΔY (m±m) diff (m)	ΔZ (m±m) diff (m)
SET I												
“1”	-1.02037 ±50.4 -73.3	-0.52277 ±52.4 -82.0	1.29626 ±32.1 -13.5	0.09 ±0.06 -0.01	0.51 ±0.05 0.01	-1.48 ±0.04 0.07	-1.00683 ±38.2 -24.6	-0.51853 ±33.6 -66.7	1.29350 ±29.0 -23.4	0.11 ±0.04 0.01	0.46 ±0.03 -0.04	-1.52 ±0.03 0.03
“2”	0.00251 ±50.5 -31.3	-1.00629 ±52.5 -105.0	-0.70170 ±31.8 -37.3	0.07 ±0.06 -0.01	-0.95 ±0.05 0.00	-1.43 ±0.04 0.04	0.01183 2.3	-1.00462 -99.0	-0.69702 -20.5	0.09 0.01	-0.99 -0.04	-1.44 0.03
“3”	-42.00052 ±47.0 -14.9	-1.43880 ±51.1 -30.9	-0.35733 ±30.3 -37.9	0.10 ±0.06 0.02	-1.01 ±0.04 -0.02	-0.90 ±0.04 0.02	-41.99458 6.5	-1.44509 -53.6	-0.35774 -39.4	0.09 0.01	-1.03 -0.04	-0.89 0.03
“4”	-89.97866 ±54.7 56.9	0.68997 ±49.1 -5.3	-1.18427 ±31.5 -25.2	0.11 ±0.06 0.04	-1.05 ±0.04 -0.08	0.20 ±0.05 0.02	-89.98384 38.2	0.67871 -45.8	-1.18271 -19.6	0.08 0.01	-1.02 -0.05	0.20 0.02
“5”	-129.00843 ±47.8 -20.6	-0.20500 ±49.7 41.7	-1.59402 ±31.4 1.2	0.13 ±0.06 0.07	-0.94 ±0.04 -0.03	0.92 ±0.04 0.00	-129.00736 -16.7	-0.22122 -16.7	-1.59741 -11.0	0.07 0.01	-0.96 -0.05	0.95 0.03
SET II												
“1”	-1.01261 ±93.7 -45.4	-0.54072 ±88.6 -146.6	1.31125 ±157.5 40.5	-0.01 ±0.09 -0.11	0.50 ±0.10 0.00	-1.35 ±0.15 0.20	-0.98738 ±46.6 45.4	-0.52677 ±39.5 -96.4	1.30150 ±47.0 5.4	0.04 ±0.05 -0.06	0.41 ±0.04 -0.09	-1.50 ±0.05 0.05
“2”	0.01685 ±94.1 20.4	-1.01351 ±89.0 -131.0	-0.67731 ±157.2 50.5	0.02 ±0.09 -0.06	-0.97 ±0.10 -0.02	-1.42 ±0.15 0.05	0.03171 73.8	-1.01331 -130.3	-0.68478 23.6	0.02 -0.06	-1.04 -0.09	-1.43 0.04
“3”	-42.02100 ±144.7 -88.6	-1.46307 ±132.1 -118.3	-0.37849 ±135.9 -114.1	0.03 ±0.16 -0.05	-0.83 ±0.22 0.16	-0.96 ±0.17 -0.04	-41.97289 84.6	-1.45963 -105.9	-0.35518 -30.2	0.02 -0.06	-1.08 -0.09	-0.87 0.05
“4”	-89.95330 ±151.9 148.2	0.71204 ±127.8 74.1	-1.19389 ±129.7 -59.8	0.16 ±0.13 0.09	-1.11 ±0.15 -0.14	0.28 ±0.16 0.10	-89.97099 84.5	0.67165 -71.3	-1.18455 -26.2	0.01 -0.06	-1.07 -0.10	0.22 0.04
“5”	-128.97912 ±137.4 85.0	-0.21702 ±128.0 -1.6	-1.62238 ±132.7 -100.9	0.08 ±0.12 0.02	-1.17 ±0.16 -0.26	1.13 ±0.15 0.21	-128.98805 52.8	-0.23277 -58.3	-1.61113 -60.4	0.00 -0.06	-1.01 -0.10	0.96 0.04

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